Primary Connections in a provincial Queensland school system: Relationships to science teaching self-efficacy and practices

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The teaching of science is important, both to meet the need for future workers in fields requiring scientific capability and to equip students for full participation in modern societies where many decisions depend upon knowledge of science. However, many teachers in Australian primary schools do not allocate science education sufficient amounts of time to achieve these outcomes. This study reports data obtained from 216 teachers in the primary schools in a provincial Australian school system. The purpose of the study was to assess the effects of existing strategies using *Primary Connections* for promoting science teaching and to inform future professional development strategies. Teachers reported moderate levels of self-efficacy for teaching science and a proportion reported allocating little or no time to teaching science. Both self-efficacy for science teaching and the amount of science taught were higher for teachers who had used *Primary Connections* curriculum materials.

Keywords: Primary Connections, primary education, self-efficacy

Introduction

The importance of science, technology, engineering, and mathematics (STEM) education has been recognized by governments around the world. In Queensland, a government report declared that "Innovation is key to economic growth and STEM is a key driver of innovation" (DETA, 2007, p. v) and proposed a ten year plan to enhance STEM education at all levels. More recently an Australian national industry group recognized the availability of a workforce with sufficient capabilities in the STEM disciplines as a key requirement for innovation and success in the modern Australian economy but noted that young people are not leaving schools and universities with the necessary levels of STEM skills (Australian Industry Group, 2013). In the United States of America, despite visible increases in employment opportunities for those who do have such skills, there are shortages of graduates with necessary STEM capabilities (Wyss, Heulskamp & Siebert, 2012), and President Obama has highlighted STEM education in three successive State

of the Union addresses (Shchetko, 2013) with emphasis on making changes in schooling to better equip graduates in those disciplines.

The lack of graduates with STEM skills is reflected in a shortage of appropriately qualified science teachers and research on the profiles of science teacher candidates indicates that positive science experiences with K-12 teachers during their own childhood are an important contributing factor in decisions to pursue STEM subjects at more advanced levels (Westerlund, Radcliffe, Smith, Lemke & West, 2011). The importance of early experience of STEM has also been recognized in Australia with recommendations for actions that include lifting "teacher quality, capability and qualifications in STEM and related disciplines", adopting more innovative and engaging pedagogies, and expanding STEM activity in primary schools (Australian Industry Group, 2013, p. 12).

Given the perceived importance of STEM for progress toward national goals and the evident shortage of STEM graduates which is driven, in part, by suboptimal early experiences with STEM, it is not surprising that the condition of science education is a matter of widespread concern. A major international conference of science educators in 2007 expressed concern about "lack of recognition of science education as a vehicle for meeting national educational goals, and social and economic needs" (Fensham, 2008). Previously the Australian Academy of Science had noted that "teaching of science in primary schools has been a cause of concern for some time … and science teaching has a low status in the primary curriculum" (Hackling & Prain, 2005). In Queensland the Masters Review (Masters, 2009) reported that science achievement among Queensland primary students had been static since 1995 despite improvements reported for other Australian states. Although this paper reports research about the state of science teaching in one region of Australia, the findings have wider implications in the context of a worldwide shortage of STEM graduates and the contribution that early experiences of STEM make to subsequent progression to further studies in STEM and associated disciplines.

Since the late 1980s Australian school curriculum has been undergoing a series of significant changes. Education in Australia is the constitutional responsibility of States and Territories. Differences in curriculum scope and sequence and in assessment regimes around a country with a relatively small population lead to inefficient use of resources and discontinuities in the educational experiences of children moving from one part of the country to another. In 1989 the State and Commonwealth Ministers of Education promoted the idea of a national curriculum (Australian Education Council, 1989) which was initially expressed in broad outline statements but has more recently led to the establishment of the Australian Curriculum, Assessment and Reporting Authority (www.acara.edu.au) and the progressive implementation of an Australian Curriculum.

States and Territories retain responsibility for implementation of the Australian curriculum within their own jurisdictions and schools and systems have scope for more local decision making within parameters established at State level. In Queensland responsibility for curriculum rests with the Queensland Studies Authority (www.qsa.qld.edu.au) which, until the first Australian Curriculum subjects became available for implementation from 2012, had been developing curriculum documents and support materials based on nationally agreed goals for Key Learning Areas developed in the 1990s.

Against this background it is not surprising that curriculum support staff in a small school system, based on a Queensland provincial city and its sparsely populated hinterland, formed the opinion, on the basis of their conversations with principals and teachers, that science was not receiving the focus that it deserved in the primary school curriculum. Their understanding, based on the anecdotal evidence, was that teachers lacked confidence with science content and pedagogy. As a consequence, teachers were limiting the class time spent on science. This observation is consistent with evidence cited elsewhere that Australian primary teachers avoid teaching science and, on average, allocate as little as 3% of teaching time to science (Fitzgerald, Dawson, & Hackling, 2009). Moreover, the limited attention given to science in primary classrooms within

the school system appeared to be exacerbated by approaches to curriculum that clustered outcomes from multiple Key Learning Area (KLA) syllabus documents within integrated units of work, thereby reducing the specific focus on science. That was especially likely when the integration included Studies of Society and Environment (SOSE), in which aspects of environmental study might be seen as substituting for science.

Awareness of the limited attention being accorded to science in primary classrooms was a contributing factor to decisions by the system authorities to promote materials developed by the Australian Academy of Science (www.science.org.au), first *Primary Investigations* (Aubusson & Steele, 2002) and later *Primary Connections* (Dawson, 2009), as resources for use by teachers in systemic schools. Those decisions were consistent with the Queensland Studies Authority (www.qsa.qld.edu.au) recommendation of *Primary Connections* as a resource option for schools. However, because the materials were developed for use throughout Australia and were not designed specifically for the Queensland curriculum there were significant challenges for teachers in linking the resources with the Queensland syllabus. Considerable time and effort were required to align the resources with curriculum outcomes for planning, teaching, assessing and reporting at the classroom level and teachers were unable to devote that time without adversely affecting other aspects of their work. As a consequence, it became evident to the system officials that in order to improve science teaching and learning in schools it would be necessary to address curriculum as well as provision of resources and pedagogical support.

The research reported here is part of a continuing commitment by the school system to address issues associated with science teaching in its primary schools. An initial exploratory phase was intended to collect data that would inform future work on development of science curriculum and pedagogy in the schools.

Literature Review

Based on discussions that occurred at an international conference of science educators, Fensham (2008) presents three imperatives for the critical importance of science education to governments around the world. The first is the importance of science education for identifying, motivating and beginning the preparation of students who will go on to study for careers in fields that involve science and technology. Modern societies require people with these STEM capabilities to ensure socially and environmentally sustainable development. In many countries the numbers of people pursuing STEM careers are falling seriously short of requirements. The second imperative is the need for all citizens in modern societies to be sufficiently prepared to participate effectively in debates and decisions about what should and should not be supported for sustainable development. Science and technology education is an important component of what is required for STEM literacies and too few students are currently receiving adequate preparation through science education. Third among Fensham's imperatives is the influence of digital technologies on society and education, which challenges schooling to develop generic and subject-based competencies. For science education, this requires a shift away from "the size of a student's store of established knowledge as the key measure of success" (p. 5) and toward contributing to the development of the competencies required for further development in STEM and related disciplines.

If science education is to respond effectively to these imperatives there is a need for new policy decisions. Fensham (2008) presents eleven issues that need to be addressed, each with one or more recommendations for action. Although some of the recommendations are more relevant to secondary schooling, several are relevant to the issues recognized by the school system in this study as important in the provision of science education in primary schools. Those include clarifying the purposes of science education, developing curriculum that links science to personal and societal interests with a focus on real world applications, addressing barriers that limit participation in science learning by girls and members of some cultural groups, changing approa-

ches to assessment to encourage higher levels of learning, and supporting teachers to develop the knowledge and skills necessary to teach science more effectively. Few, if any, of these are wholly new directions but their inclusion in an international report published by the United Nations Educational, Scientific and Cultural Organization (UNESCO) confirms their significance and should add support to existing efforts to implement appropriate changes in science education.

Primary Connections

The Australian Academy of Science has been actively working to improve science education over the past two decades and has been successful in obtaining support from the Australian Government to develop and promote resource packages for that purpose. *Primary Investigations* (Aubusson & Steele, 2002) was launched in 1995 with the aim of helping reluctant primary school teachers to teach science by providing a stepwise guide for a constructivist approach to teaching science through the whole primary school. The evaluation by Aubusson and Steele (2002) found that there had been significant uptake by schools in several states, including Queensland, that teachers using it were more confident about teaching science and less reluctant to do so, and that the improvements in the teaching of science had resulted in more students having positive attitudes to science. The data collected in the evaluation pointed to the importance for success of support from education systems and the presence of local teachers committed to its implementation.

Following the evaluation of *Primary Investigations*, the Australian Academy of Science collaborated with governments and other organisations on the development of *Primary Connections* as a strategy for improving learning outcomes in science and literacy through a combination of curriculum resources and professional learning for teachers (Peers, 2007; Hackling & Prain, 2005). If students are to develop understanding of the nature of science and scientific evidence they must learn through inquiry. Hence *Primary Connections* adopted a learning model with five phases: Engage, Explore, Explain, Elaborate, and Evaluate as shown in Table 1. This 5Es model was originally developed for the Biological Sciences Curriculum Study (BSCS) in the USA but has been adopted more widely in science education and continues to be developed and promoted by BSCS (Bybee, 2009).

For many teachers, *Primary Connections* represents a new approach to teaching science. Rather than a traditional didactic approach presenting scientific knowledge, it begins by engaging with and exploring students' own ideas in order to build new understanding based on what they already understand (Peers, 2007; Hackling, Peers, & Prain, 2007). Moreover, it emphasizes cooperative learning in which students work in small groups to learn through solving problems. Students in the groups share leadership and responsibility for their learning but are assigned specific roles for an activity to promote equitable participation that avoids traditional stereotypes.

Primary Connections is more than the 5Es instructional model and a set of curriculum resources. It is built around a professional learning program for teachers with workshops of lengths varying from one to three days for school groups or facilitators who assist with promoting *Primary Connections* to a wider audience (Peers, 2007).

The workshops model the teaching and learning approach of *Primary Connections* so that participants experience the instructional model, as well as having it explained, and they are empowered to develop their own curriculum units using the *Primary Connections* model. Feedback from participants was very positive and some schools have reported extending the 5Es approach to other curriculum areas after having experienced its success with students in science. A key difference between *Primary Connections* and some previous approaches to science education is the linking of science and literacy.

Table 1. 5Es Instructional Model (Peers, 2007)

Phase	Focus
Engage	Engage students and elicit prior knowledge
Explore	Provide hands-on experience of the phenomenon
Explain	Develop scientific explanations for observations and represent developing conceptual understanding
	Consider current scientific explanations
Elaborate	Extend understanding to a new context or make connections to additional concepts through a student-planned investigation
Evaluate	Students 're-present' their understanding and reflect on their learning journey and teachers collect evidence about the achievement of outcomes

In order for the learners to develop and communicate their understandings, they are required to develop their everyday literacy and science-specific literacy skills. The materials are designed to provide opportunities for developing the necessary literacies through meaningful literacy activities in which they interpret and construct science texts (Hackling et al., 2007).

The *Primary Connections* program was implemented in stages, commencing in 2003 with Stage 1 in which a conceptual model was developed and support enlisted from State education authorities. Stage 2 developed curriculum resources and a professional learning program for teachers, leading to a 2005 trial with more than 3000 students taught by 106 teachers in 56 schools (Hackling & Prain, 2005). Following an initial five days of professional preparation, teachers taught a sequence of a trial *Primary Connections* unit, their own unit based on the model, and a second trial *Primary Connections* unit. Data were collected using questionnaires to teachers and students, case studies and analysis of student work samples. Teachers reported significant increases in mean confidence (from 3.34 to 4.04 on a five point scale) with nine relevant science and literacy teaching strategies over the period of the trial (Hackling et al., 2007). Self-efficacy for science teaching was assessed using a version of the Science Teaching Efficacy Belief Instrument (STEBI) (Riggs & Enochs, 1990) and, on average, increased significantly from 35 to 41 out of 50 as measured using a ten item five point scale. During interviews, the teachers confirmed that their confidence for teaching science had increased and reported allocating more time to science teaching using a wider range of teaching strategies. Teachers also reported that the trial had raised the profile of science in their schools and generally improved the teaching of science. Almost all of the teachers (87%) reported that students responded positively to *Primary Connections* and about three-quarters indicated that quantity (76%) and quality (78%) of students' science learning was better than previously (Hackling et al., 2007). Examination of student work samples corroborated teacher impressions, with mean scores on the *Engage* and *Evaluate* phases for a sample of Year 5 students doubling over the course of a *Primary Connections* unit and 78% of the sample of Year 5 students working at or beyond the national proficiency standard for Year 6 by the end of the unit.

Stage 3 of the *Primary Connections* project extended from 2006 to 2008. A report on evaluation of that stage (Dawson, 2009) found that there was evidence that it had achieved its stated objectives, namely, to improve student learning outcomes in science and the literacies of science, enhance teacher self-efficacy and confidence in teaching science and literacy, increase teaching time for science, and raise the profile for the teaching of science in Australian primary schools. These are important goals for science teaching and are closely aligned with the concerns of the school system in this study and the broader international agenda for science education as described above.

Written feedback from 206 teachers who trialled *Primary Connections* materials between 2005 and 2012 was subjected to content analysis for a major evaluation (Skamp, 2012). Broadly

the evaluation found that the materials had a positive influence on teachers' thoughts about inquiry-oriented and constructivist science teaching using the 5Es model and that those ideas were implemented in many classrooms to varying extents. Teachers who had taught more than one *Primary Connections* unit with the same students reported enhanced conceptual understanding and inquiry-skills among those students. Moreover, the positive experience of teaching with the *Primary Connections* materials increased teachers' confidence to teach science, at least in part because of students' increased interest in science and enhanced learning.

Confidence and Self-Efficacy

Teachers' confidence in their capabilities for teaching science was an issue noted in the informal data gathering of the school system officers as described above and was an important variable in the evaluations of the *Primary Connections* project (Dawson, 2009; Hackling et al., 2007; Hackling & Prain, 2005). Those evaluations also included data about self-efficacy, a construct hypothesised by Bandura (1977) as determining whether a behavior will be initiated and how long it will be continued in the face of challenges. Self-efficacy recognises that competent functioning in an activity depends on having both the required skills and the confidence to use them to effect. Belief about personal efficacy has been described as "the most central and pervasive mechanism of personal agency" (Bandura, 1997) and defined as referring to "beliefs in one's capabilities to organize and execute the courses of action required to produce given attainments" (p. 3). Bandura distinguished between self-efficacy and confidence:

> It should be noted that the construct of self-efficacy differs from the colloquial term 'confidence.' Confidence is a nondescript term that refers to strength of belief but does not necessarily specify what the certainty is about. I can be supremely confident that I will fail at an endeavor. Perceived self-efficacy refers to belief in one's agentive capabilities, that one can produce given levels of attainment. A self-efficacy assessment, therefore, includes both an affirmation of a capability level and the strength of that belief (Bandura 1997).

Self-efficacy is not concerned with the level of skill that a person possesses but with judgements about what can be done with the skill that is possessed. Bandura (1977) identified two components of self-efficacy. Efficacy expectations represent the belief that a person can perform the behaviour necessary to produce a particular result. Outcome expectations are estimates of the likelihood that a behaviour will produce a certain result. "Efficacy and outcome judgements are different because individuals can believe that a particular course of action will produce certain outcomes, but they do not act on that outcome belief because they question whether they can actually execute the necessary activities" (Bandura, 1986). Instruments for measurement of self-efficacy conventionally include two sub-scales to measure efficacy expectations (often referred to as self-efficacy) and outcome expectations respectively.

Instruments to measure general self-efficacy, that is belief in ability to perform well in a variety of situations, have been constructed and validated (Scherbaum, Cohen-Charash, & Kern, 2006). However, such measures are problematic because the respondents are required to make judgements about their ability to perform without a clear activity or task in mind. If the intention is to use self-efficacy measurements as predictors of success at an activity, it is preferable to use domain-specific assessments (Pajares, 1996).

Research on teachers' beliefs has suggested that there is a "strong relationship between teachers' educational beliefs and their planning, instructional decisions, and classroom practices" (Pajares, 1992). Self-efficacy beliefs of teachers have been investigated by researchers using general measures of teaching efficacy (Gibson & Dembo, 1984; Woolfolk, Rosoff, & Hoy, 1990)

and have been found to be associated with successful engagement in change processes (McKinney, Sexton, & Meyerson, 1999) and with other desirable outcomes.

As noted above, domain-specificity is important for self-efficacy and, in addition to general measures of teaching efficacy (Gibson & Dembo, 1984; Woolfolk et al., 1990), measures have been developed for specific teaching areas. One of the most widely known and used of these is the Science Teaching Efficacy Belief Instrument (STEBI) which was originally developed for use with practising teachers (Riggs & Enochs, 1990), the STEBI-A, and subsequently revised for use with pre-service teachers (Enochs & Riggs, 1990), the STEBI-B. Both versions of STEBI include the two sub-scales indicated by self-efficacy theory (Bandura, 1977), the Personal Science Teaching Efficacy (PSTE) for efficacy expectations, or self-efficacy (SE), and Science Teaching Outcome Expectancy (STOE) for outcome expectancy (OE). PSTE measures a teacher's belief about his or her ability to effectively perform science teaching behaviour while STOE measures belief that teaching will be successful in producing the desired learning for students. Despite being first developed more than 20 years ago, the STEBI is still being used in research (Sinclair, Naizer, & Ledbetter, 2011; Swars & Dooley, 2010; Cantrell, Young, & Moore, 2003) and was the basis for the measurement of self-efficacy for science teaching in the *Primary Connections* project (Hackling et al., 2007; Hackling & Prain, 2005). In addition to the STEBI-B, the original STEBI-A has also been used as the basis for development of similar instruments for other purposes, including the MUTEBI for measurement of self-efficacy for classroom computer use (Enochs, Riggs, & Ellis, 1993) and the BioTSEB for a study of Greek Primary teachers' Biology teaching self-efficacy (Mavrikaki & Athanasiou, 2011).

Because self-efficacy is such a strong determinant of behaviour, development of science teaching efficacy is an important goal of teacher preparation and subsequent professional development (Swars & Dooley, 2010). Researchers have reported that teachers with low efficacy for science teaching typically devote less time to the subject (Raymey-Gassert & Shroyer, 1992), that graduates with a stronger sense of efficacy for science teaching make better progress as beginning teachers of science (Appleton & Kindt, 2002), and that teachers with higher levels of efficacy are more likely to use inquiry methods to teach science ((Andersen, Dragsted, Evans, & Sørensen, 2004).

Measurements obtained using either form of the STEBI have been reported differently by different researchers, either as aggregate scores across all items or as mean values on the five point scale used for each item. Moreover, the number of items included in the scale may vary. As a consequence, any comparison across studies needs to be treated carefully to ensure that the measurements are comparable. Self-efficacy (PSTE) for teachers participating in the *Primary Connections* trial was measured using 10 items from the STEBI-A rather than the 13 items used by other studies. Scores were reported as increasing from 35 to 41 (/50) (Hackling et al., 2007) which would correspond to a change from 3.50 to 4.10 if reported on the five point scale. Swars and Dooley (2010) found that a field-based science methods course produced significant increases in self-efficacy for science teaching, though not in outcome expectancy, for a group of pre-service teachers. They reported a pre-test to post-test change in aggregate score from 39.33 to 49.90 for 13 items in the efficacy sub-scale of the STEBI-B, corresponding to a change from 3.02 to 3.83 if converted to a five point scale. The lower values reported in that study may result from differences between the A and B forms of the STEBI or from the teachers in the *Primary Connections* trial having generally higher efficacy as a consequence of successful experience, which is the most powerful contributor to development of self-efficacy (Bandura, 1997). Another study using the STEBI-A to evaluate a year long professional development program for teachers reported statistically significant gains and post-test scores ranging from 2.60 to 3.16 (Sinclair et al. 2011) which is notably lower than the values reported for other studies. The implication appears to be that comparison of STEBI scores across contexts should be made with care to ensure that the comparisons are valid. Nevertheless, the STEBI is widely regarded as valid for its purpose and a useful tool for research about the preparedness of teachers for teaching science.

Research suggests that outcome expectations as measured by the STEBI sub-scale for STOE are more difficult to influence than efficacy expectations (PSTE). For example, a study of pre-service teachers reported significant changes for PSTE but not for STOE and explained the difference by reference to pre-service teachers lack of context for judgement of STOE because of limited classroom experience (Hechter, 2011). A study of the effect of a two year professional development program on self-efficacy of middle-school teachers for teaching environmental health used the STEBI-A and reported significant increases in PSTE but not for STOE (Haney, Jing, Keil, & Zoffel, 2007). No reason was suggested for the difference. Another study with early childhood teachers reported significant increases in both PSTE and STOE (Duran & Ballone-Duran, 2005) as did a more recent study using a problem-based learning approach to professional development (Shin et al., 2010). The latter study reported means of 3.45 and 3.97 for STOE and PSTE respectively prior to the professional development, which extended over four years by which time the means had increased to 3.67 and 4.16 respectively.

Focus of the Study

This study emerged because the school system was aware that science education in primary schools within the system exhibited characteristics common to science education in primary or elementary schools in Australia and elsewhere around the world. That is, many teachers appeared to lack confidence for science curriculum and pedagogy and some were allocating very limited time to science in primary school classrooms. In some cases the time being allocated was within integrated curriculum units where the focus was on other subjects and science was not appropriately emphasised.

These conditions are similar to those reported for other school systems as outlined in the literature review above and correspond to the issues that *Primary Connections* was intended to address. The purpose of this study was to collect current data about the teaching of science in the systemic primary schools in order to gauge the effects of the previous implementation of *Primary Connections* and to inform the Science Education Strategy being developed for the school system. Data collected included measures of teachers' self-efficacy for teaching science, information about current science teaching, and teachers' responses to the implementation of *Primary Connections* in the schools.

The key research questions addressed in this paper are:

1. To what extent (time teaching science and curriculum coverage) are primary teachers in the system engaging with science teaching?
2. What responses do teachers report to the implementation of *Primary Connections* in the schools?
3. What levels of self-efficacy and outcome expectancy for science teaching do teachers report as measured by the STEBI-A?
4. How are teachers' reported levels of self-efficacy and outcome expectancy for science teaching related to their teaching of science in schools?
5. What effects appear to be associated with the promotion of *Primary Connections* within the systemic primary schools?

Method

The data reported here were collected using a questionnaire based on the STEBI-A with additional questions developed by the researchers in collaboration with education officers from the school system. The design of the questionnaire was informed by the observations of system staff in schools, reports from the *Primary Connections* project, and published research on science edu-

cation. At the suggestion of the system representatives, and in order to encourage teachers to respond by ensuring anonymity of responses, no demographic items (age, gender, location, or similar) were included in the survey. The system Director approved the content of the questionnaire, the method of administration, and the invitation to teachers.

The questions from the original STEBI-A (Riggs & Enochs, 1990) were reviewed and the language in some was adjusted where it was considered that the intended meaning of the original might be better conveyed for the contemporary Australian context by a change of wording. For example, item 3 in the STEBI-A was changed from "Even when I try very hard, I don't teach science as well as I do most subjects" to "Even when I try very hard I don't teach science as well as I do in other KLAs" where KLA refers to one of the nine Key Learning Areas described by the Queensland Studies Authority (www.qsa.qld.edu.au). Other changes included substitution of "primary" for "elementary" and replacement of "what to do to turn students on to science" by "how to engage students with science". Items on the adapted STEBI-A scales were presented using a five point scale from 'Strongly Disagree' to 'Strongly Agree' with the middle point labelled as 'Neutral'.

Additional questions on the questionnaire investigated the time spent on teaching science, the aspects of science curriculum included, experience with the use of *Primary Connections* units, and opinions about aspects of support for science teaching in the schools. These items used the same scale as the STEBI where they could be appropriately expressed as statements that invited agreement or disagreement. In other cases the respondents were able to select from a range of options appropriate to the item or enter a number. Three items at the end of the questionnaire allowed for open responses to questions about the importance of science in the curriculum, likes and dislikes about the *Primary Connections* units, and factors that reduce time spent on science in primary classrooms.

Because schools in the system are spread across a wide geographic region but all have Internet connections the questionnaire was administered online. This approach also facilitated the processes of collating data and transferring to SPSS 19 for analysis. LimeSurvey (www.limesurvey.org) was used to develop and administer the online questionnaire. Names and email addresses provided by system authorities were uploaded and used to generate personal email invitations to teachers. The software supported anonymous tracking of responses so that, although responses could not be linked to individuals, reminders could be sent selectively to those who had not responded within a week and again after two weeks.

Results

Invitations were sent to all 361 teachers in the primary schools administered by the system. Of those teachers, 226 (63%) commenced the questionnaire and 216 (60%) completed sufficient items for the responses to include data useful for at least some analysis. Once the questionnaire had closed, data were transferred to SPSS 19 for analysis.

Teachers' Engagement With Science Teaching

Figure 1 displays the distribution of 212 responses to a question about the amount of time spent teaching science in a typical week. The majority of teachers (61%) reported spending between 31 and 90 minutes per week on science, with 41% reporting 31 to 60 minutes and 20% reporting 61 to 90 minutes. A small number (6%) reported spending more than 90 minutes per week but a larger number (33%) reported spending 30 minutes or less per week teaching science. Using 0, 120 and the mid-points of the other bands as the basis for calculating, the mean and median times are estimated at 44 and 43 minutes respectively. The data from this study are comparable to results reported by the *Primary Connections* evaluation (Hackling and Prain 2005) where, of 91 teachers for whom pre-trial data were reported, 27.5% taught science for less than 30 minutes per

week, 40.7% taught science for between 30 and 60 minutes per week, and the remaining 30.8% taught science for 60 minutes or more per week.
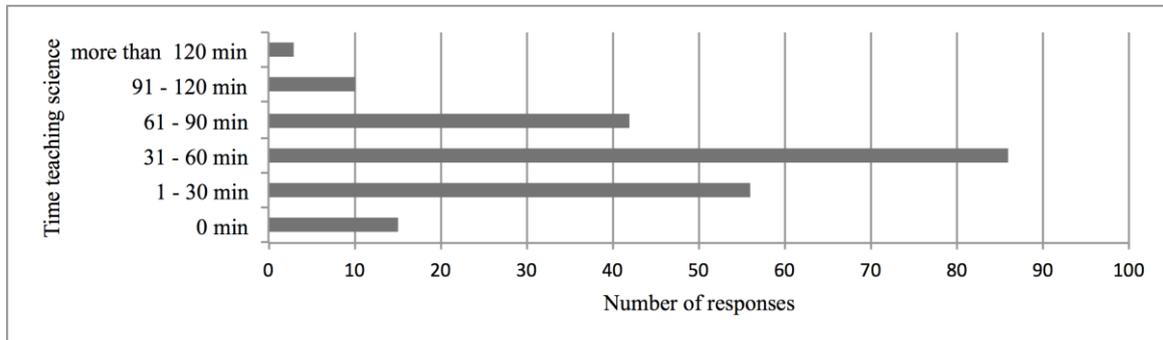

Figure 1. Teachers' Reported Time spent Teaching Science Per Week (N = 212)

Figure 2 presents the distribution of 212 responses to a question that asked teachers about the coverage of science curriculum. The options recognized the possibility of integrating science with another curriculum area as well as the existing Queensland science curriculum being presented in four strands: Earth and Beyond, Energy and Change, Natural and Processed Materials, and Life and Living. The most commonly selected response was that "integrated units of work have some science content" (38%). The next most common responses were "2 units from at least 2 strands during the year" (26%) and "a different unit per term from all 4 strands during the year" (20%).

Figure 3 reports data from responses about the number of units planned, taught and assessed across the year according to science curriculum strand. For each strand, 8 to 11 teachers reported no activity and up to 83 did not respond to the item at all. Based on the data presented in Fig. 3 it seems that the Life and Living strand is included more often by teachers in their planning.
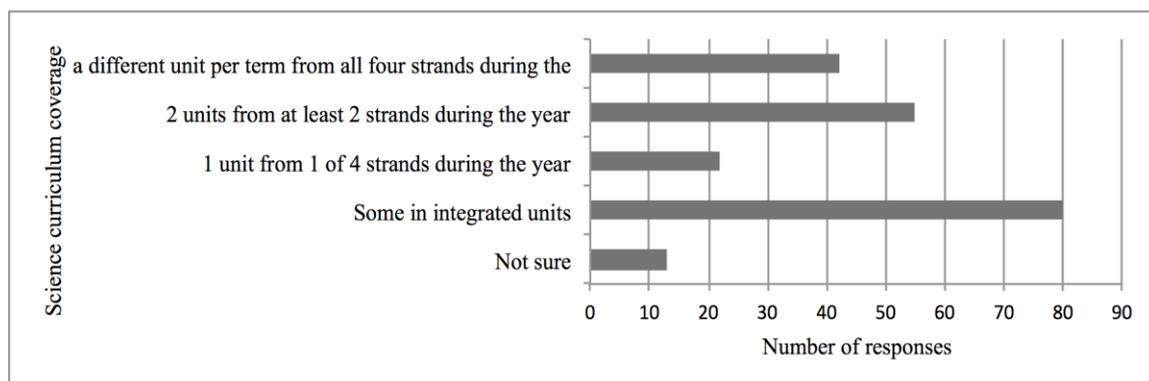

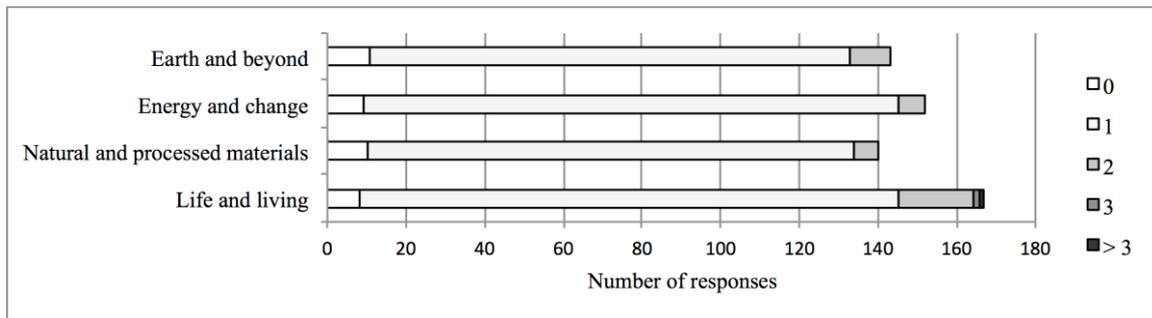Figure 2. Teachers' Reported Science Curriculum Units (N = 212)

Figure 3. Distribution of Units Planned, Taught and Assessed by Curriculum Strand (N varies by strand)

Responses to an item about whether teachers planned, taught and assessed a science based unit of work each semester included 137 (61%) affirmative responses and 51 (23%) negative, with 38 (16%) abstaining. The data represented in Fig. 2 included 97 (46%) who claimed at least 2 units per year or 1 per term which is not sufficient to account for the affirmative responses to this item. The balance may relate to the inclusion of science in integrated units of work.

Responses to implementation of Primary Connections

In response to a question about whether they had used *Primary Connections* units for teaching science, 99 (44%) of responding teachers answered with 'yes', 98 (43%) with 'no', and the remaining 29 (13%) abstained. Two questions that followed were presented only to those who responded 'yes' and the data from those are presented in Table 2. These items used a five-point scale ranging from 'Strongly disagree' (SD) to 'Strongly agree' (SA). Participants who had used *Primary Connections* overwhelmingly agreed that the units were easy to use and most thought that lessons based on *Primary Connections* were not difficult to set up and resource.

Table 3 summarizes the responses to two additional closed response questions that were presented to all participants. The responses have been split according to whether respondents had used *Primary Connections*. Although the difference was more marked for the question about understanding of *Primary Connections*, for both items the differences in responses for those who had used *Primary Connections* compared to those who had not were statistically significant; t(160)=13.273, p<0.001 and t(156)=3.135, p=0.002.

Table 2. Response of *Primary Connections* Users

	N	SD	D	U	A	SA	Mean	Median	Std Dev
Primary Connections units are easy to use	99	0	2	5	46	46	4.37	4	0.68
Primary Connections lessons are difficult to set up and resource	95	18	50	18	8	1	2.20	2	0.88

Although there is no surprise that users were more likely to report good understanding, it is notable that even non-users reported a perception that using *Primary Connections* would encourage an increase in science teaching.

Table 3. Responses to Items about School System Science Strategy

	Primary Connections user	N	Mean	Std Dev
I have a good understanding of Primary Connections.	Yes	82	3.61	0.84
	No	80	1.95	0.75
The use of Primary Connections will encourage me to do more science teaching in my classroom.	Yes	82	3.94	0.67
	No	76	3.55	0.87

Self-Efficacy And Outcome Expectancy For Science Teaching

The STEBI-A (Riggs & Enochs, 1990) is a well-known research instrument. The version used in this study was based on the 25 items of the STEBI-A, with some slightly reworded for the current day Australian context, which differs from the US mid-west of 1990 where the instrument originated. Hence it was considered prudent to apply some tests to confirm the characteristics of the instrument.

Analysis related to the STEBI-A was conducted for the 175 cases in which all 25 items from the STEBI-A scales were completed. Confirmatory factor analysis was undertaken using Principal Components Analysis with Varimax Rotation, which converged in three iterations confirming the two component solution corresponding to self-efficacy (PSTE) and outcome expectancy (STOE) as reported in the original research (Enochs & Riggs, 1990; Riggs & Enochs, 1990). The two factors (PSTE and STOE) had eigenvalues of 6.05 and 2.75, and accounted for 24.21% and 10.99% of the variance respectively. These values are comparable to the eigenvalues (6.26 and 2.71) and variance contributions (25.0% and 10.8%) reported in the original study for the STEBI-A (Riggs & Enochs, 1990).

In the original STEBI-A study, item 25, "Even teachers with good science teaching abilities cannot help some students learn science", was reported as loading on STOE (Riggs & Enochs, 1990) but was dropped from the STEBI-B because it cross-loaded (Enochs & Riggs, 1990). In this analysis it failed to load on STOE but loaded weakly and negatively (-.113) on PSTE and was dropped from the scale for subsequent analysis. This resulted in 13 items being used for the PSTE subscale and 11 for STOE. Cronbach's Alpha reliability was calculated at 0.89 for the PSTE subscale and 0.71 for STOE. A commonly cited lower limit of acceptability for Alpha for research purposes is 0.70 (Johnson & Christensen, 2004) and the values obtained here are comparable to the 0.92 and 0.77 reported for the original STEBI-A study (Riggs & Enochs, 1990).

Scores for PSTE and STOE were calculated for each of the 175 participants who completed all items on the scales as the averages (on the 5-point scale) for the items comprising the scales. Table 4 summarizes those data, showing mean, standard deviation, minimum, maximum and key percentile values for PSTE and STOE. On the 5-point scale (Strongly disagree to Strongly agree) used for the STEBI items, the mean values for PSTE and STOE fall between Neutral (3) and Agree (4), suggesting moderate levels of positive self-efficacy for their own ability as teachers of science and belief in the efficacy of good science teaching. However, the results are spread, with 22.9% and 19.4% of respondents scoring at or below the midpoint of 3 on the PSTE and STOE subscales, respectively, indicating limited belief in the efficacy of good teaching and limited self-efficacy for teaching science among about a fifth of the responding teachers.

Table 4. STEBI-A Subscale Results (N = 175)

	Mean	Std Dev	Min	Max	25%	50%	75%
Self-Efficacy (PSTE)	3.47	0.57	1.54	4.69	3.08	3.46	3.92
Outcome Expectancy (STOE)	3.37	0.41	2.18	4.45	3.09	3.36	3.55

Table 5 summarises data collected for the self-efficacy sub-scale (PSTE) of the STEBI-A with means and standard deviations for the data from this study and mean values for the ten equivalent items (*PC* Mean) for which initial data were collected from 89 participants in the *Primary Connections* trial (Hackling & Prain, 2005). Items marked with '*' were reverse scored so that for each item higher scores indicate higher levels of self-efficacy. The overall mean score of 3.47 indicates a moderate level of self-efficacy for teaching science and none of the individual items has a mean less than the mid-range value of 3.00. Although the mean value reported for *Primary Connections* trial participants at the commencement of that study was slightly greater (3.51), the difference is not statistically significant. Respondents to this study appear to have levels of self-efficacy for science teaching that are comparable to those of the *Primary Connections* trial participants at the commencement of the trial. The original STEBI-A study (Riggs & Enochs, 1990) reported average scores for PSTE and STOE equivalent to 4.30 and 4.12 respectively but did not report standard deviations. Hence it was not possible to test for statistical significance of those differences.

Table 6 summarises the data collected for the outcome expectancy sub-scale (STOE) of STEBI-A. The overall mean score (3.37) is greater than 3.00, indicating that respondents generally affirm that good science teaching improves student achievement in science. The only item in the 11 item scale to record a mean score of less than 3.00 was number 10, which appears to suggest that the respondents believe that there may be some students for whom good teaching may not make a sufficient difference.

STEBI-A Scores and Science Teaching

Despite the absence of conventional demographic data (age, gender, location) it is possible to use some of the data from the survey to develop comparisons by considering groups formed on the basis of differences in key variables.

Cases (N = 175) for which the presence of responses for all STEBI-A items permitted calculation of scores for PSTE and STOE, as reported above, were partitioned into two groups, high and low, by splitting at the median value for each of the variables. The responses of these groups on selected other items were then compared.

Respondents classified in the high group for PSTE were significantly more likely to report larger amounts of time spent teaching science, $\chi^2(5, N = 171) = 11.182$, $p = 0.048$ but there was no significant difference in time spent by those reporting higher levels of STOE. Higher levels of PSTE were not associated with significantly greater science curriculum coverage (expressed as numbers of units of work taught during a year) but there was a significant difference for those reporting higher levels of STOE, $\chi^2(4, N = 171) = 12.325$, $p = 0.015$. There were no significant differences between high and low groups on either PSTE or STOE for inclusion of the different curriculum strands in their teaching.

Table 5. STEBI-A Self-Efficacy Scores (PSTE) (N = 175)

#	Self efficacy items (* reverse scored)	Mean	Std Dev	*PC* Mean
2	I am continually finding better ways to teach science.	3.60	0.82	3.76
3	* Even when I try very hard, I don't teach science as well as I do in other KLAs.	3.07	1.01	3.24
5	I know the steps necessary to teach science concepts effectively.	3.24	0.88	3.37
6	* I am not very effective in monitoring science investigations.	3.24	0.90	3.22
8	* I generally teach science ineffectively.	3.65	0.82	3.60
12	I understand science concepts well enough to be effective in teaching primary science.	3.61	0.87	-
17	* I find it difficult to explain to students why science investigations work.	3.41	0.85	3.38
18	I am typically able to answer students' science questions.	3.54	0.82	3.51
19	* I wonder if I have the necessary skills to teach science.	3.06	0.96	-
21	* Given a choice, I would not invite the principal to evaluate my science teaching.	3.19	0.96	3.07
22	* When a student has difficulty understanding a science concept, I am usually at a loss as to how to help the student understand it better.	3.55	0.77	3.60
23	When teaching science, I usually welcome student questions.	4.15	0.75	4.35
24	* I don't know how to engage students with science.	3.77	0.78	-
	Mean score	3.47		3.51

Primary Connections and science teaching

Teachers in the group who reported using *Primary Connections* recorded a significantly higher mean PSTE value (M = 3.64, SD = 0.499) than non-users (M = 3.26, SD = 0.581); t(162) = 4.470, p < 0.001. There was no significant difference in the mean values of STOE for users (M = 3.39, SD = 0.414) compared to non-users (M = 3.39, SD = 0.354).

In general teachers who had used *Primary Connections* were more likely to select the higher options in response to the question about the amount of science curriculum covered in their teaching, χ^2(4, N = 197) = 16.15, *p* = 0.003. However, there was no significant relationship between the use of *Primary Connections* and the time spent on science each week, although teachers who used *Primary Connections* were significantly more likely to plan, teach and assess a science based unit each semester, χ^2(1, N = 183) = 19.92, *p* < 0.001.

Table 6. STEBI-A Outcome Expectancy Scores (STOE) (N = 175)

#	Outcome expectancy items (* reverse scored)	Mean	Std Dev
1	When a student does better than usual in science, it is often because the teacher exerted a little extra effort.	3.54	0.80
4	When the science achievement of students improves, it is most often due to their teacher having found a more effective teaching approach.	3.76	0.72
7	If students are underachieving in science, it is most likely due to ineffective science teaching.	3.11	0.91
9	The inadequacy of a student's science background can be overcome by good teaching.	3.82	0.76
10	* The low science achievement of some students cannot generally be blamed on their teachers.	2.52	0.85
11	When a low-achieving child progresses in science, it is usually due to extra attention given by the teacher.	3.53	0.74
13	* Increased effort in science teaching produces little change in some students' science achievement.	3.36	0.87
14	The teacher is generally responsible for the achievement of students in science.	3.43	0.79
15	Students' achievement in science is directly related to their teacher's effectiveness in science teaching.	3.19	0.84
16	If parents comment that their child is showing more interest in science at school, it is probably due to the performance of the child's teacher.	3.43	0.83
20	* Effectiveness in science teaching has little influence on the achievement of students with low motivation.	3.37	0.87
	Mean score	3.37	

Discussion

Analysis of the data tended to confirm the impressions of the system officers that many teachers were not allocating sufficient time to teaching science. The Queensland Studies Authority (2011) has recommended that time allocations for science under the new Australian Curriculum should range from one hour per week in the early years to about 90 minutes per week in the later years of primary schooling. The data collected in this study did not include year level but even without that information it is clear that, with more than half of the teachers reporting less than an hour per week spent on science, science is not receiving the recommended level of attention in the primary school curriculum. The estimated values for mean and median at 44 and 43 minutes are both less than the recommended time for the early years and 74% of teachers who responded to the item reported teaching science for less than the recommended minimum of an hour per week. There is no reason to suspect that teachers responding to the questionnaire would have underestimated the time spent on science teaching. If the schools in the system are to meet the QSA recommended times for science, most teachers will require support to change their teaching patterns. Of particular concern will be the 33% of teachers who reported that they are spending 30 minutes or less per week teaching science.

Representation of the variety in science curriculum is no less a concern than the time devoted to science. The most common response (38%) to the question about amount of the curriculum covered was that some science was included in integrated curriculum units. Fewer than half

the teachers who responded claimed to address two or more of the four strands of the science curriculum during a typical year. These data suggest that many teachers are not addressing the breadth of the science curriculum in any meaningful way and will require support to extend the scope of their science teaching.

Early experiences of science in primary school are known to be important factors in learners' subsequent decisions about further studies in STEM disciplines (Australian Industry Group, 2013; Westerlund et al., 2011) with ultimate consequences for the availability of graduates with the STEM capabilities needed for innovation and economic growth (DETA, 2007; Wyss et al., 2012). If teachers in primary schools are not offering science experiences of sufficient duration and breadth to meet curriculum requirements, then there is reason to expect that pupils are having limited experiences of science and may consequently be less likely to choose science in later stages of their education. As noted above, governments (DETA, 2007) and business groups (Australian Industry Group, 2013) have recognized the need for more graduates with STEM capabilities and have proposed action to address the lack of STEM graduates beginning with enhancing the teaching of STEM subjects in primary schools. The school system in which this study was conducted had recognized the need and taken steps to address it through actions to enhance science education.

Given that implementation of *Primary Connections* has been the major systemic initiative for enhancing science teaching, the system officers can draw some comfort from the positive responses to those materials. Among the 44% of respondents who had used *Primary Connections* there was almost universal (92%) agreement that the materials were easy to use and only 10% considered the lessons difficult to set up and resource. Even among respondents who had not used the materials there was broad agreement (3.55 on the 5 point scale) that using the materials would encourage more science teaching. These results should encourage continued efforts to extend the reach of the *Primary Connections* materials and approaches to more schools and teachers within the system.

The results from the STEBI-A administration for self-efficacy (PSTE) and outcome expectancy (STOE) suggest that the teachers in this study are generally comparable to the Australian teachers who participated in the Stage 2 *Primary Connections* trial. They scored somewhat lower on both subscales than the USA teachers in the original STEBI-A study (Riggs & Enochs, 1990) but it is not clear how to interpret that difference given the differences in time and context.

The data from this study indicate that teachers reporting higher levels of PSTE were significantly more likely to also report larger amounts of time teaching science. They were also significantly more likely to be found among the group who reported having used *Primary Connections*. Although there was evidence that *Primary Connections* users were more likely to cover more of the science curriculum in their classes and to teach more science units in a year, there was no significant association between higher levels of PSTE and increased curriculum coverage. None of these associations amounts to evidence for a causal connection in either direction. However, when their existence is considered alongside the increase in PSTE reported in the Stage 2 *Primary Connections* trial (Hackling & Prain, 2005) and the increased confidence for teaching science reported in a more recent evaluation of *Primary Connections* (Skamp, 2012), there is reason for confidence that the decision of the school system to implement *Primary Connections* was well founded and that the strategy is worth continuing and extending.

Self-efficacy beliefs are a key determinant of personal agency and related behavior, influencing whether a behavior will be initiated and how long it will continue in the face of challenges (Bandura, 1977). Many primary school teachers have had only limited experiences of science in their own education and that lack of exposure to the most important source of information for developing self-efficacy, enactive attainment or successful experience (Bandura, 1986), will have contributed to low levels of self-efficacy for teaching science. It is known that teachers' planning and classroom practices are strongly influenced by their beliefs (Pajares, 1992) and lower self-efficacy for science teaching is likely to be an important influence on teach-

ers' decisions about the breadth and duration of science experiences in their classes. If access to resources like *Primary Connections* and the associated professional development can contribute to an increase in self-efficacy for teaching science then there is likely to be, as reported by the teachers in this study, an increase in science teaching. If even some teachers experience more success with science teaching as a consequence of engagement with *Primary Connections* or similar interventions there is a likelihood that colleagues who become aware of their success may also have an increase in self-efficacy as a consequence of the second major source of self-efficacy information, vicarious experience or observing the performances of others (Bandura, 1986).

The school system has a history of encouraging teachers to use science curriculum materials developed by the Australian Academy of Science, beginning in the late 1990s with *Primary Investigations* (Aubusson & Steele, 2002) and moving to *Primary Connections* when that material became available commencing from 2006. However, it was not until 2010 that the system initiated a Science Education Strategy and appointed an education officer to provide ongoing professional development and other support for implementation in schools. The current study was conceived to evaluate the first phase of that initiative and to inform its ongoing work.

From the particular perspective of the local school system, the data collected in this paper confirmed that there was scope for increasing teachers' attention to teaching science, both in the time allocated and the breadth of curriculum topics addressed. The data also confirmed that where *Primary Connections* had been implemented there was an increase in teachers' attention to science teaching and their confidence for teaching science. In response the system officers have continued to promote the use of *Primary Connections* and have provided additional support with professional development and provision of resources for science teaching. The second phase of the research will collect survey data to assess any changes in patterns of science teaching and associated self-efficacy. Interviews with teachers are planned to allow more detailed exploration of their experience of *Primary Connections* and the associated systemic initiatives.

Conclusion

Evidence obtained through this study has confirmed the impressions of the education system officials that science teaching is not receiving the attention it deserves in systemic primary schools. At the same time it has confirmed that the existing strategies using *Primary Connections* materials and associated processes are having some success and that it would be helpful to maintain and extend that approach. Teachers who have worked with the *Primary Connections* materials are positive about their experience and mention of the materials evoked a positive response even from teachers who had not worked with them.

Although the study was not designed to obtain evidence about the more general success of *Primary Connections*, the findings do tend to confirm the positive evaluations reported elsewhere (Hackling & Prain, 2005; Skamp, 2012). Moreover, where the previous findings were obtained in the context of an evaluation of the *Primary Connections* program under 'ideal' conditions the findings of this study were obtained from a field implementation, without specific project support and in a school system simultaneously contending with a range of other projects and priorities. The apparent success of *Primary Connections* under those conditions is testament to the quality of the program and its capacity to provide continuing value into education systems seeking to enhance science teaching.

This study was conducted within the context of a small school system in provincial Queensland and the results should not be assumed to be generalizable to other contexts. Nevertheless, the results do suggest that well supported interventions like the implementation of *Primary Connections* in this system can make a difference to science teaching. There is sufficient evidence to encourage other systems seeking to enhance STEM education to investigate similar approaches.

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