UTS

Faculty of Arts & Social Sciences

Primary Connections: Linking Science With Literacy

Stage 6 Research Evaluation Final Report

UTS CRICOS 00099F

PRIMARY CONNECTIONS: LINKING SCIENCE WITH LITERACY
STAGE 6 RESEARCH EVALUATION
FINAL REPORT

Prepared for the Australian Academy of Science

Ian Potter House, 9 Gordon Street, Canberra ACT 2601

by

University of Technology Sydney ABN 77 257 686 961

15 Broadway, Ultimo NSW 2007, PO Box 123, Broadway NSW 2007

Primary Contact: Professor Peter Aubusson: 02 9514 5264 Peter.Aubusson@uts.edu.au

Acknowledgement

The UTS research team would like to acknowledge the timely support and efficient assistance given to the Stage 6 evaluation process by Australian Academy of Science *Primary Connections* staff Ms Shelley Peers and Ms Hristina Milenkovska. At all times, your concern for the independence of the evaluation was central to the process, and the UTS team values your professional integrity and thoughtful feedback provided when sought.

Suggested citation

Peter Aubusson, Keith Skamp, Paul F. Burke, Kimberley Pressick-Kilborn, Wan Ng, Tracey-Ann Palmer, Andy Goodall, and Jennifer Fergusson (2019). *Primary Connections: Linking science with literacy Stage 6 research evaluation final report.* Prepared for Steering Committee of Primary Connections, Australian Academy of Science.

TABLE OF CONTENTS

EXECUTIVE SUMMARY

This report presents findings from the External Independent Evaluation and Research for *Primary Connections* Stage 6 (2014–2018) conducted by a research team from the University of Technology Sydney (UTS). The purpose of the Stage 6 Evaluation was:

- to assess the program outcomes against the Stage 6 objectives, and
- to assess the impact of the program more broadly in order to enable program improvement.

The Stage 6 objectives are:

- to increase the uptake of *Primary Connections* in schools;
- to support primary school teachers and pre-service primary school teachers to teach science through inquiry; and
- to ensure primary school teachers, pre-service primary teachers and school educators are informed about *Primary Connections*.

Background to Primary Connections: linking science with literacy

Primary Connections: linking science with literacy (Primary Connections) is an initiative of the Australian Academy of Science (AAS). It is an innovative, inquiry-based approach for the teaching and learning of science and the literacies of science in primary schools. *Primary Connections* is supported through professional learning resources and workshops, a broad range of high-quality curriculum units, and other supporting resources that align with the *Australian Curriculum: Science*.

The progressive development and initial implementation of *Primary Connections* were funded by the Australian Government ($11.2 million) in five stages from 2004 to 2014. Stage 6 (2014 – 2018) has brought the Australian Government financial commitment to the program to $14.7 million from 2014 to 2018.

Methodology

This evaluation employed a range of qualitative and quantitative methods, including observations of professional learning workshop delivery, a literature review, focus group and individual interviews, and surveys with a range of stakeholders. Survey methods included Best Worst Scaling (BWS) and Discrete Choice Experiment (DCE), methods that allow the relative importance of factors relating to an issue to be determined.

Evaluation findings

This evaluation has revealed the significant impact of *Primary Connections* on teachers of primary science. Their feedback about the effectiveness of the resources, and their enthusiasm to employ *Primary Connections* in their science teaching, show that teachers value *Primary Connections* highly.

- Workshop participants reported/showed increased levels of interest, enjoyment, confidence, and comfort in teaching science after they had attended a *Primary Connections* workshop. (sources of data: surveys, focus groups)
- Participants' understanding of primary science pedagogy improved as a result of attending Stage 6 workshops. (surveys, focus groups)
- Workshop participants didn't necessarily realise the importance of the 5Es model for *Primary Connections* previously. (focus groups)
- The workshops increased the likelihood of teachers comprehensively implementing the *Primary Connections* program in their teaching. (surveys, focus groups)
- Ninety-nine per cent of teachers agreed that *Primary Connections* would help them to implement the *Australian Curriculum: Science*. (surveys)

- The top 10 areas nominated by in-service teachers as being relatively more important for inclusion in *Primary Connections* professional learning were (in order of importance):
    1. Investigation-based science
    2. Science teaching strategies
    3. Guiding inquiry in science
    4. Adapting *Primary Connections* for multi-stage classes
    5. Understanding the *Primary Connections* approach
    6. Various ways of teaching each 5E phase
    7. Differentiating *Primary Connections* for student diversity
    8. Activity-based science
    9. Doing hands-on science activities
    10. Implementing *Primary Connections* units (source of data: BWS)
- Overall, teachers were satisfied with the *Primary Connections* workshops. When asked to suggest workshop improvements, they mentioned assessment activities, more hands-on activities, some type of online support or follow-up from the workshops, and more activities using digital technologies. (surveys, focus groups)
- As a workshop follow-up activity, teachers were most interested in accessing online videos with workshop-related content, or an expert-led online discussion forum. (BWS, DCE)
- Both in-service and pre-service teachers prefer face-to-face professional learning workshops. (surveys, BWS, DCE, focus groups)
- In-service teachers were not in favour of the use of online only workshops. (DCE)
- Workshop fees were the most important consideration in whether or not participants would attend a future *Primary Connections* workshop. The next most important considerations were: travel time; the timing of the workshop; additional follow-up; duration; and content. (DCE)
- Face-to-face workshops are valuable and critical but opportunities for on-going professional learning, including online activities, should be explored and implemented. (expert interviews)
- In addition to face-to-face workshops, online professional learning may offer some benefits, not least being flexibility of access, but currently internet access in schools is perceived to be inadequate for the task. (expert interviews)

In this Stage 6 evaluation, the levels of confidence and enjoyment in teaching science were found to be higher, relative to teachers surveyed in other settings. For example, Burke et al. (2017) found that NSW Association of Independent Schools teachers reported lower levels of enjoyment and comfort in teaching primary science than teachers surveyed in this evaluation. However, the teachers surveyed in the Stage 6 evaluation said they work with other teachers with low science capacity, hence there is a need to provide further professional learning opportunities and to increase the reach of *Primary Connections*.

Conclusions

Primary Connections has extraordinary brand recognition and it has been widely implemented. Past *Primary Connections* phases have attracted many teachers to use *Primary Connections*. By almost any measure it has been a great success. Stage 6 has been very successful in extending the reach of *Primary Connections* among regional, rural and remote teachers, primarily in building capacity among current users to implement *Primary Connections* more faithfully and with greater skill and confidence.

The research team takes the view that *Primary Connections* should continue much as it has, by continuing to develop hard copy resources, providing units online with support materials, together with professional learning workshops on *Primary Connections* to increasing numbers of teachers. These activities should continue to be supported by professional learning, building collaboration among teams of primary teachers, and working with expert *Primary Connections* support to effectively implement *Primary Connections* in classes across their schools.

The research team is conscious that much of the evaluation data about *Primary Connections* come from those who have chosen to use it rather than those who have chosen not to use it. To engage teachers who have chosen not to use *Primary Connections* and not to engage in *Primary Connections* professional learning, consideration should be given to investigating/researching the adaption and development of a new *Primary Connections* science learning program. Such a program could be based on the fundamental *Primary Connections* teaching model, the 5Es, but provide resources in ways that exploit the opportunities provided by an online platform that allows teachers to readily select, adapt and build their own program of work, and students to directly engage with varied learning activities that make the most effective use of digital learning.

In the short term this would require two forms of *Primary Connections* to coexist and the cost of achieving this would be substantial. The argument is not that the Australian Academy of Science should abandon *Primary Connections* in its current form and suddenly invest in the digital learning environment. Rather, the argument is that it is essential to plan for such a development and recognise that for an extended period both digital and more traditional ways of improving science teaching and learning are likely to coexist.

Recommendations

Following are recommendations arising from the *Primary Connections* Stage 6 evaluation, arranged by research stream: Appropriateness, Efficiency, Effectiveness and Governance.

Appropriateness: Is the program consistent with Australian Government priorities?

1) Continue to update *Primary Connections* resources and related activities to ensure that they support Australian Government priorities in science and STEM education and make this public through the *Primary Connections* website.

Efficiency: Is Stage 6 implementation achieving the goals within identified budgets and timeframes?

2) Continue to provide initial *Primary Connections* professional learning workshops face-to face for in-service teachers, while considering delivery and accessibility for educators in regional, rural and remote areas.
3) Develop and/or adapt an online learning platform that facilitates on-going, blended professional learning in *Primary Connections*.
4) Plan for the development of online *Primary Connections* resources that exploit the affordances (e.g. interactivity and adaptability to learner needs through use of learning analytics) of an online environment. The online environment should not primarily be a repository providing access to e-versions of hardcopy resources.
5) Phase out hardcopy *Primary Connections* materials and resources only when, or if, demand for these diminishes.
6) Consider collaboration with teacher education course providers to integrate the use of *Primary Connections* into initial teacher education programs, drawing on *Primary Connections* resources as an outstanding example of effective science education, rather than focusing on the implementation of *Primary Connections*.

Effectiveness: How well are we doing what we said we would do and could it be done better?

7) Ensure that teachers focus on student learning of key ideas expressed in *Primary Connections* (which are entirely consistent with the *Australian Curriculum: Science*) rather than the implementation of the *Primary Connections* program of study per se (that is, recognise that the 5Es and *Primary Connections* program are a means to an end, not the end in and of themselves).
8) Continue to emphasise science and literacy outcomes (as reflected in its title) and workshops clearly indicate how *Primary Connections* addresses both sets of outcomes (e.g., through its learning outcomes, introductory pages and some of its appendices).
9) Provide advice, and develop case studies, about how schools could develop a culture that encourages the continuous use of *Primary Connections* across Year levels, supported by an experienced school-level *Primary Connections* facilitator.

10) Trial and evaluate the use of a variety of strategies for professional learning with *Primary Connections*, including coverage of those matters identified in the Best-Worst Scaling survey as of greatest importance to teachers. Online videos of best practice in implementing *Primary Connections* would be a suggested starting point.
11) If online training is used as an adjunct to face-to-face workshops, then *Primary Connections* workshop developers should be mindful of the quality of internet access available to teachers and the concerning issues raised by pre- and in-service teachers in focus groups about the use of online professional learning.
12) Consider a range of workshop follow-up options as ways to consolidate the learning that was commenced as a consequence of the professional learning workshop, e.g. annotated videos, a forum, communication networks.
13) Conduct ongoing research to inform iterative development in *Primary Connections* professional learning.

Governance: How effective are the governance arrangements for Stage 6 of *Primary Connections*?

14) Consider having one committee that provides oversight of *Primary Connections* in future funding stages, given that there has been considerable overlap in the oversight of Stage 6 by the Management Committee and the Steering Committee.

INTRODUCTION AND BACKGROUND

This report presents findings from the External Independent Evaluation and Research for *Primary Connections* Stage 6 (2014 – 2018), a project commissioned by the Australian Academy of Science (AAS) with particular reference to work undertaken under the Stage 6 funding agreement with the Australian Government.

ABOUT PRIMARY CONNECTIONS

Primary Connections: linking science with literacy (*Primary Connections*) is an initiative of the AAS. It is an innovative, inquiry-based approach for the teaching and learning of science and the literacies of science in primary schools.

The aims of *Primary Connections* are to:

- Improve teaching and student outcomes in science and the literacies of science within primary schools.
- Raise primary school students' interest and engagement in learning about science.
- Improve the skills and confidence of primary teachers to teach science through inquiry.

Primary Connections is supported through professional learning resources and workshops, a broad range of high-quality curriculum units, and other supporting resources that align with the *Australian Curriculum: Science*.

BACKGROUND TO PRIMARY CONNECTIONS

The progressive development and initial implementation of *Primary Connections* was funded by the Australian Government ($11.2 million) in five stages from 2002 to 2014:

- The development of a conceptual model for the program was funded by the Australian Foundation for Science, an entity within the Australian Academy of Science (2002-2003).
- Stage 2 (2004-2006): Funded through the *Australian Government Quality Teacher Programme,* this stage resulted in the development, trial and evaluation of a draft professional learning program, a professional learning DVD (*Questioning Minds*), eight sample curriculum units, and a curriculum unit template.
- Stage 3 (2006-2009) involved the publication of a suite of 19 curriculum units, training of 'Professional Learning Facilitators' across the country, workshops for pre-service teacher educators in universities, ongoing research and evaluation, and the incorporation of Indigenous perspectives.
- Stage 4 (2009-2012) consisted of ongoing support for 'Professional Learning Facilitators' training for 'Master Facilitators', the development of nine new curriculum units and additional resources, the inclusion of Indigenous perspectives in the curriculum links section of new curriculum resources, and alignment of some existing curriculum resources to the new *Australian Curriculum: Science*. By the end of Stage 4 there were 12 curriculum units that were fully aligned to the *Australian Curriculum* and loaded to Scootle on the Education Services Australia (ESA) website.
- Stage 5 (2012-2014): Development and online publication of a further 19 units (3 new titles and 16 redeveloped titles) to complete a suite of 31 units fully aligned to the *Australian Curriculum*; professional learning for 100 pre-service teacher educators; and promotion to schools including through a short online video for principals and school leaders. All 31 units are available free of charge to all Australian teachers and pre-service teachers through Scootle on the ESA website or through state and territory online portals.

Stage 6 (2014-2018) has brought the Australian Government financial commitment to the program to $14.7 million from 2014 to 2018.

STAGE 6 PURPOSE AND OBJECTIVES

The purpose of the Stage 6 Evaluation was:

- to provide a summative evaluation of the work completed under the current funding agreement through an assessment of outcomes against the Stage 6 objectives; and
- to assess the impact of the program more broadly in order to enable program improvement.

The Stage 6 Objectives are:

- to increase the uptake of *Primary Connections* in schools.
- to support primary school teachers and pre-service primary school teachers to teach science through inquiry.
- to ensure primary school teachers, pre-service primary teachers and school educators are informed about *Primary Connections*.

The Stage 6 Evaluation determines the extent to which Stage 6 is delivering the desired outcomes and assesses the extent and quantum of the impact of the program. The research questions addressed are in four streams - Appropriateness, Efficiency, Effectiveness and Governance - as follows:

Appropriateness: Is the program consistent with Australian Government priorities?

- RQ 1.1 How well does Stage 6 align with the current Australian Government education policy priorities, particularly in relation to STEM education in schools?
- RQ 1.2 Is training teachers in *Primary Connections* a priority for the government in order to improve the teaching of primary school science teaching?

Efficiency: Is Stage 6 implementation achieving the goals within identified budgets and timeframes?

- RQ 2.1 What is the cost of training in-service and pre-service teachers in *Primary Connections*?
- RQ 2.2 Does training teachers and pre-service teachers in *Primary Connections* increase the likelihood of teachers and schools comprehensively implementing the program?
- RQ 2.3 What are the differences in fidelity of implementation of *Primary Connections* units and using an inquiry approach by those who have done no professional learning in *Primary Connections* and those who have undertaken the Stage 6 professional learning?[1]
- RQ 2.4 Is training in-service teachers and pre-service teachers in *Primary Connections* the most efficient way to increase the effective implementation of the program?
- RQ 2.5 Are there any unintended benefits or disadvantages in providing training in particular ways for in-service teachers and pre-service teachers?

Effectiveness: How well are we doing what we said we would do and could it be done better?

- RQ 3.1 What are the anticipated outputs and outcomes, when are these expected to be achieved and how is the program designed to achieve them?
- RQ 3.2 To what extent has Stage 6 met the aims and objectives as set out in the funding agreement?
- RQ 3.3 What else can the *Primary Connections* program offer to assist teachers and pre-service teachers to implement the Australian science curriculum?

Governance: How effective are the governance arrangements for Stage 6 of Primary Connections?

- RQ 4.1 How well has the Academy, the Department of Education and Training and the Steering Committee been able to support and oversee the implementation and delivery of Stage 6?
- RQ 4.2 Have there been any major contract management issues?

---

[1] RQ 2.3 required comparison of teachers who had and had not attended professional learning. Due to time constraints and with agreement from the Stage 6 Project Steering Committee, RQ 2.3 was not addressed in this evaluation.

THE STEERING COMMITTEE

The Evaluation was overseen by the *Primary Connections: linking science with literacy* Stage 6 Project Steering Committee (Steering Committee) made up of representatives from the Australian Government Department of Education and Training and the AAS. The Steering Committee's purpose was to provide broad direction for the *Primary Connections* Stage 6 Project and facilitate communication about the Project between the Project stakeholders. The terms of reference of the Steering Committee were:

- to oversee and monitor the Project.
- to review Project planning, Project Reports, and workshop resources developed under the Stage 6 agreement.
- to monitor overall Project progress and provide a process for accountability, including in relation to timelines, expenditure, high quality contract deliverables and appropriate staffing.
- to facilitate communication between the Department of Education and Training, AAS and other relevant stakeholders.

THE RESEARCH TEAM

A research team from the University of Technology Sydney (UTS) was commissioned to conduct this external independent evaluation and research review of the *Primary Connections* Stage 6 objectives. The team used a range of qualitative and quantitative methods in their evaluation. These methods included observations of professional learning workshop delivery, a literature review, focus group and individual interviews, and surveys with a range of stakeholders. The design of the evaluation approach was determined in consultation with the Steering Committee. Details of the research team are presented at the end of this report.

STRUCTURE OF THIS REPORT

The evaluation approach for this study is provided in the next section arranged by stream: Appropriateness, Efficiency, Effectiveness and Governance*. A range of research methods was used to address research questions in and across each of the streams.

As the evaluation progressed through phases, research reports on each research phase were prepared for, and reviewed by, the AAS. These reports are presented in the appendices and each report addresses specific research questions within the four streams.

A summary of findings organised by research stream is included in this report.

---

*For reasons pertaining to confidentiality, sections relating to Governance, and spending, were redacted before publishing this report.

EVALUATION APPROACH

This section provides an overview of the research and evaluation methodologies used to address the research questions in each stream. For details on each of the research methodologies, including the analysis and interpretation of data, please refer to the reports relevant to the particular research phase as presented in the appendices.

OVERVIEW

Previous research by the UTS research team found strong evidence that there is great variation in the science teaching capability of schools and in and amongst the teachers within those schools. Evaluation of *Primary Connections* Stage 6 therefore required a range of methodologies that are effective with varied groups of teachers, particularly those in regional, rural and remote areas.

This evaluation used both qualitative and quantitative research methods. The combination of focus group, interview and survey data allowed multiple opportunities for participants and stakeholders in *Primary Connections* to express views on the phenomena under investigation. The comparison of similarities in responses contrasted with areas of difference provides triangulation of data and thus increases confidence in the findings ([2]Lincoln & Guba, 1985).

There already has been extensive research and evaluative work that has investigated *Primary Connections* and its impact. There also have been previous studies of the effectiveness of teacher professional learning in enhancing the design and delivery of primary science. Where practicable, previous research was analysed and instruments from previous studies used to maximise efficiency of the study and to allow productive comparison between the findings of this Stage 6 evaluation with existing data and findings.

QUALITATIVE RESEARCH METHODS

The traditional qualitative research methods of focus groups, interviews and a systematic literature review were used in this evaluation. Focus groups allowed for investigation of the views of stakeholders such as *Primary Connections* leaders, in-service and pre-service teachers. Focus groups were employed to gather stakeholders' views, to gain an understanding of how participants perceive and think about *Primary Connections* Stage 6. Focus group data were analysed and informed the generation of items and factors for quantitative methods used in subsequent stages of the evaluation. Interviews allowed an in-depth analysis from the point-of-view of key and well-informed stakeholders in *Primary Connections*. A systematic literature review was conducted to determine evidence-based characteristics of effective professional learning in primary science to ensure findings from prior research were considered. The methodology for the governance evaluation involved reviewing Steering Committee terms of reference and meeting minutes, and interviews with Steering Committee and Management Committee members.

QUANTITATIVE RESEARCH METHODS

The quantitative methods used in this evaluation were surveys developed from the findings of the qualitative research. The surveys were conducted before and after pre-service and in-service teachers had attended *Primary Connections* professional learning workshops and they included closed- and open-ended questions to determine respondents' views on a range of issues relating to the research questions. Importantly, surveys also incorporated two novel approaches: Best-Worst Scaling and a Discrete Choice Experiment. These novel methodologies are explained in detail in the appendices, but in summary, Best-Worst Scaling is a unique

[2] Lincoln, Y. S., & Guba, E. G. (1985). Establishing trustworthiness. In E. G. Guba (Ed.), *Naturalistic inquiry* (pp. 289–331). Beverly Hills, CA: Sage Publications.

methodology shown to be a valuable way to identify and analyse differences in groups of individuals. Best-Worst Scaling is a survey approach that allows the relative importance of factors relating to an issue to be determined. The traditional method employed to determine importance (e.g. Likert Scales) only allows each factor to be evaluated in isolation, meaning that respondents can rank all items as important, leaving the researcher with little idea of where to target changes or resources.

A further benefit of using Best-Worst Scaling is that the method results in a discrete outcome, a choice of one item over another. In contrast, a score on a continuous scale (e.g. rating on 1 to 7 scale) can lead to several response-style biases. Best-Worst Scaling therefore avoids response-style biases such as some respondents' tendency to avoid the extreme ends of the rating scales, or a tendency to remain neutral. Best-Worst Scaling is also advantageous because it is easier for respondents, since there is no allocation of points or percentages to items, or a need to rank a lengthy list of items simultaneously ([3]Louviere & Islam, 2008). This choice of scale was motivated by the ambition to make the task easier for respondents to complete, to reduce overall response times, and supported by growing evidence that the use of such indicators does not compromise measurement reliability.

The Discrete Choice Experiment was the final quantitative methodology used in this evaluation. This survey-based method relied on input from other research methods used in the Stage 6 evaluation and presented teachers with combinations of factors that had been identified as being influencers of whether teachers would participate in professional learning in *Primary Connections* in future or not.

Each set of research questions relating to this evaluation is presented in tabular format in this section under the research stream heading. The table should not be interpreted as suggesting that each research question was investigated with a different set of surveys, interviews and focus groups. Rather, the table indicates how data were gathered and analysed. A single data collection event, such as a focus group or a survey, was used to address a range of research questions.

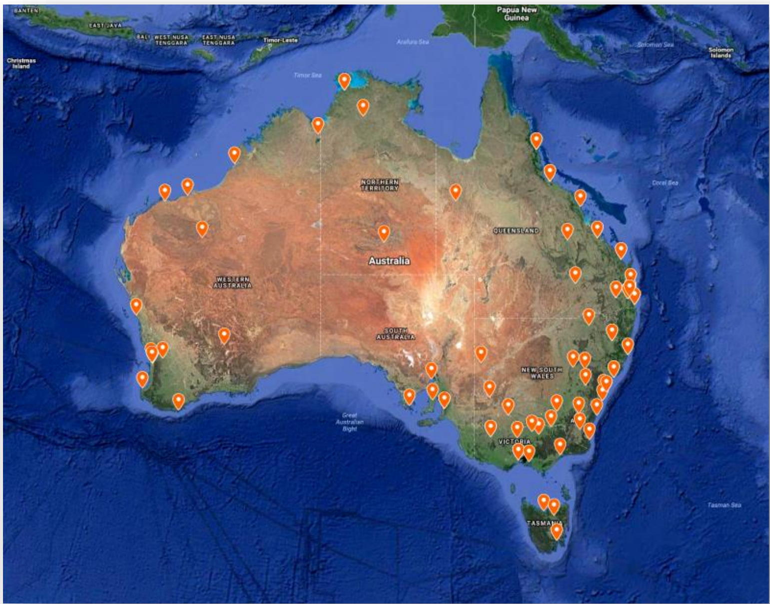


FIGURE 1 MAP OF *PRIMARY CONNECTIONS* STAGE 6 WORKSHOP LOCATIONS

[3] Louviere, J., & Islam, T. (2008). A Comparison of Importance Weights and Willingness-To-Pay Measures Derived from Choice-Based Conjoint, Constant Sum Scales and Best-Worst Scaling. Journal of Business Research, 61(9), 903-911.

In these tables Professional Learning is abbreviated as 'PL' and *Primary Connections* as 'PC'. 'RQ' stands for Research Question and is followed by an identifying number.

Appropriateness

Is the program consistent with Australian Government priorities?

Research Question	Sources	Data Gathering	Data Analysis	Deliverable
RQ 1.1 How well does Stage 6 align with the current Australian Government education policy priorities, particularly in relation to STEM education in schools?	Documents Interview with relevant stakeholders including, Steering Committee and AAS PC leadership team	Document review Interview	Content analysis Open coding thematic analysis	Report comparing Australian Government education policy priorities to Stage 6 outcomes and materials (See Appendix 1)
RQ 1.2 Is training teachers in *Primary Connections* a priority for the government in order to improve the teaching of primary school science teaching?	Documents Interview with relevant stakeholders including, Steering Committee and AAS PC leadership team	Document review Interview	Content analysis Open coding thematic analysis	Report appraising priority given by the government to training teachers in *Primary Connections* (See Appendix 1)

Efficiency

Is Stage 6 implementation achieving the goals within identified budgets and timeframes?

Research Question	Sources	Data Gathering	Data Analysis	Deliverable
RQ 2.1 What is the cost of training in-service and pre-service teachers in *Primary Connections*?	Financial documents	Document review	Statistical Package for the Social Sciences (SPSS)	Report describing mean cost per pre- and in- teacher and mean cost of course by (for example) location, mode of delivery, by program delivered
RQ 2.2 Does training teachers and pre-service teachers in *Primary Connections* increase the likelihood of teachers and schools comprehensively implementing the program?	In-service and pre-service teachers who attended PC PL Courses	Survey PL participants prior to PL to determine intentions and post PL to determine actual uptake of PC	Thematic interpretive analysis and SPSS, descriptive statistics	Report indicating planned and actual uptake of PC following PL training (See Appendix 8)
RQ 2.3 What are the differences in fidelity of implementation of *Primary Connections* units and using an inquiry approach by those who have done no professional learning in *Primary Connections* and those who have undertaken the Stage 6 professional learning?	Due to time constraints and with agreement from the Stage 6 Project Steering Committee, RQ 2.3 was not addressed in this evaluation.			
RQ 2.4 Is training in-service teachers and pre-service teachers in Primary Connections the most efficient way to increase the effective implementation of the program?	In-service and pre-service teachers who attended PC PL Courses	Best-Worst Scaling Survey (This is part of the post survey – see RQ 2.2) Discrete Choice Experiment	MaxDiff analysis and factor analysis to determine effectiveness within different teacher groups identified in the data Analysis of clustered variables	Report defining insights to how PC is implemented and comparing the mode of delivery with others identified in focus groups (below). (See Appendix 6 and Appendix 7)
RQ 2.5 Are there any unintended benefits or disadvantages in providing training in particular ways for in-service teachers and pre-service teachers?	In-service and pre-service teachers Lead facilitators in PL Literature	Focus groups Systematic literature review of teacher PL in primary science and effective development PL primary science	Thematic interpretive analysis Systematic analysis using explicit methods to identify relevant publications, analysis and synthesis of findings	Report describing benefits and disadvantages of PL delivery and how this compares with PC PL (See Appendix 2 and Appendix 4)

Effectiveness

How well are we doing what we said we would do and could it be done better?

Research Question	Sources	Data Gathering	Data Analysis	Deliverable
RQ 3.1 What are the anticipated outputs and outcomes, when are these expected to be achieved and how is the program designed to achieve them?	Document AAS PC leadership team	Document review Interview	Content analysis Open coding thematic analysis	Report on combined results from analysis of relevant literature on PL in PC. (See Appendix 2)
RQ 3.2 To what extent has Stage 6 met the aims and objectives as set out in the funding agreement?	AAS stage 6 documents Data from other research questions In-service and pre-service teachers Lead facilitators in PL	Document review Focus groups Interviews and surveys listed elsewhere in table	Content analysis Thematic interpretive analysis Overarching analysis of outcomes identified in varied data sources categorised against aims and objectives	Report synthesising data gathered from AAS Stage 6 documents compared against outcomes assessed through other data collection including interviews, focus groups and surveys.
RQ 3.3 What else can the *Primary Connections* program offer to assist teachers and pre-service teachers to implement the Australian science curriculum?	Panel science education/professional learning experts Data from other research questions including In-service and pre-service teachers Lead facilitators in PL Literature	Focus groups/interview Interviews and surveys listed elsewhere in table Best-Worst Scaling – included with post-survey Discrete Choice Experiment Literature review	Thematic interpretive analysis and analysis compared to teacher groups identified in BWS (Discrete Choice Experiment as noted above) Systematic analysis using explicit methods to identify relevant publications, analysis and synthesis of findings	Report of gap analysis and potential developments. (See Appendix 6 and Appendix 7)

Governance

How effective are the governance arrangements for Stage 6 of *Primary Connections*?

Research Question	Sources	Data Gathering	Data Analysis	Deliverable
RQ 4.1 How well has the Academy, the Department of Education and Training and the Steering Committee been able to support and oversee the implementation and delivery of Stage 6? RQ 4.2 Have there been any major contract management issues?	Documents Committee members Suppliers	Review of Steering committee terms of reference and meeting minutes, Interviews with members Document review, interviews with suppliers, performance to contract (For example, supplier selection and content delivery)	Thematic interpretive analysis of interviews Document analysis	Review of background material and method. Review of decisions and contract performance over the first period of the program review.

SAMPLING

Sampling processes to identify potential participants for survey, interview and focus groups, including primary school teachers and Steering Committee members, were developed in conjunction with AAS staff (Shelley Peers). In summary, the sampling was as follows:

SURVEYS

The AAS sent Survey 1 (the pre-workshop survey) to workshop participants prior to their workshop. The research team provided text for an email inviting participation, along with a link to the survey. For some participants, an invitation to participate in a focus group at the end of the workshop was included. Researchers from UTS attended selected workshops during the year when the dates and locations were finalised.

Survey 2 (the post-survey, which included the post workshop survey and the Best-Worst Scaling survey) was sent to all workshop participants after completion of the workshop. The Best-Worst Scaling component was developed based on responses from focus groups.

Survey 3 (Discrete Choice Experiment) was sent to *Primary Connections* workshop participants from the AAS database and via the AAS Facebook page, and these participants were invited to forward the survey to colleagues (snowball technique).

Survey sample size

- Survey 1 (pre-workshop survey of in-service and pre-service teacher participants) completed by 114 in-service teachers and 169 pre-service teachers
- Survey 2 (post workshop/Best-Worst Scaling survey) completed by 126 in-service teachers and 171 pre-service teachers
- Survey 3 (Discrete Choice Experiment) completed by 189 in-service teachers and 81 pre-service teachers

Interviews and Focus Groups

- Interviews or focus groups with 6 Steering Committee and Management Committee members, including AAS and Department of Education and Training staff
- Focus groups of in-service teacher workshop participants: 18 in-service teachers (3 focus groups)
- Focus groups of pre-service teachers workshop participants: 19 pre-service teachers (3 focus groups)
- Expert panel advice on *Primary Connections* Stage 6 possible developments held with 4 leading science educators

EVALUATION FINDINGS

The Stage 6 evaluation findings are presented according to each research stream and specific guiding research questions. It is noted here, however, that the evaluation was conducted in a series of stages, or phases. The respective phases provide the focus of the appendices in this report:

Appendix 1: Appropriateness: Consistency with Government priorities

Appendix 2: *Primary Connections*: A review of literature

Appendix 3: Governance evaluation (redacted)

Appendix 4: Focus group reports: An overview

Appendix 5: Expert advice on *Primary Connections*

Appendix 6: Report on Best-Worst Scaling (BWS) and program perceptions

Appendix 7: Discrete Choice Experiment

Appendix 8: Comparison of pre- and post-workshop quantitative data

Appendix 9: Analysis of survey open responses

Appendix 10: Cost of workshops (redacted)

APPROPRIATENESS

Is the program consistent with Australian Government priorities?

The research team examined three relevant and current policy documents, and interviewed members of the *Primary Connections* Stage 6 Steering Committee and Management Committee. The relevant policy documents (the *National STEM School Education Strategy 2016-2026* and the *Quality Schools Quality Outcomes* documents) were identified in consultation with the AAS and the Department of Education and Training. The research team analysed these policy documents to determine the extent to which *Primary Connections* supports the broad goals and strategic actions proposed. This analysis was limited to elements of policy documents addressed by *Primary Connections* Stage 6.

Appropriateness RQ 1.1 How well does Stage 6 align with the current Australian Government education policy priorities, particularly in relation to STEM education in schools?

Evidence from the analysis of policy documents and interviews with Steering and Management Committee members indicate that *Primary Connections* Stage 6 aligns with the current Australian Government education policy priorities in relation to STEM education in schools.

Appropriateness RQ 1.2 Is training teachers in Primary Connections a priority for the government in order to improve the teaching of primary school science teaching?

The alignment of *Primary Connections* resources with the *Australian Curriculum: Science* and relevant Australian Government education policy priorities indicates that it is a priority for the government in order to improve the teaching of primary school science teaching.

EFFICIENCY

Is Stage 6 implementation achieving the goals within identified budgets and timeframes?

The findings in the Efficiency research stream were informed by document reviews, a systematic literature review, surveys of in-service and pre-service teachers prior to, and after, attending a *Primary Connections* workshop, and focus group interviews of workshop attendees.

*Efficiency RQ 2.1 What is the cost of training in-service and pre-service teachers in Primary Connections?**

*For reasons pertaining to confidentiality, sections relating to Governance and spending, including Table 1, were redacted before publishing this report.

Efficiency RQ 2.2 Does training teachers and pre-service teachers in Primary Connections increase the likelihood of teachers and schools comprehensively implementing the program?

The impact of having completed a *Primary Connections* workshop increased both in-service and pre-service teachers' confidence in a number of different areas. There was a statistically significant increase, according to a paired samples t-test, in in-service teachers' confidence in their understanding of the aims, major principles and pedagogy of *Primary Connections*, and of the 5Es teaching and learning model from the pre-workshop survey to the post-workshop survey. They also significantly increased their confidence in understanding the relationship between science and literacy, and their ability to use *Primary Connections* to enhance student learning in these areas. Table 2 shows pre- and post-workshop means and standard deviations relating to in-service teacher confidence on a 5-point scale (1=Not confident, 2=Limited confidence, 3=OK, 4=Confident, 5=Very confident).

TABLE 2 IMPACT OF PRIMARY CONNECTIONS WORKSHOPS ON CONFIDENCE OF IN-SERVICE TEACHERS

	In-service teachers' pre-workshop survey		In-service teachers' post-workshop survey	
Confidence in ability to:	Mean	S.D.	Mean	S.D.
Understand the aims of the *Primary Connections* Program	3.70	0.90	4.13	0.69**
Understand the major principles and the pedagogy of *Primary Connections*	3.58	0.90	4.06	0.70**
Understand the 5Es teaching and learning model	3.60	0.94	4.14	0.75**
Understand the relationship between science and literacy	3.88	0.77	4.21	0.73**
Use *Primary Connections* tools to enhance student learning in science and literacy	3.86	0.73	4.04	0.74*
Apply the research that *Primary Connections* is based on	3.74	0.74	3.73	0.77
Use the range of *Primary Connections* curriculum units and other resources	3.88	0.70	4.13	0.77

Items were measured on a 5-point scale with 1=Not confident to 5=Very confident.

*/** Significant difference between pre- and post-surveys at the p <0.05/0.01 confidence level.

Pre-service teachers' confidence in relation to their understanding of the aims and pedagogical principles of *Primary Connections* and the relationship between science and literacy also showed a statistically significant increase after they had attended a workshop, as shown in Table 3.

TABLE 3 IMPACT OF PRIMARY CONNECTIONS WORKSHOPS ON CONFIDENCE OF PRE-SERVICE TEACHERS

	Pre-service teachers' pre-workshop survey		Pre-service teachers' post-workshop survey	
Confidence in ability to:	Mean	S.D.	Mean	S.D.
Understand the aims of the *Primary Connections* Program	3.71	0.95	4.12	0.68**
Understand the major principles and the pedagogy of *Primary Connections*	3.74	1.03	4.15	0.66**
Understand the 5Es teaching and learning model	3.91	0.92	4.22	0.69**
Understand the relationship between science and literacy	3.89	0.79	4.14	0.76**
Use *Primary Connections* tools to enhance student learning in science and literacy	4.07	0.73	4.06	0.74
Apply the research that *Primary Connections* is based on	3.95	0.68	3.85	0.76
Use the range of *Primary Connections* curriculum units and other resources	4.07	0.73	4.15	0.70

Items were measured on a 5-point scale with 1=Not confident to 5=Very confident.

** Significant difference between pre- and post-surveys at the p <0.01 confidence level.

Among in-service teachers, more than four in five agreed that the workshops increased their confidence in their ability to use the range of *Primary Connections* resources, their understanding in relation to the major principles of *Primary Connections* and the 5Es teaching and learning model, and their confidence in understanding the relationship between science and literacy. Around three in four teachers indicated that the workshops increased their confidence to use *Primary Connections* tools to enhance student learning in science and literacy (Figure 2). Pre-service teachers showed similar levels of agreement.

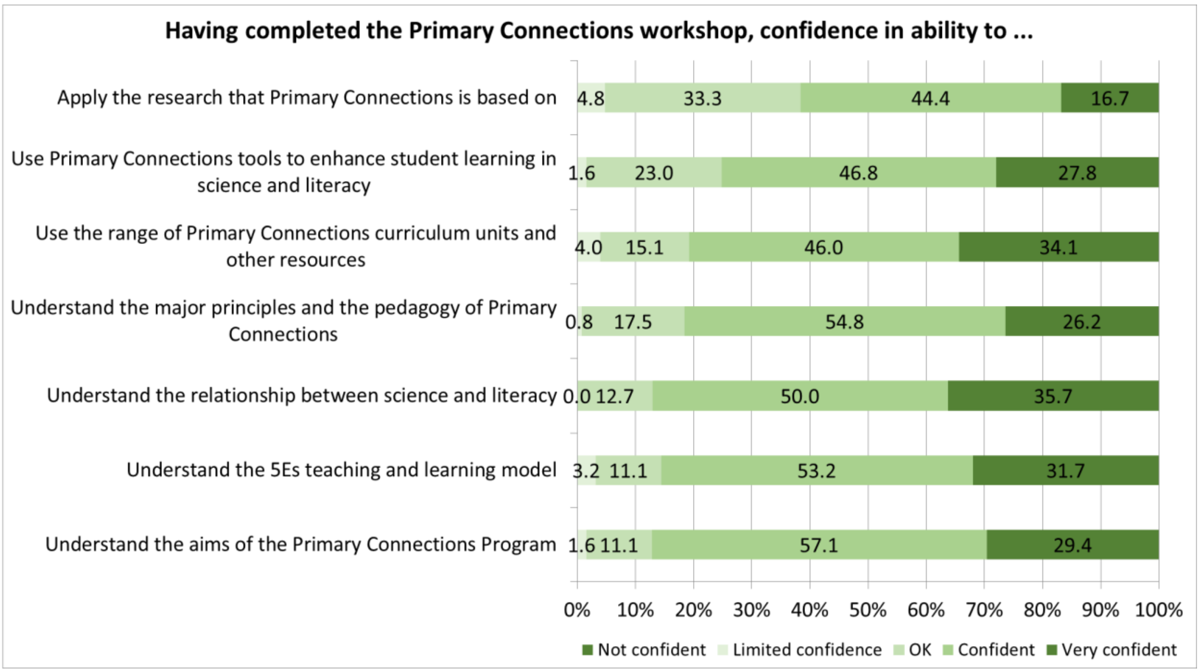


FIGURE 2 IMPACT OF PRIMARY CONNECTIONS WORKSHOPS ON CONFIDENCE OF IN-SERVICE TEACHERS

Teachers were extremely positive about *Primary Connections* workshops. Almost all in-service teachers (97%) would recommend the workshops to other teachers. Ninety-nine per cent of teachers agreed that *Primary Connections* would help them to implement the *Australian Curriculum: Science* and 97% agreed that the workshop increased the likelihood of them comprehensively implementing the *Primary Connections* program in their teaching. A similar percentage indicated that *Primary Connections* would improve student achievement in science (Figure 3).

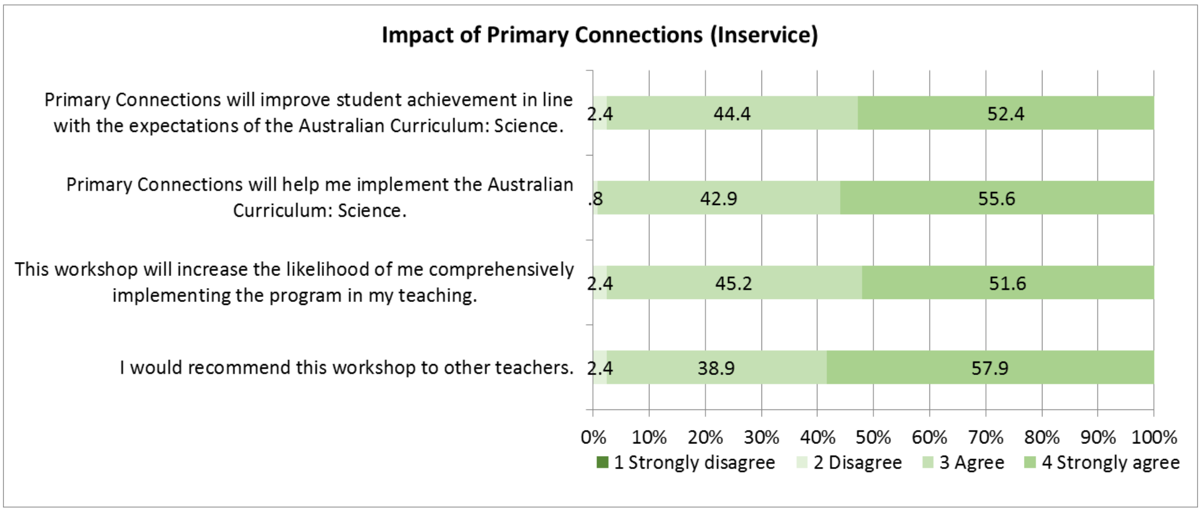


FIGURE 3 PERCEIVED VALUE OF PRIMARY CONNECTIONS

When asked about their perceptions of school capabilities with respect to primary science teaching (Figure 4), around 60% of in-service teachers agreed that their school placed a strong emphasis on primary science, and that the teachers had the confidence, skills and understanding of the syllabus to teach primary science competently. Just over half agreed that the background knowledge of teachers in the area of primary science was good, although 69% indicated that teachers have the opportunity to receive ongoing professional learning in primary science. There was 73% agreement that time is a major factor inhibiting science program delivery. However, 79% indicated that there was a positive attitude to the teaching of primary science at their school.

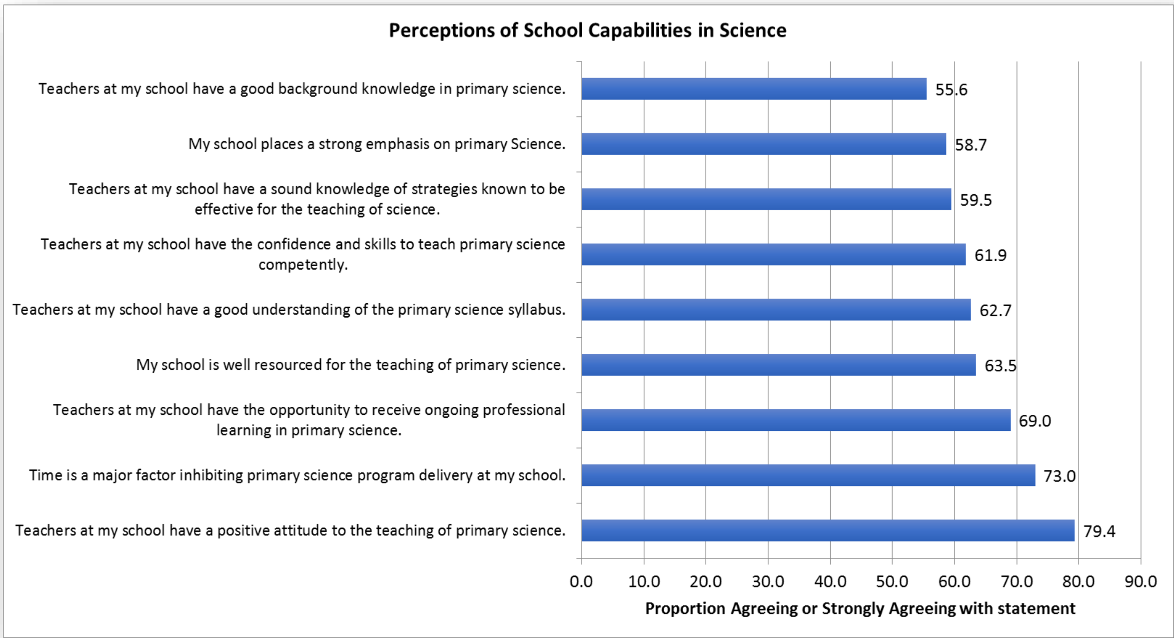


FIGURE 4 PERCEPTIONS OF SCHOOL CAPABILITIES IN PRIMARY SCIENCE TEACHING

The survey results clearly showed that attending a *Primary Connections* workshop has a significant impact on primary science teaching. Both in-service and pre-service teachers indicated that their understanding of primary science pedagogy and their confidence and interest in teaching science had significantly increased following completion of a *Primary Connections* workshop. This strongly suggests that training teachers and pre-service teachers in *Primary Connections* increases the likelihood of teachers and schools implementing the program well.

Efficiency RQ 2.4 Is training in-service teachers and pre-service teachers in Primary Connections the most efficient way to increase the effective implementation of the program?

All focus group participants reported that the Stage 6 workshops were efficient and better than expected. Following the workshop, both pre-service and in-service teachers stated that they intended to implement the *Primary Connections* program. In-service teachers found that the workshops addressed many of their needs for teaching science and most pre-service teachers were surprised at how relevant the workshops were and at the engaging way in which they were presented. As mentioned above, 97% of teachers surveyed would recommend the *Primary Connections* workshop to other teachers.

According to survey results, in-service and pre-service teachers preferred workshops that are face-to-face or a combination of online and face-to-face delivery. The majority of in-service teachers opposed the use of online only workshops. Only a third of in-service teachers are likely to attend workshops that take place on a weekend or during school hours. On the other hand, close to 70% of pre-service teachers are likely to attend workshops at these times.

Efficiency RQ 2.5 Are there any unintended benefits or disadvantages in providing training in particular ways for in-service teachers and pre-service teachers?

The systematic literature review presented results from the analysis of 63 empirical studies that focused on professional learning in primary science. The key features of the successful programs were aggregated and analysed to provide an account of effective professional learning provision. In these review studies, teachers attributed changes in their subsequent classroom practice to the following aspects of the program:

- content;
- active participation;
- collaboration;
- duration of the program;
- a meaningful context;
- varied strategies;
- a school-based program catering for student interest;
- teachers learning using inquiry as their students would;
- a rich source of practical resources;
- demonstrations and strategies that connect to curriculum standards; and
- maintaining support for teachers.

These features of professional learning that have been shown to lead to changes in classroom practice can be found in the *Primary Connections* professional learning program.

Researchers conducting the review studies identified some of the barriers to implementing professional learning as: limited resources; time constraints; mandated curriculum pacing; classroom management issues; and the failure of some programs to reveal and address existing beliefs of teachers. *Primary Connections* workshops address the first four items on this list, and teachers involved in this Stage 6 evaluation have indicated in surveys and focus groups that *Primary Connections* workshops have been successful in revealing and addressing their existing beliefs in regard to primary science and literacy. For example, in focus groups, many in-service and pre-service teachers reported that they had not realised or fully understood the importance of the 5Es model for *Primary Connections*.

Focus group teachers reported that face-to-face workshops are much preferred to online or related delivery mechanisms but they noted that for some teachers, attendance at workshops is difficult for a variety of reasons. Focus groups provided suggestions related to further workshops for professional learning in *Primary Connections*, including follow-up support. The systematic literature review found that teachers regarded videoconferencing as an effective tool for facilitating professional learning communities when distance and time were barriers to face-to-face meetings, as it provided similar social interactions.

Some benefits associated with face-to-face delivery mentioned by teachers were:

- immediate clarification of issues;
- learning from peers (especially if an external university student);
- modelling of the teaching and learning approaches and strategies;
- enhancement of deeper learning (e.g. about 5Es framework);
- ensuring that participation in hands-on experiences occurs and with follow-up reflection;
- the 'flow-on' effect of appreciating the impact of many workshop participants going out to implement *Primary Connections* and 'spreading the word';
- interacting with other teachers; and
- having 'time-off' to complete professional learning and to be out of the classroom.

The Best-Worst Scaling/post-survey and the Discrete Choice Experiment results supported the focus group finding that in-service and pre-service teachers prefer workshops that are face-to-face, or a combination of online and face-to-face delivery. The majority of in-service teachers opposed the use of online only workshops. Around three in five teachers were open to workshops that require two hours travel, whilst just less than half would consider a workshop requiring an overnight stay. Less than a third were likely to attend workshops requiring four hours of travel or a flight. The sensitivity to length of travel is more pronounced among pre-service teachers. Almost all teachers preferred workshops that are face-to-face, require less than 30 minutes travel and are held during term and during school hours. The Discrete Choice Experiment revealed that workshop fees were the most important consideration for teachers in their decision about whether or not to attend a future *Primary Connections* workshop**.** The remaining drivers of choice about attending workshops, in order of importance, were travel time, the timing of the workshop, additional follow-up, duration and content.

EFFECTIVENESS

How well are we doing what we said we would do and could it be done better?

Evidence for the Effectiveness stream was gathered from document reviews, interviews, pre-and post-workshop surveys of in-service and pre-service teachers, focus group interviews and a systematic literature review.

Effectiveness RQ 3.1 What are the anticipated outputs and outcomes, when are these expected to be achieved and how is the program designed to achieve them?

The aims of Primary Connections are:

- to improve teaching and student learning outcomes in science and the literacies of science within primary schools;
- to raise primary school students' interest and engagement in learning about science; and
- to improve the skills and confidence of primary teachers to teach science through inquiry.

There is ample evidence from this evaluation of Stage 6 that the *Primary Connections* resources are aligned to *the Australian Curriculum: Science,* and analysis of policy documents and interviews with Steering and Management Committee members indicates that *Primary Connections* Stage 6 aligns with the current Australian Government education policy priorities in relation to STEM education in schools. The enthusiasm for the *Primary Connections* program expressed by teachers during this evaluation attests to the quality of the resources and to the widespread adoption of these resources in schools to improve student outcomes, interest and engagement in science. There is also evidence to be found in the literature for the high regard in which the *Primary Connections* program is held. A survey conducted by the Australian Science Teachers Association, with support from the Office of the Chief Scientist and the Australian Primary Principals Association, showed that the *Primary Connections* materials were highly valued by primary teachers across all sectors, with 85% of the 810 primary teachers, principals and affiliate personnel completing the survey indicating that they had used the resource (Australian Science Teachers Association, 2014).

Four of the studies included in the systematic literature review conducted as part of the Stage 6 evaluation, made use of *Primary Connections* materials as professional learning resources for teachers (Albion & Spence, 2013; Laidlaw, Taylor, & Fletcher, 2009; Lowe & Appleton, 2015; Smith & Hackling, 2016). Those studies reported positive outcomes in teacher self-efficacy, amount of science taught, pedagogical content knowledge, and capacity to manage discourse. Three of the review studies reported positive results from the use of *Primary Connections* resources with pre-service teachers (Cooper et al., 2012; Hume, 2012; Laidlaw et al., 2009). The *Primary Connections* resources may be regarded as educative curriculum materials, i.e. materials explicitly designed to support teacher and student learning (Arias, Bismack, Davis, & Palincsar, 2016). Positive outcomes were reported in the review studies from other such materials, e.g. Townsend et al. (2016) reported that using educative curricula improved the pedagogical content knowledge of rural and remote science teachers as well as student learning outcomes. Campbell and Chittleborough (2014) found that *Primary Connections* facilitator training was an effective strategy in the Primary Science Specialists Professional Learning Program and that this program subsequently assisted in implementing the *Primary Connections* program in schools. The primary science specialists reported that networking and collegial support were also vital aspects of their training, suggesting that the combination of *Primary Connections* and a support network would be a powerful combination for primary teachers.

The results of teacher surveys carried out for this review showed a significant increase in the levels of interest, enjoyment, confidence, and comfort in teaching science among teachers after they had attended a *Primary Connections* workshop. The results also showed that the impact of *Primary Connections* workshops has been to increase confidence among teachers in terms of understanding the aims of the program, the 5Es teaching and learning model, and the relationship between science and literacy. More than 97% of teachers agreed that they would recommend *Primary Connections* workshops to other teachers and a similar percentage of teachers indicated that the workshop would increase the likelihood of implementing *Primary Connections* in their teaching.

In this Stage 6 evaluation, the levels of confidence and enjoyment in teaching science were found to be higher, relative to teachers surveyed in other settings. For example, Burke et al. (2017) found that NSW AIS teachers reported lower levels of enjoyment and comfort in teaching primary science than teachers surveyed in this evaluation.

Effectiveness RQ 3.2 To what extent has Stage 6 met the aims and objectives as set out in the funding agreement?

Evidence supports the conclusion that Stage 6 has met the objectives as set out in the funding agreement. For example:

Objective 1: To increase the uptake of Primary Connections: linking science with literacy in schools.

After the workshop, in-service teachers indicated their desire to implement or to continue using *Primary Connections*. Many had not implemented it in full previously. Most expressed a commitment to implement *Primary Connections* in full, with greater fidelity, in future – subject to school-based constraints. Many teachers reported that they had not understood the importance of the 5Es model for *Primary Connections,* and their improved understanding, resulting from the workshops, seems to have influenced their determination to implement *Primary Connections* with greater fidelity. Pre-service teachers reported that, after the workshop, they had increased confidence to teach science, and many intend to use *Primary Connections*, and use the 5Es, when they enter the teaching profession.

Objective 2: To support primary school teachers and pre-service primary school teachers to teach science through inquiry.

Following the workshop, teachers and pre-service teachers expressed commitment to implementing inquiry, which, by implication from other data, emphasises the 5Es.

Objective 3: To ensure primary school teachers, pre-service primary teachers and school educators are informed about Primary Connections.

Most pre-service and practising teachers appeared to know about *Primary Connections*. Participants in workshops all indicated that they had learnt a lot about *Primary Connections* from the workshops and indicated that this would influence their teaching of science.

Effectiveness RQ 3.3 What else can the Primary Connections program offer to assist teachers and pre-service teachers to implement the Australian science curriculum?

To answer this research question, evidence was gathered from a systematic literature review, in-service and pre-service teacher focus groups and surveys, including Best-Worst Scaling and Discrete Choice Experiment, and from science education experts.

The systematic review of literature aggregated and analysed the key features of successful professional learning to inform the current *Primary Connections* professional learning program. The findings suggest that *Primary Connections* could offer sustained professional learning support to promote collaborative analysis of practice, while leveraging face-to-face interactions. Sustained professional learning support would not only contribute to the duration and potential impact of *Primary Connections* professional learning but would offer the opportunity to conduct ongoing research to inform iterative developments in a long-term program of *Primary Connections* professional learning. Several of the review studies were able to provide evidence of the sustainability of their programs in this way. Recommendations for additional *Primary Connections* professional learning opportunities include: providing sustained on-going professional learning support in addition to initial workshops;

- promoting and supporting teacher collaborative practices and *Primary Connections* networks among teachers;
- leveraging face-to-face workshops by expanding to a blended learning model;
- conducting ongoing research to inform iterative development in *Primary Connections* professional learning; and
- collaborating with teacher educators to facilitate the use of *Primary Connections* in initial teacher education courses.

Focus groups of in-service and pre-service teachers appreciated that *Primary Connections* units included both explicit connections to the *Australian Curriculum: Science and* a consistent approach to learning through inquiry processes. The only request for additional support related to the *Primary Connections* units was for support for differentiation of learners. When asked what else *Primary Connections* could do to assist their professional learning (related to teaching primary science), suggestions included:

- follow-up processes of various types (e.g. a forum; communication networks; email contact to respond to emerging questions);
- feedback mechanisms to assist in follow-up implementation (e.g. *Primary Connections* members visit their schools);
- video-extracts of experienced *Primary Connections* teachers teaching (for later, and ongoing, reflection);
- other workshops/processes to assist with science content; and
- additional workshops in isolated areas.

The most frequent survey response from in-service teachers, when asked what *Primary Connections* can offer to assist them to implement the *Australian Curriculum: Science*, was to suggest additional *Primary Connections* components, like assessment activities and more hands-on activities. Most teachers were happy with *Primary Connections* as is, which was indicated either by a nil response to this question or a response in praise of the program. Other suggestions were for some type of online support or follow-up from the workshops and to have access to more activities using digital technologies. Pre-service teachers most frequently indicated that they would like to see best practice pedagogy, mostly suggesting online videos of teachers in classrooms using the *Primary Connections* resources with their classes. They also seemed satisfied with what *Primary Connections* currently offered, and requested additional workshops and online support.

According to the BWS survey, the top 10 areas nominated by in-service teachers as being relatively more important for inclusion in *Primary Connections* professional learning were (in order of importance):

1. Investigation-based science
2. Science teaching strategies
3. Guiding inquiry in science
4. Adapting *Primary Connections* for multi-stage classes
5. Understanding the *Primary Connections* approach
6. Various ways of teaching each 5E phase
7. Differentiating *Primary Connections* for student diversity
8. Activity-based science
9. Doing hands-on science activities
10. Implementing *Primary Connections* units

Teachers were also asked about their likelihood to attend workshops depending on the support that was offered outside of the workshops. In-service teachers were least receptive to support coming in the form of feedback from experts on their own *Primary Connections* lessons. Around four in five were likely to participate in workshops if they were supplemented with online spaces to share ideas or to ask questions of experts (Figure 5). The most popular professional learning support came in the form of annotated videos demonstrating how to teach with *Primary Connections*. The level of support for all these initiatives was much higher among pre-service teachers, with more than 90% in agreement that they would be likely or very likely to attend if these resources were available.

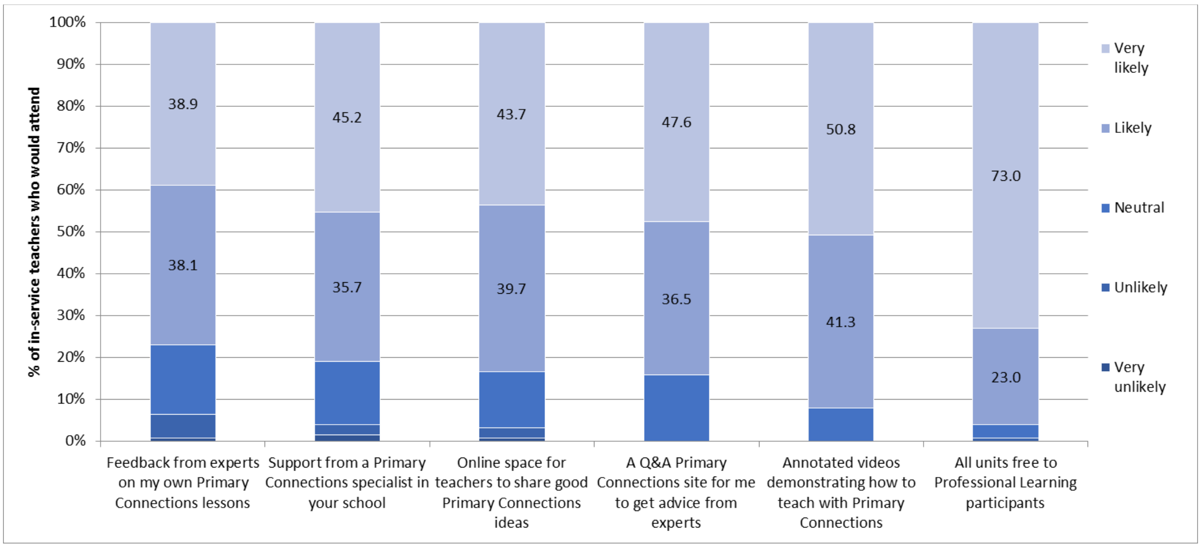


FIGURE 5 PREFERENCE FOR PROFESSIONAL LEARNING SUPPORT RELATING TO PRIMARY CONNECTIONS

In the Discrete Choice Experiment, teachers were asked to evaluate workshops with respect to potential follow-up activities. Face-to-face workshops were more attractive when presented with follow-up that involved expert-led online discussion forums one month after workshops. This type of follow-up activity was particularly favoured among pre-service teachers. There was strong objection to follow-up that involved a phone-call from a *Primary Connections* expert to discuss implementation. This follow-up activity was less preferable than having no follow-up at all.

Science education experts provided a range of advice on what else *Primary Connections* could do. The underlying position expressed was that *Primary Connections* supports the implementation of the *Australian Curriculum: Science* Foundation Year to Year 10 (particularly Foundation to 6).

Their recommendations specific to the *Australian Curriculum: Science* included:

- gradually reducing scaffolding to enhance the development of students' capability for increasingly independent scientific inquiry;
- emphasising the latter three Es in the 5Es model, including strengthening teachers' understanding of explain, elaborate (application) and evaluate phases; and
- ensuring teachers focus on student learning of key ideas expressed in *Primary Connections* (which are entirely consistent with the *Australian Curriculum: Science*) rather than the implementation of the *Primary Connections* program of study per se (that is, recognise that the 5Es and *Primary Connections* program are a means to an end, not the end in and of themselves).

They advised that:

- the focus of professional learning should shift from individual teachers to groups of teachers who can work together after and between professional learning events;
- one-off Primary Connections workshops need to be expanded with the provision of follow up professional learning activities which could include virtual and face-to-face interactions, and sharing and feedback among teachers as well as with the Primary Connections lead facilitators; and
- face-to-face workshops are valuable and critical but opportunities for on-going professional learning, including online activities, should be explored and implemented.

The only points of significant disagreement among experts were on whether teacher and student *Primary Connections* resources and units should be accessed online or provided as hard copy, and the extent to which online professional learning could be implemented now. It is as if *Primary Connections* is on the cusp of needing to move from being primarily available as hard copy to being primarily available online but two of the experts doubted that this action should be taken immediately. It seems that the fundamental difference in opinion is not whether resources should be online or hard copy; rather, some experts are concerned that internet access is poor for some teachers. This makes online resources unattractive until access improves. It seems that access to online primary science education resources in schools may be inadequate, suffering from connectivity or bandwidth limitations. Similarly, in addition to face-to-face workshops, online professional learning may offer some benefits, not least being flexibility of access, but currently internet access in schools is perceived to be inadequate for the task.

RECOMMENDATIONS

Following are recommendations arising from the *Primary Connections* Stage 6 evaluation, arranged by research stream: Appropriateness, Efficiency, Effectiveness and Governance.

Appropriateness: Is the program consistent with Australian Government priorities?

1) Continue to update *Primary Connections* resources and related activities to ensure that they support Australian Government priorities in science and STEM education and make this public through the *Primary Connections* website.

Efficiency: Is Stage 6 implementation achieving the goals within identified budgets and timeframes?

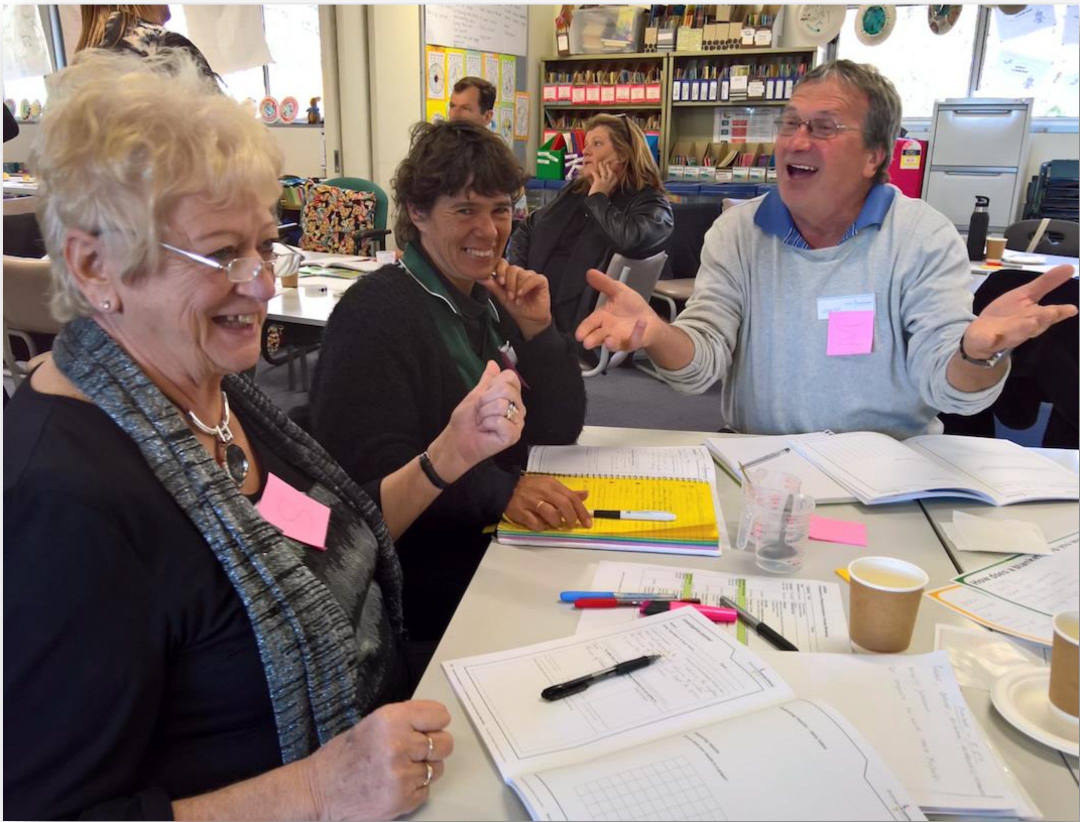
2) Continue to provide initial *Primary Connections* professional learning workshops face-to face for in-service teachers, while considering delivery and accessibility for educators in regional, rural and remote areas.
3) Develop and/or adapt an online learning platform that facilitates on-going, blended professional learning in *Primary Connections*.
4) Plan for the development of online *Primary Connections* resources that exploit the affordances (e.g. interactivity and adaptability to learner needs through use of learning analytics) of an online environment. The online environment should not primarily be a repository providing access to e-versions of hardcopy resources.
5) Phase out hardcopy *Primary Connections* materials and resources only when, or if, demand for these diminishes.
6) Consider collaboration with teacher education course providers to integrate the use of *Primary Connections* into initial teacher education programs, drawing on *Primary Connections* resources as an outstanding example of effective science education, rather than focusing on the implementation of *Primary Connections*.

Effectiveness: How well are we doing what we said we would do and could it be done better?

7) Ensure that teachers focus on student learning of key ideas expressed in *Primary Connections* (which are entirely consistent with the *Australian Curriculum: Science*) rather than the implementation of the *Primary Connections* program of study per se (that is, recognise that the 5Es and *Primary Connections* program are a means to an end, not the end in and of themselves).
8) Continue to emphasise science and literacy outcomes (as reflected in its title) and workshops clearly indicate how *Primary Connections* addresses both sets of outcomes (e.g., through its learning outcomes, introductory pages and some of its appendices).
9) Provide advice, and develop case studies, about how schools could develop a culture that encourages the continuous use of *Primary Connections* across Year levels, supported by an experienced school-level *Primary Connections* facilitator.
10) Trial and evaluate the use of a variety of strategies for professional learning with *Primary Connections*, including coverage of those matters identified in the Best-Worst Scaling survey as of greatest importance to teachers. Online videos of best practice in implementing *Primary Connections* would be a suggested starting point.
11) If online training is used as an adjunct to face-to-face workshops, then *Primary Connections* workshop developers should be mindful of the quality of internet access available to teachers and the concerning issues raised by pre- and in-service teachers in focus groups about the use of online professional learning.
12) Consider a range of workshop follow-up options as ways to consolidate the learning that was commenced as a consequence of the professional learning workshop, e.g. annotated videos, a forum, communication networks.
13) Conduct ongoing research to inform iterative development in *Primary Connections* professional learning.

Governance: How effective are the governance arrangements for Stage 6 of *Primary Connections*?

14) Consider having one committee that provides oversight of *Primary Connections* in future funding stages, given that there has been considerable overlap in the oversight of Stage 6 by the Management Committee and the Steering Committee.



REFLECTION

FUTURE DIRECTION, SPECULATION, POSSIBILITIES AND ALTERNATIVES FOR *PRIMARY CONNECTIONS*

It is not sensible to complete this evaluation of *Primary Connections* Stage 6, and the specified research questions, without reflecting more broadly on *Primary Connections*.

Primary Connections has extraordinary brand recognition and it has been widely implemented. Past *Primary Connections* phases have attracted many teachers to use the program. By almost any measure it has been a great success.

Stage 6 has been very successful in extending the reach of *Primary Connections* among regional, rural and remote teachers, primarily in building capacity among current users to implement *Primary Connections* more faithfully and with greater skill and confidence.

The key question for *Primary Connections* relates to the Research Question:

- What else can the *Primary Connections* program offer to assist teachers and pre-service teachers to implement the Australian science curriculum?

Framed differently we could ask whether *Primary Connections* initiatives should concentrate on developing the capacity of those, who already have some familiarity with *Primary Connections*, to teach science better or on expanding engagement to draw in teachers who would be new to using *Primary Connections*. Delivering on the former would be a worthy outcome for the AAS but should *Primary Connections* aspire to better?

The research team is conscious that much of the data about *Primary Connections* comes from those who have chosen to use it rather than those who have chosen not to use it. Proposed improvements for *Primary Connections* and its professional learning program, as expressed in recommendations, relate primarily to building on past *Primary Connections* success and current feedback. The adage, "if it ain't broke why fix it" comes to mind, with regard to *Primary Connections* because it certainly "ain't broke" and has made a singularly powerful contribution to primary science. Nevertheless, it is difficult to see how this approach would now lead to a major expansion in the use of *Primary Connections* and a profound extension to the effective teaching and learning of science.

The research team takes the view that a twin pronged approach may be advantageous. *Primary Connections* should continue much as it has, by continuing to develop hard copy resources, providing units online with support materials, together with initial workshops on *Primary Connections* to increasing numbers of teachers. These activities should be extended by providing ongoing professional learning, building collaboration among teams of primary teachers, working with *Primary Connections* expert support, to effectively implement *Primary Connections* in classes across their schools. However, there is probably a need to explore ways of building on the knowledge developed through more than two decades of work with *Primary Investigations* and *Primary Connections* to think about how to engage teachers, who have not chosen to use *Primary Connections* but continue to need support, in effective teaching of science. This requires more radical thinking than building on what has been done.

One suggestion is that an alternative approach and set of resources could be developed; counter intuitively, an approach that is distinct and different from that which has proved attractive to so many. Indeed, the level and brand recognition of *Primary Connections* is so great that perhaps the non-use of *Primary Connections* is no accident or oversight by *Primary Connections* non-users, but rather a conscious decision by many teachers. If the AAS is to encourage teachers, who have chosen not to use *Primary Connections* and not to engage in *Primary Connections* professional learning, then consideration should be given to the adaption and development of a *Primary Connections* science learning program based on the fundamental *Primary Connections* teaching model, the 5Es, but providing resources in ways that exploit the opportunities provided by an online platform that allows teachers to readily select, adapt and build their own program of work, and students to directly engage with varied learning activities that make the most effective use of digital learning.

AAS may tinker about the edges of *Primary Connections* and continue to make an extremely valuable contribution to the teaching and learning of science in Australia. The AAS should also consider whether a quantum shift in *Primary Connections* is timely, or soon would be timely, to expand its impact radically rather than incrementally. In the short term this would require two forms of *Primary Connections* to coexist and the cost of this achieving this would be substantial. The argument is not that the AAS should abandon *Primary Connections* in its current form and suddenly invest in the digital learning environment. Rather, the argument is that it is essential to plan for such a development and recognise that for an extended period both digital and more traditional ways of improving science teaching and learning are likely to coexist.

RESEARCH TEAM AND ETHICS

UTS RESEARCH MANAGEMENT TEAM MEMBERS

Professor Peter Aubusson, School of Education, FASS, UTS

Adjunct Professor Keith Skamp, School of Education, Southern Cross University

UTS RESEARCH TEAM MEMBERS

Associate Professor Paul F. Burke, Department of Marketing and Deputy Director, Centre for Business Intelligence and Data Analytics (BIDA), UTS: Business

Dr Kimberley Pressick-Kilborn, School of Education, FASS, UTS

Associate Professor Wan Ng, School of Education, FASS, UTS

Dr Tracey-Ann Palmer, School of Education, FASS, UTS

Dr Andy Goodall, Institute for Public Policy and Governance, UTS

Dr Jennifer Fergusson, Research Associate, School of Education, FASS, UTS

RESEARCH ETHICS

Research was carried out in accordance with the UTS Ethical Conduct of Research Involving Human Participants Vice-Chancellor's Directive

The Directive outlines the responsibilities of UTS researchers whose research activities involve interaction with human participants. It also highlights the role and functions of the UTS Human Research Ethics Committee (HREC) in relation to human research and the University's requirements to ensure compliance with government regulations and directives. http://www.gsu.uts.edu.au/policies/research-ethical-conduct-humans.html

Appendix 1: Appropriateness: Consistency with Government priorities

This report addresses the following research questions:

Appropriateness RQ 1.1 How well does Stage 6 align with the current Australian Government education policy priorities, particularly in relation to STEM education in schools?

Appropriateness RQ 1.2 Is training teachers in Primary Connections a priority for the government in order to improve the teaching of primary school science teaching?

In answering these Appropriateness research questions, the research team has examined three relevant and current policy documents and interviewed members of the *Primary Connections* Steering Committee and *Primary Connections* Management Committee.

Policy documents relevant to this evaluation were identified in consultation with AAS. The research team identified the National Strategy document as the most appropriate document on which to base the analysis. Following consultation with the AAS and Department of Education, the Quality Schools Quality Outcomes documents were also included.

The research team analysed these policy documents to determine the extent to which *Primary Connections* supports the broad goals and strategic actions proposed. This analysis is limited to elements of policy documents addressed by *Primary Connections* Stage 6. There has been no attempt made to report on all goals and actions proposed in the statements because it is unrealistic to expect one program, in this case *Primary Connections* Stage 6, to address every aspect of the national strategy.

Policy documents considered in this evaluation were:

- Quality Schools Quality Outcomes (Australian Government, 2016. Available at: https://docs.education.gov.au/system/files/doc/other/quality_schools_acc.pdf)
- Quality Schools Quality Outcomes. Areas of Future focus. *Boosting Literacy, Numeracy and STEM.* This document expanded on Quality Schools Quality Outcomes to focus on Literacy, Numeracy and STEM. (Australian Government, 2016. Available at: https://www.education.gov.au/quality-schools-quality-outcomes-areas-future-focus)
- National STEM School Education Strategy 2016-2026. A Comprehensive Plan For Science, Technology, Engineering And Mathematics Education In Australia. (Education Council, 2015. Available at: http://www.educationcouncil.edu.au/site/DefaultSite/filesystem/documents/National%20STEM%20School%20Education%20Strategy.pdf)

Each of these documents is considered below. With regard to STEM education strategy, both *Quality Schools Quality Outcomes* and *Quality Schools Quality Outcomes: Areas of Future focus* refer to the implementation of National STEM School Education Strategy 2016-2026. The National STEM School Education Strategy 2016-2026 was endorsed by all Australian education ministers on 11 December 2015. The purpose of the strategy is to build on the range of reforms and activities already underway in STEM education. It aims to better coordinate and target this effort and to sharpen the focus on the key areas where collaborative action will deliver improvements to STEM education. Thus these are not distinct, but related, policies and strategies.

Quality Schools Quality Outcomes May 2016

Quality Schools Quality Outcomes May 2016 states:

A greater emphasis is also needed on science, technology, engineering and mathematics (STEM) skills to ensure that Australian students are equipped with the knowledge they need to thrive in a globalised, interconnected world.

Jobs of the future will require a high level of technological literacy from all workers. Increasing the uptake of STEM subjects by students at school and improving achievement in this important area will ensure that all young people are prepared for jobs of the future.

(Australian Government, 2016. https://docs.education.gov.au/system/files/doc/other/quality_schools_acc.pdf)

Quality Schools Quality Outcomes: Areas of Future focus

Quality Schools Quality Outcomes: Areas of Future focus states:

In the context of rapidly changing technology, and with three quarters of the fastest growing occupations in Australia requiring STEM skills, the Strategy supports a long-term change agenda aimed at ensuring that students have a stronger foundation in STEM.

(Australian Government, 2016. https://www.education.gov.au/quality-schools-quality-outcomes-areas-future-focus)

Primary Connections Stage 6 addresses the need to improve STEM, particularly science, teaching and learning. *Primary Connections* Stage 6 focuses on primary science teaching, which is acknowledged as critical in underpinning capacity building in STEM (see also, e.g. Teacher Education Ministerial Advisory Group (TEMAG) Report).

National STEM School Education Strategy 2016-2026

The National STEM School Education Strategy calls for:

… a renewed national focus on STEM in school education is critical to ensuring that all young Australians are equipped with the necessary stem skills and knowledge that they will need to succeed. (p. 3)

A stated aim of *Primary Connections* is to "improve teaching and student learning outcomes in science and the literacies of science within primary schools". The focus of *Primary Connections* Stage 6 is on developing teacher science teaching capability that will in turn improve science learning and achievement among primary school children.

The National STEM School Education Strategy states:

Australian data shows that inequities currently exist in STEM. Girls, students from low socio-economic status backgrounds, Aboriginal and Torres Strait Islander students, and ***students from non-metropolitan areas*** *can be less likely to engage with STEM education and therefore have a higher risk of not developing high capabilities in STEM-related skills. These groups are more likely to miss out on the opportunities STEM-related occupations can offer. (bold emphasis added) (p. 4)*

Primary Connections Stage 6 targets in service and pre-service teacher science education professional learning in regional, rural and remote areas.

The National STEM School Education Strategy also states:

The National Strategy is focused on action that lifts foundational skills in STEM learning areas, develops mathematical, scientific and technological literacy, and promotes the development of the 21st century skills of problem solving, critical analysis and creative thinking. **It recognises the importance of a focus on STEM in the early years** and maintaining this focus throughout schooling. (bold emphasis added) (p. 5)

Primary Connections Stage 6 targets science learning in the early years, i.e., in primary school years, with particular reference to the requirements of the Australian Curriculum F to 6. (F to 6 refers to primary sections of Foundation to Year 12 Australian Curriculum).

Key Areas for National Action

The National Strategy identified five key areas for national action through which school education has the greatest leverage. Elements from these actions of particular relevance to *Primary Connections* Stage 6 are considered below.

Area 1: Increasing student STEM ability, engagement, participation and aspiration

- Supporting a focus on STEM in early childhood education to build on early curiosity for science … (p. 8)

Primary Connections Stage 6, as noted above, targets early years of schooling, including children aged 4 to 8. *Primary Connections* employs a 5Es inquiry model. Inquiry approaches in science are consistent with the promotion and use of curiosity in science teaching and learning. The extent to which the 5Es inquiry model, in general or as specifically employed in *Primary Connections*, promotes inquiry is beyond the scope of this study.

- Recognising the primary and middle years as critical periods when students begin to cement their aspirations for, and confidence in, STEM. (p. 8)

Primary Connections Stage 6, as noted above, targets primary science teaching and learning. It therefore, addresses a 'critical' period of learning experiences

Area 3: Supporting STEM education opportunities within school systems in science when student confidence in and aspirations for science are formed.

- … effort under the national strategy will build on, and link to, the Australian curriculum and national assessments to support the attainment of core STEM subject knowledge and the underlying skills of problem solving and analytical thinking. (p. 8)

Primary Connections documentation provides clear links to knowledge and skills outlined in the Australian Curriculum F to 6. As such, it is reasonable to interpret *Primary Connections* as an effort to build STEM subject knowledge and skills in line with the Australian curriculum and national assessments.

- Supporting the key progress points in the learning of maths and science (p.8)

The primary years of schooling have been identified as a key progress point for science learning, confidence and aspirations. As noted above, primary school years are the focus for *Primary Connections*, Stage 6.

Steering Committee and Management Committee Members' Views

Six members were asked to respond to questions relevant to these research questions. One of those interviewed declined to comment due to uncertainty regarding STEM education policy. The others all affirmed that *Primary Connections* Stage 6 is aligned to Australian Government education policy priorities for STEM/science education.

One interviewee observed that "The *Coalition's Policy for Schools: Students First,* specifically" [refers to *Primary Connections* by name]. Another interviewee explained that "*Primary Connections* is about developing curriculum resources to build the confidence of primary teachers to deliver science in an engaging way that aligns with evidence-based pedagogy".

Three of those interviewed responded by elaborating on the alignment of *Primary Connections* with the Australian Curriculum. For example, "Yes there is close alignment as *Primary Connections*, and *Science by Doing*, have their foundation in the national curriculum, and supporting teachers to be better science teachers is essential for boosting student engagement in STEM". One interviewee went on to question whether the national curriculum itself adequately served government policy. She/he consequently asked whether *Primary Connections* was addressing the most appropriate science concepts to meet government policy goals. However, all other interviewees were satisfied that because *Primary Connections* was underpinned by the national curriculum, it was meeting government policy goals.

Government Priority for Primary Connections

Four of those interviewed affirmed that training teachers in *Primary Connections* is a priority for the government. Most did not elaborate extensively when asked whether *Primary Connections* was a government priority. One enthused that there is "100% alignment with [government] priorities for more children to be learning science in schools… the alignment of … *Primary Connections* with government priorities is evidenced by the longevity of government funding". Here, it is worth noting that *Primary Connections* Stage 6 funding will bring the Australian Government financial commitment to the *Primary Connections* program to $14.7 million from 2004 to 2018.

One of those interviewed advised that she/he could not comment on whether *Primary Connections* was a priority for Government.

Another explained that *Primary Connections* Stage 6 may be a priority but she/he was unsure whether it should be a priority for the Australian Government. She/he raised the possibility that the provision of professional learning in *Primary Connections* Stage 6 should be a responsibility for State Governments rather than the Australian Government.

The prolonged and substantial funding of *Primary Connections,* together with the views expressed by many interviewees, indicates that training teachers in *Primary Connections* has been a priority for the government in order to improve the teaching of primary school science. None of those interviewed asserted that *Primary Connections* was not a priority.

Conclusion

Evidence from the analysis of policy documents and interviews with Steering and Management Committee members indicates that *Primary Connections* Stage 6 aligns with the current Australian Government education policy priorities in relation to STEM education in schools.

The prolonged and substantial funding of *Primary Connections* indicates that *Primary Connections* has been a priority for government. There is insufficient evidence to draw a conclusion as to whether *Primary Connections* is or is not a current Australian Government priority.

References

Australian Government (2016). Quality Schools Quality Outcomes: Areas of Future focus. Available at:

https://www.education.gov.au/quality-schools-quality-outcomes-areas-future-focus

Australian Government (2016). *Quality Schools Quality Outcomes. Available at:* https://docs.education.gov.au/system/files/doc/other/quality_schools_acc.pdf

Education Council (2015). National STEM School Education Strategy 2016-2026. A Comprehensive Plan For Science, Technology, Engineering And Mathematics Education In Australia. Available at: http://www.educationcouncil.edu.au/site/DefaultSite/filesystem/documents/National%20STEM%20School%20Education%20Strategy.pdf

Teacher Education Ministerial Advisory Group (2014). *Action now: Classroom ready teachers*. Available at: https://docs.education.gov.au/system/files/doc/other/action_now_classroom_ready_teachers_print.pdf

Appendix 2: *Primary Connections*: A review of literature

Abstract

This report analyses the empirical evidence on teacher professional learning in primary science. We have conducted a Systematic Literature Review (SLR) using the guidelines for evidence-based practice. The SLR resulted in 63 studies (68 papers) published between 2006 and 2017. Content and thematic analyses were used to investigate the resulting studies of professional learning programs for the key elements of each program, its context, learning focus and outcomes. The review has made some observations about the benefits and disadvantages of professional learning delivery and highlighted gaps in existing literature on the topic. The review reports on potential developments in professional learning delivery for consideration by future researchers and developers of professional learning programs like *Primary Connections*.

Keywords

primary science, elementary science, teacher professional learning, professional development, *Primary Connections*

Introduction

The teaching of science is mandated from the earliest years of schooling (Australian Curriculum Assessment and Reporting Authority (ACARA), 2015). However, there are particular challenges to the teaching of science in primary schools (Aubusson, Schuck, Ng, Burke, & Pressick-Kilborn, 2015; Goodrum, Hackling, & Rennie, 2001; Tytler, Osborne, Williams, Tytler, & Clark, 2008). These challenges relate to teachers' lack of confidence, lack of science content knowledge and skills, timetabling, teacher beliefs and other issues. Since research findings indicate that the teacher is the most important factor in improving student learning in schools (Rivkin, Hanushek, & Kain, 2005; Rowe, 2003) and in determining a student's interest in and attitudes toward science (Lyons & Quinn, 2010; Office of the Chief Scientist, 2012; Osborne, Simon, & Collins, 2003), it is critical that primary teachers have access to effective professional learning programs to lay the foundation for primary students' achievement in science. Research to determine how best to provide high quality teacher professional learning to improve science teaching is therefore important.

The aim of this systematic literature review is to explore the provision of professional learning activities for teachers of primary science. The review forms part of an evaluation of the *Primary Connections* program and is based on the following research questions regarding studies of professional learning in primary science education:

Efficiency RQ 2.5 Are there any unintended benefits or disadvantages in providing training in particular ways for in-service teachers and pre-service teachers?

Effectiveness RQ 3.3 What else can the Primary Connections program offer to assist teachers and pre-service teachers to implement the Australian science curriculum?

Background

Teacher Professional Learning

In this review the term 'professional learning' is used to describe all activities that support teachers to alter their teaching behaviours in ways that improve their students' learning. Although often used interchangeably, in the literature, 'professional development' usually refers to the activities that develop professional skills, knowledge and expertise (OECD, 2009), while 'professional learning' refers to changes in thinking, knowledge, skills, and approaches to teaching practice and/or changes in actual practice (Knapp, 2003; Timperley, 2011) and is consistent with the notion of teacher-as-learner (Loughran, 2014). In Australia in recent times there has been a shift in terminology away from 'professional development' to 'professional learning', perhaps because of a past association with de-contextualised, one-off 'in-service workshops'.

There has been a consensus in recent research on what design features constitute an effective professional learning program. Programs that positively impact teacher knowledge, skills, beliefs, and ultimately student learning should have: a focus on content knowledge; active learning; a coherent program; opportunities for collaboration; duration and sustainability; and adequate support (Hilda Borko, 2004; H Borko, Jacobs, & Koellner, 2010; Desimone, 2009; Loucks-Horsley, Stiles, Mundry, & Love, 2010; Luft & Hewson, 2014). Roth (2014, p. 383) argues that 'high-leverage' professional learning initiatives have "meaningful conceptual frameworks for teachers". He cited examples such as "teaching science as argument'' and "modelling-centered inquiry". The latter could include the 5Es model used in *Primary Connections*.

Teacher Professional Learning in Primary Science

There is a particular need for high quality science-focused professional learning programs for primary teachers, who are generalists and typically have limited preparation for teaching science. Primary teachers' lack of confidence to teach science and limited knowledge of science content and inquiry pedagogy is well documented in the research literature (Alake-Tuenter et al., 2012; Capps & Crawford, 2013; Goodrum et al., 2001; Murphy, Neil, & Beggs, 2007; Tytler, 2003; van Aalderen-Smeets, Walma van der Molen, & Asma, 2012). Therefore professional learning programs need to address teachers' confidence to teach science; their content knowledge and associated pedagogical knowledge (PCK); beliefs about science teaching and learning; and knowledge of inquiry pedagogies. Aubusson, Griffin, and Palmer (2015) surveyed 173 primary school teachers in Australia in order to understand their professional learning preferences. The findings showed that they preferred professional learning programs that included expert input, sustained in-school support and teacher collaboration. These teacher preferences broadly concur with the elements of effective professional learning noted above.

Primary Connections

Primary Connections: Linking Science with Literacy is an initiative of the Australian Academy of Science, developed with the broad aim to enhance primary school teachers' confidence and competence for teaching science (Hackling, Peers, & Prain, 2007). It is a teacher professional learning program supported with curriculum resources, modelling inquiry-based teaching and learning, which is an approach to teaching science now mandated by the *Australian Curriculum: Science* (Australian Curriculum Assessment and Reporting Authority (ACARA), 2015). *Primary Connections* has developed professional learning modules and trained professional learning facilitators to deliver workshops to primary teachers throughout Australia, as well as to pre-service primary teachers. The facilitators are able to explain and model the teaching approaches that underpin the curriculum resources. The *Primary Connections* materials align with the *Australian Curriculum: Science* and the professional learning program offers an opportunity to practise science teaching supported with resources; reflections on practice; and is linked to a set of principles of learning and teaching. *Primary Connections* encourages teachers to embrace constructivist and inquiry-oriented pedagogies. The 5Es model (Bybee, 2014) for planning and implementing science was the basis for the development of *Primary Connections*. The 5Es model is based on a learning progression through the five phases of Engage, Explore, Explain, Elaborate and Evaluate.

A survey conducted by the Australian Science Teachers Association with support from the Office of the Chief Scientist and the Primary Principals Association showed that the *Primary Connections* materials were highly valued by primary teachers across all sectors, with 85% of the 810 primary teachers, principals and affiliate personnel completing the survey indicating that they had used the resource (Australian Science Teachers Association, 2014).

Review Method and Execution

The focus of studies in this review is professional learning for primary school science teachers. A systematic literature review is a means of identifying, evaluating and interpreting all available research relevant to a particular topic. It follows a meticulous procedure to search for and select the studies for coding and analysis and to collate the published empirical studies suitable for inclusion. The systematic review process is validated by multiple researchers to ensure the authenticity and reliability of the results to provide an overview of existing empirical research undertaken within a field.

This systematic review is constrained within the following boundaries:

- Scope of educational level: In our review, we have focused on the studies of professional learning for primary school teachers.
- Scope of subject domain: Our domain is limited to empirical studies that research professional learning in science.
- Focus of review: We focus on specific attributes of the results, e.g. study focus and outcomes, study context, and the pedagogical approaches of the studies.
- Review timeline: Our review covers publications from 2006 – 2017.
- Type of included studies: The included studies are those that have followed empirical research designs for investigating science-related professional learning. Evidence-based reviews require the researchers to follow rigorous methods to collect and collate the evidence in order to present accurate results.

In the following section we briefly describe our search, selection and analysis process in order to make the review transparent and repeatable.

Search Strategy

A comprehensive search of all possible relevant peer-reviewed studies was undertaken as required for a systematic literature review. The following steps were taken to search for relevant studies:

1. Deriving search terms or key words from the Research Question(s)
2. Identifying synonyms for the search terms
3. Constructing a search string from key words to be used in online databases (see below)
4. Selecting a range of online databases and journals for searching and customising the search string for different interfaces.
5. Managing the results

Based on the research questions, five major search terms were identified i.e. primary science, elementary science, teacher professional learning, professional development, and *Primary Connections*.

Combining the terms, the following set was used in this study: (“primary science” OR “elementary science” AND (“professional learning” OR “professional development”)). A separate search was conducted for “*Primary Connections*” and any results relevant to the other key words were included. The string was modified for different online databases as necessary.

The following education research databases were selected for the searches:

- A+ Education
- Australasian Education Directory (AED)
- EBSCO Host Education Research Complete
- ERIC
- Professional Development Collection
- ProQuest Education Journals

Study Selection

A filter was applied so that only peer-reviewed studies were considered for this review. Irrelevant studies were excluded from the results by reading their titles and abstracts. By scanning and reviewing the references at the end of papers retrieved from the search results, other relevant studies were able to be included. After all filters had been applied, 85 studies were considered to be relevant to the research questions.

These papers were further assessed for their relevance and quality of research design. Articles were considered independently by a research assistant and two members of the research team, professors of education, who had published in the field of professional learning in primary science education. Any points of difference regarding which studies to include were resolved through discussion of the extent to which the studies met the constraints identified for the systematic literature review (see above). This process left 68 papers for analysis and synthesis. The list of these studies can be found in Appendix 2A.

Data Extraction, Synthesis and Analysis

The following data were extracted from the included publications for cross analysis: authors; publication year; where study was conducted; professional learning focus; professional learning strategies; professional learning duration; study methodology and scale; data collection methods; reported outcomes of the study; and recommendations for professional learning. The studies were also coded for: whether the impact was measured on teachers, students or pre-service teachers; inclusion of inquiry pedagogy; rural location; or mention of an online component. A table of that data is included as Appendix 2B. The data were then synthesised into similar themes and categories for further analysis.

Results

Our systematic review resulted in 63 discrete studies (68 papers). Three of the studies were the subject of papers by the same researchers and are represented only once each in the table included as Appendix 2B (Cotabish, Dailey, Hughes, & Robinson, 2011; Cotabish, Dailey, Robinson, & Hughes, 2013; Kenny, 2009, 2012; G. Smith, 2014, 2015). One study is represented twice in the table since the second paper is a follow-up of the participants to determine the sustainability of the original outcomes (Sandholtz & Ringstaff, 2014, 2016); and another study is represented twice because one paper deals with impact of the program on teachers and the other with the impact on students (Shymansky, Wang, Annetta, Yore, & Everett, 2012, 2013).

Synthesis and Frequency Analysis of study attributes

In this section we present the results from data analysis and synthesis of the resulting studies. A summary of the frequency analysis can be found in Figure 6.

FIGURE 6 SUMMARY OF DATA SYNTHESIS AND ANALYSIS OF 63 SELECTED STUDIES

Criterion	Analysis (number of studies)
Year of publication	2007 (2), 2008 (2), 2009 (5), 2010 (3), 2011 (6), 2012 (12), 2013 (7), 2014 (10), 2015 (6), 2016 (14), 2017 (1)
Location	Australia (24), United States (21), United Kingdom (4), Sweden (3), Other (11) – [Canada, Chile, Germany, Israel, NZ, Philippines, Senegal, South Africa, The Netherlands, Turkey]
Rural	9
Professional learning focus	Pedagogical Content Knowledge, PCK (30), Science Content Knowledge, SCK (14), collaborative analysis of practice (13), self-efficacy/confidence (10)
Professional learning strategies	Workshops (26), action research (20), mentoring/coaching (11), CPD (7), PLC (4)
Category of professional learning[4]	1 (15), 2 (21), 3 (26) n/a (1)
Inquiry pedagogy	45
Online element	11
Participants measured	Teachers (58), Students (17), pre-service teachers (10) PSTs only (5)
Data Collection	Mixed methods (32), qualitative (21), quantitative (10)
Study scale[5]	Small (30), medium (22), large (11)
Professional learning duration[6]	Short (19), medium (14), long (30)
Reported positive outcomes, e.g. improved teaching or learning	PCK (23), Teacher confidence/efficacy/attitudes/beliefs (23), Collaborative reflection on action (17), SCK (16), Student learning outcomes (15), Successful use of educative curriculum materials (11), Inquiry pedagogy (10), Consideration of context (6)
Recommendations re professional learning	Collaborative reflection on action (22), Ongoing Support (12), Consideration of context (9), Inquiry pedagogy (8), Use of educative curriculum materials (7), Teacher confidence/efficacy/attitudes (7), PCK (5), SCK (4), Mentoring (3) PLC (3)

Geographical Distribution

This review only included studies reported in English. Studies from Australia (38%) and the United States (33%) predominated, with the highest number of empirical studies. By comparison, other countries were only minimally represented. Fifteen per cent of the studies catered for teachers in rural areas.

Foci of the Studies

The main focus of all these studies was professional learning in primary science; however, the studies were concerned with different aspects of professional learning and often more than one aspect. The stated focus of 48% of the studies was pedagogical content knowledge (PCK), in 22% of the studies it was science content knowledge (SCK) and in 16% self-efficacy or confidence. Twenty-one per cent of the studies were concerned with programs where teachers examine their practice collaboratively.

Professional Learning Strategies

There was a wide range of professional learning strategies represented in the studies. Forty-one per cent employed workshops as a delivery vehicle for professional learning. None of the professional learning consisted solely of one-off workshops but was either part of a series of sessions or an initial workshop followed up with other activities and/or support. Collaborative reflection on action was a feature of 32% of the studies. In this synthesis, the term 'collaborative reflection on action' covers such collaborative practices as action research,

[4] 1 – front loaded, little support, 2 – front loaded, ongoing support, 3 – continuous ongoing support

[5] Small - 0-20 teachers, medium - 20-100 teachers, large - over 100 teachers

[6] Short – less than two months, medium – 2-12 months, long – 12 months or more

formative assessment, lesson study, CoRes (Content Representations), and reflection on practice. Other professional learning strategies employed were mentoring/coaching (17%), continual professional development (CPD) (!!%), and professional learning communities (PLCs) (6%).

Research Paradigms and Methodologies

Professional learning programs may be placed on a continuum from 'front-loaded' with little follow-up, through initial workshops with varying degrees of follow-up and support, all the way to a continuous support program. The included studies have been categorised as: front-loaded with little follow-up support (1); workshops with some follow-up/support (2); or continuous support or collaborative programs (3). As shown in Table 1*, 24% of the studies were categorised as front-loaded, 33% as front-loaded with support and 41% as collaborative support programs.

The impact of the professional learning programs was not measured exclusively on teachers. The effect of the professional learning on school students was measured in 27% of the studies. Pre-service teachers were involved in 16% of the programs and 8% were conducted with pre-service teachers only. Ninety-two per cent of the studies measured impact on teachers.

The included set of studies contains diverse approaches to research design, with a range of qualitative and quantitative research methodologies. Fifty-one per cent of the studies used mixed data collection methods, 33% collected qualitative data and 16% collected quantitative data. Teachers' self-reports (by questionnaires and/or interviews) were used in the majority of studies but knowledge assessments and observations were used in several studies, often as additional data sources.

Inquiry pedagogy was a feature of 71% of the studies, although not necessarily the main focus. This reflects the emphasis on inquiry pedagogy in current primary science curriculum documents in many countries (Australian Curriculum Assessment and Reporting Authority (ACARA), 2015; Department for Education [England], 2014).

Scale and Duration of Studies

Many of the studies considered were small scale i.e. 48% involved fewer than 20 teachers. Thirty-five per cent of the studies were medium scale (20-100 teachers) and 17% involved more than 100 teachers and could be classified as large scale. Thirty per cent of the studies were of short duration (less than two months), 22% were medium term (2–12 months) and 48% lasted for more than 12 months and could be considered long term programs.

Study Outcomes

Study outcomes were analysed through content analysis, and all studies reported some positive results or did not report negative results. A comparison of stated study foci and reported outcomes shows that there were outcomes reported in many more areas than the stated focus of the study. This shows that many areas of professional learning are related and reflect the interrelated aspects of teacher knowledge, i.e. content knowledge, curriculum knowledge, pedagogical content knowledge (Shulman, 1987) and attitudes. Thirty-five per cent of studies reported positive outcomes in the area of PCK, 24% in SCK, 16% in teacher confidence and 10% in self-efficacy. The use of educative curriculum materials (curriculum materials explicitly designed to support both teacher and student learning) was reported to contribute to positive outcomes in science teaching and learning in 16% of the studies and improvements in inquiry pedagogy were reported in 16% of studies.

---

*For reasons pertaining to confidentiality, sections relating to Governance and spending, including Table 1, were redacted before publishing this report.

Study Recommendations for Professional Learning

The recommendations made in the studies tend to reflect the guidelines for effective professional learning found in the literature (Cordingley & Bell, 2012; Luft & Hewson, 2014). The need for ongoing support to be provided for teachers was highlighted in 16% of the studies, the importance of context for successful professional learning was mentioned in 15% of studies and the need for teacher collaboration was stressed in 13% of studies. The use of educative curriculum materials was recommended in 11% of the studies.

Discussion

Based on the aggregation of the empirical studies included in our review, almost all studies reported positive outcomes. The findings indicate some strengths and weaknesses in relation to existing research in the field.

Reporting on Negative Outcomes

The results have shown that the studies present mainly positive outcomes and hardly any study reported negative aspects. This may be due to pressure on authors to publish positive and favourable results to obtain research funds, or a perception that readers would have little interest in negative results. But researchers could also learn from studies that present detailed descriptions of failures. It has been shown that published empirical work is more skewed towards positive and statistically significant ($p<0.05$) research (Dickersin & Min, 1993b; Dwan, Gamble, Williamson, & Kirkham, 2013). Such study publication bias makes it difficult to present an accurate picture of the body of research in any field (Dwan et al., 2013).

Researcher Bias

The results showed a significant trend by researchers to empirically assess their own professional learning intervention. Many of these studies were small scale, concerned with one program in one setting where the researcher was often a participant and the study collected qualitative data only. It would be advantageous to have more independent research studies in this field.

Implications for research questions

Efficiency RQ 2.5: Are there any unintended benefits or disadvantages in providing training in particular ways for in-service teachers and pre-service teachers?

Even though the desired outcome of effective professional learning is change in professional practice and, ultimately, enhanced student learning opportunities, it is not always easy to show this outcome in simple causal ways. Analysis of the professional learning strategies and outcomes of the studies included in this review, however, can help to identify successful elements and barriers to effective professional learning.

Principles of Effective Professional Learning

In the professional learning programs represented in these review studies, teachers attributed changes in their subsequent classroom practice to the following aspects of the program: content; active participation; collaboration; and duration of the program (Smith, G., 2014; Smith, G., 2015; Murphy, Smith, Varley, & Razi, 2015); a meaningful context; varied strategies; a school-based program catering for student interest (Paige, Zeegers, Lloyd, & Roetman, 2016); teachers learning using inquiry as their students would; a rich source of practical resources; demonstrations and strategies that connect to the curriculum standards; and maintaining support for teachers (Nichols, Gillies, & Kleiss, 2016).

Barriers to Effective Professional Learning

Researchers conducting the review studies identified some of the barriers to implementing professional learning as: limited resources; time constraints; mandated curriculum pacing; and classroom management issues (Buczynski & Hansen, 2010); as well as the failure of some programs to reveal and address existing beliefs of teachers (e.g. Lowe & Appleton, 2015).

Impact of Teacher Professional Learning on Students

The purpose of any professional learning program is ultimately to improve outcomes for students. Of the 63 studies considered in this review, 15 measured student achievement gains. The US studies often made use of the national testing program to measure these gains. The professional learning foci that were associated with student achievement gains were mostly a combination of PCK and SCK. Also, 13 of the studies that reported student achievement gains employed inquiry pedagogy. Although, as stated earlier, it is not possible to attribute improved student achievement to the professional learning program alone, it is encouraging to see researchers undertaking such studies.

Online vs Face-to Face Professional Learning

None of the studies in this review made a comparison between online and face-to-face professional learning and, perhaps surprisingly, few made use of online learning as a major plank in their program. A report by Cordingley and Bell (2012) explored the literature for evidence about the relative merits of professional learning delivered by face-to-face methods in comparison with distance/online learning approaches. They found no studies that set out directly to make the comparison though some research into online learning included some comparisons with other approaches. Other researchers have found that studies that have considered the effectiveness of online versus face-to-face learning have generally found that there are no major differences to be considered, although some reported positive benefits from online learning (particularly where face-to-face opportunities are logistically difficult) (Dash, Magidin de Kramer, O'Dwyer, Masters, & Russell, 2012; Herbert, Campbell, & Loong, 2016). According to the available evidence, online professional learning should not be treated as if it represents a particular approach, but rather as a delivery vehicle. In general, 'online' and 'face-to face' are not useful terms for understanding the nature of the teaching and learning activities contained within a professional learning program, but there are contexts where either online or face-to-face delivery is preferable, for reasons of cost, location, or content (Fishman et al., 2013). An online environment may facilitate professional learning by overcoming issues of time and distance, providing access to people and resources, and enabling networking and collaboration that are not possible in a face-to face situation (Herbert et al., 2016). A study of the professional learning needs of teachers in regional and remote areas of Western Australia (Broadley, 2010) found that a blend of face-to-face and online professional learning was preferred. Analysis of the reflections of participants in another Australian study (McConnell, Parker, Eberhardt, Koehler, & Lundeberg, 2013) revealed that the teachers regarded videoconferencing as an effective tool for facilitating professional learning communities when distance and time were barriers to face-to-face meetings, as it provided similar social interactions.

Efficiency RQ3.3 What else can the Primary Connections program offer to assist teachers and pre-service teachers to implement the Australian science curriculum?

Primary Connections professional learning research studies

Four of the studies included in this review made use of *Primary Connections* materials as professional learning resources for teachers (Albion & Spence, 2013; Laidlaw, Taylor, & Fletcher, 2009; Lowe & Appleton, 2015; P. Smith & M. Hackling, 2016) and they reported positive outcomes in teacher self-efficacy, amount of science taught, PCK, and capacity to manage discourse. The *Primary Connections* resources may be regarded as educative curriculum materials, i.e. materials explicitly designed to support teacher and student learning (Arias, Bismack, Davis, & Palincsar, 2016). Positive outcomes have been reported in the review studies from other such materials, e.g. Townsend et al. (2016) reported that using educative curricula improved the PCK of regional, rural and remote science teachers as well as student learning outcomes. Arias et al. (2016) found that teachers drew on various educative features of such materials to support their practice, depending on their particular context. These results are an endorsement of the current *Primary Connections* approach but other study results may offer additional professional learning strategies.

Sustained Professional Learning Support

Campbell and Chittleborough (2014) found that *Primary Connections* facilitator training was an effective strategy in the Primary Science Specialists Professional Learning Program and that this program subsequently assisted in implementing the *Primary Connections* program in schools. The primary science specialists reported that networking and collegial support were also vital aspects of their training, suggesting that the combination of *Primary Connections* and a support network would be a powerful combination for primary teachers. The importance of ongoing support and collegial networks was evident in the number of recommendations made in the review studies for their inclusion in any professional learning program (Diamond, Maerten-Rivera, Rohrer, & Lee, 2014; Drits-Esser, Gess-Newsome, & Stark, 2016; Kenny & Colvill, 2008; Klieger & Yakobovitch, 2012; Laidlaw et al., 2009; Nichols, Gillies, & Kleiss, 2016; Zeegers, Paige, Lloyd, & Roetman, 2012). Ongoing adequate support has been identified in the research literature as an element of effective professional learning (Desimone, 2009; Luft & Hewson, 2014).

Another element of effective professional learning is generally considered to be the duration of the program, with long-term professional learning considered to have an impact on a range of teacher beliefs and practice (Drits-Esser et al., 2016). Shymansky et al. (2012) found a significant positive relationship between the number of teacher professional learning hours and student achievement scores on national tests. One-off, short-term interventions appear to be less effective than long-term interventions combined with continuing follow-up support (i.e. follow-up interventions or support for teacher collaboration and ongoing facilitation of learning). To this end, it may be advantageous for *Primary Connections* to add a long-term element to its existing professional learning program. This could be achieved by facilitating ongoing teacher collaboration following the face-to face teacher workshop.

Follow-up Data Collection Process

Sustained professional learning support would not only contribute to the duration and potential impact of *Primary Connections* professional learning but would offer the opportunity to conduct ongoing research to inform iterative developments in a long-term program of *Primary Connections* professional learning. Several of the review studies were able to provide evidence of the sustainability of their programs in this way (Drits-Esser et al., 2016; Lakshmanan, Heath, Perlmutter, & Elder, 2011; Palmer, 2011; Sandholtz & Ringstaff, 2016).

Collaborative Analysis-of-practice

As well as being a follow-up to initial workshop style professional learning, teacher collaborations of various kinds are often used as professional learning strategies in themselves. These strategies reportedly contributed to the positive outcomes of 27% of the studies in this review, which concurs with the literature on effective professional learning strategies: that collaboration is one of the elements of effective professional learning (Desimone, 2009; Luft & Hewson, 2014). Aubusson et al. (2015) also confirmed a teacher preference to engage in professional learning that offered a structured framework for collaboration. Some examples of collaborative reflection on, and analysis of, practice that have contributed to positive professional learning outcomes in the review studies include: action research (K. Smith & Lindsay, 2016); the CoRes (Content Representations) approach (Bertram & Loughran, 2012; Hume, 2016; Nilsson, 2013; Townsend et al., 2016); lesson study (Baricaua Gutierez, 2016; Miyazaki, 2016); Science Teachers Learning from Lesson Analysis (STeLLA) (Roth et al., 2011); instructional core framework (Loughland & Nguyen, 2016); formative assessment (Falk, 2012); and professional learning communities (PLCs) (Lakshmanan et al., 2011; Mintzes, Marcum, Messerschmidt-Yates, & Mark, 2013). It may be possible to apply these collaborative strategies to *Primary Connections* resources to enrich or extend the current professional learning model. Smith and Hackling’s study, which utilised action research on *Primary Connections* units (2016), is a successful example of this.

Leveraging Face-to-face Interactions

At present the *Primary Connections* program may be able to more effectively leverage its face-to-face workshop experience. A blended learning model allows the initial stimulus and opportunities for group formation (workshop) to be sustained by ongoing online contact (McConnell et al., 2013). Some review studies successfully employed the model of an initial face-to-face professional learning session followed by longer-term online support (Berry, Loughran, Smith, & Lindsay, 2009; Lakshmanan et al., 2011; Townsend et al., 2016). By employing a blended learning model, *Primary Connections* would extend the duration of the professional learning experience and possibly extend the range of professional learning strategies to include more collaborative analysis of practice.

Pre-service Teachers

Evidence from this review supports the current *Primary Connections* strategy of holding workshops for teacher educators and pre-service teachers. This strategy has three major benefits: it provides pre-service teachers with quality examples of inquiry learning, as mandated by the *Australian Curriculum: Science*; it has the potential to introduce *Primary Connections* to more in-service teachers during pre-service teachers' professional experience; if made an assignment as part of a pre-service teacher's professional experience in schools, it could provide a rich science experience that is often lacking for pre-service teachers (Cooper, Kenny, & Fraser, 2012; Hume, 2012; Kenny, 2009, 2012; Laidlaw et al., 2009; Sullivan-Watts, Nowicki, Shim, & Young, 2013). Three of the review studies reported positive results from the use of *Primary Connections* resources with pre-service teachers (Cooper et al., 2012; Hume, 2012; Laidlaw et al., 2009). Since the 31 Australian Government funded *Primary Connections* resources are now free to all Australian schools, this resolves any ethical dilemma for teacher educators of promoting a commercial product.

Conclusion

In this paper we have presented the results from the analysis of 63 empirical studies (68 papers) that focused on professional learning in primary science, published from 2006 to 2017. Almost all of the included studies reported positive outcomes of their stated foci, albeit with some barriers to professional learning noted. The key features of the successful programs have been aggregated and analysed to provide an account of effective professional learning provision and to inform the current *Primary Connections* professional learning program to assist teachers and pre-service teachers to implement the Australian science curriculum. Recommendations for additional professional learning opportunities include:

- providing sustained on-going professional learning support in addition to initial workshops;
- promoting and supporting teacher collaborative practices and *Primary Connections* networks among teachers;
- leveraging face-to-face workshops by expanding to a blended learning model;
- conducting ongoing research to inform iterative development in *Primary Connections* professional learning; and
- collaborating with teacher educators to facilitate the use of *Primary Connections* in initial teacher education courses.

APPENDIX 2A: LIST OF 68 PROFESSIONAL LEARNING IN PRIMARY SCIENCE STUDIES INCLUDED IN THE REVIEW

Albion, P. R., & Spence, K. G. (2013). "*Primary Connections*" in a Provincial Queensland School System: Relationships to Science Teaching Self-Efficacy and Practices. *International Journal of Environmental and Science Education, 8*(3), 501-520.

Appleton, K. (2008). Developing Science Pedagogical Content Knowledge Through Mentoring Elementary Teachers. *Journal of Science Teacher Education, 19*(6), 523-545.

Arias, A. M., Bismack, A. S., Davis, E. A., & Palincsar, A. S. (2016). Interacting with a suite of educative features: Elementary science teachers' use of educative curriculum materials. *Journal of Research in Science Teaching, 53*(3), 422-449.

Bantwini, B. D. (2009). District professional development models as a way to introduce primary-school teachers to natural science curriculum reforms in one district in South Africa. *Journal of Education for Teaching, 35*(2), 169-182.

Baricaua Gutierez, S. (2016). Building a classroom-based professional learning community through lesson study: insights from elementary school science teachers. *Professional Development in Education, 42*(5), 801-817.

Berg, A., & Moore Mensah, F. (2014). De-Marginalizing Science in the Elementary Classroom by Coaching Teachers to Address Perceived Dilemmas. *Educational Policy Analysis Archives & Education Review, 22*(50-57), 1-35.

Berry, A., Loughran, J., Smith, K., & Lindsay, S. (2009). Capturing and Enhancing Science Teachers' Professional Knowledge. *Research in Science Education, 39*(4), 575-594.

Bottoms, S., Ciechanowski, K., & Hartman, B. (2015). Learning to Teach Elementary Science Through Iterative Cycles of Enactment in Culturally and Linguistically Diverse Contexts. *Journal of Science Teacher Education, 26*(8), 715-742.

Buczynski, S., & Hansen, C. B. (2010). Impact of professional development on teacher practice: Uncovering connections. *Teaching and Teacher Education, 26*(3), 599-607.

Campbell, C., & Chittleborough, G. (2014). The 'new' science specialists : promoting and improving the teaching of science in primary schools. *Teaching Science, 60*(1), 19-29.

Cofré, H., Vergara, C., Lederman, N., Lederman, J., Santibáñez, D., Jiménez, J., & Yancovic, M. (2014). Improving Chilean In-service Elementary Teachers' Understanding of Nature of Science Using Self-contained NOS and Content-Embedded Mini-Courses. *Journal of Science Teacher Education, 25*(7), 759-783.

Cooper, G., Kenny, J., & Fraser, S. (2012). Influencing Intended Teaching Practice: Exploring pre-service teachers' perceptions of science teaching resources. *International Journal of Science Education, 34*(12), 1883-1908.

Cotabish, A., Dailey, D., Hughes, G. D., & Robinson, A. (2011). The Effects of a STEM Professional Development Intervention on Elementary Teachers' Science Process Skills. *Research in the Schools, 18*(2), 16-25.

Cotabish, A., Dailey, D., Robinson, A., & Hughes, G. (2013). The Effects of a STEM Intervention on Elementary Students' Science Knowledge and Skills. *School Science & Mathematics, 113*(5), 215-226.

Dalehefte, I. M., & Rieck, K. (2014). How do German primary school teachers prepare students for science standards? Findings from a video study of the Professional Development Program SINUS for Primary Schools. *Form@re - Open Journal for network training, 14*(2), 7-20.

Davies, D. (2010). What's changed? Issues of impact and evaluation in primary science professional development. *Professional Development in Education, 36*(3), 511-523.

Diamond, B. S., Maerten-Rivera, J., Rohrer, R. E., & Lee, O. (2014). Effectiveness of a Curricular and Professional Development Intervention at Improving ElementaryTeachers' Science Content Knowledge and Student Achievement Outcomes: Year 1 Results. *Journal of Research in Science Teaching, 51*(5), 635-658.

Drits-Esser, D., Gess-Newsome, J., & Stark, L. A. (2016). Examining the sustainability of teacher learning following a year-long science professional development programme for inservice primary school teachers. *Professional Development in Education*, 1-22.

Falk, A. (2012). Teachers learning from professional development in elementary science: Reciprocal relations between formative assessment and pedagogical content knowledge. *Science Education, 96*(2), 265-290.

Fraser, C. A. (2010). Continuing professional development and learning in primary science classrooms. *Teacher Development, 14*(1), 85-106.

Goodnough, K. (2016). Professional Learning of K-6 Teachers in Science Through Collaborative Action Research: An Activity Theory Analysis. *Journal of Science Teacher Education, 27*(7), 747-767.

Grigg, J., Kelly, K. A., Gamoran, A., & Borman, G. D. (2013). Effects of two scientific inquiry professional development interventions on teaching practice. *Educational Evaluation and Policy Analysis, 35*(1), 38-56.

Hackling, M., Smith, P., & Murcia, K. (2011). Enhancing classroom discourse in primary science: The Puppets Project. *Teaching Science: The Journal of the Australian Science Teachers Association, 57*(2), 18-25.

Harlow, D. (2014). An Investigation of How a Physics Professional Development Course Influenced the Teaching Practices of Five Elementary School Teachers. *Journal of Science Teacher Education, 25*(1), 119-139.

Heller, J. I., Daehler, K. R., Wong, N., Shinohara, M., & Miratrix, L. W. (2012). Differential effects of three professional development models on teacher knowledge and student achievement in elementary science. *Journal of Research in Science Teaching, 49*(3), 333-362.

Hume, A. (2012). *Primary Connections*: Simulating the Classroom in Initial Teacher Education. *Research in Science Education, 42*(3), 551-565.

Hume, A. (2016). The CoRe of the matter: Developing primary teachers' professional knowlegde in science. *Teaching Science, 62*(4), 43-55.

Johnson, C. C., & Fargo, J. D. (2014). A study of the impact of transformative professional development on Hispanic student performance on state mandated assessments of science in elementary school. *Journal of Science Teacher Education, 25*(7), 845-859.

Karaman, A., & Apaydin, S. (2012). Enhancing Unsophisticated Views of Science held by Elementary and Science Teachers. *International Journal of Learning, 18*(5), 71-86.

Kenny, J. (2009). A partnership based approach to professional learning: Pre-service and in-service teachers working together to teach primary science. *Australian Journal of Teacher Education (Online), 34*(6), 1.

Kenny, J. (2012). University-school partnerships: pre-service and in-service teachers working together to teach primary science. *Australian Journal of Teacher Education, 37*(3), 57-82.

Kenny, J., & Colvill, M. (2008). Primary science: Professional learning and curriculum development in Northern Tasmania. *Teaching Science: The Journal of the Australian Science Teachers Association, 54*(1), 35-38.

Klieger, A., & Yakobovitch, A. (2012). Contribution of professional development to standards implementation. *Teacher Development, 16*(1), 77-88.

Koch, J., & Appleton, K. (2007). The Effect of a Mentoring Model for Elementary Science Professional Development. *Journal of Science Teacher Education, 18*(2), 209-231.

Laidlaw, K.-R., Taylor, N., & Fletcher, P. (2009). Teaching Primary Science in Rural and Regional Australia: Some Challenges Facing Practicing and Pre-service Teachers. *Journal of Science & Mathematics Education in Southeast Asia, 32*(2), 105-130.

Lakshmanan, A., Heath, B. P., Perlmutter, A., & Elder, M. (2011). The Impact of Science Content and Professional Learning Communities on Science Teaching Efficacy and Standards-Based Instruction. *Journal of Research in Science Teaching, 48*(5), 534-551.

Loughland, T., & Nguyen, H. T. M. (2016). Using the instructional core to implement a professional learning programme for primary science teachers in Australia: teacher learning and student skill outcomes. *Teacher Development, 20*(4), 498-520.

Lowe, B., & Appleton, K. (2015). Surviving the implementation of a new science curriculum. *Research in Science Education, 45*(6), 841-866.

Lumpe, A., Czerniak, C., Haney, J., & Beltyukova, S. (2012). Beliefs about Teaching Science: The relationship between elementary teachers' participation in professional development and student achievement. *International Journal of Science Education, 34*(2), 153-166.

McKinnon, M., & Lamberts, R. (2014). Influencing science teaching self-efficacy beliefs of primary school teachers: A longitudinal case study. *International Journal of Science Education, Part B, 4*(2), 172-194.

Miller, R. G., Curwen, M. S., White-smith, K. A., & Calfee, R. C. (2015). Cultivating Primary Students' Scientific Thinking Through Sustained Teacher Professional Development. *Early Childhood Education Journal, 43*(4), 317-326.

Mintzes, J. J., Marcum, B., Messerschmidt-Yates, C., & Mark, A. (2013). Enhancing self-efficacy in elementary science teaching with professional learning communities. *Journal of Science Teacher Education, 24*(7), 1201-1218.

Miyazaki, T. (2016). Is changing teaching practice the mission impossible? A case study of continuing professional development for primary school teachers in Senegal. *Compare-a Journal of Comparative and International Education, 46*(5), 701-722.

Morgan, A.-M. (2012). 'Me as a Science Teacher': Responding to a Small Network Survey to Assist Teachers with Subject-Specific Literacy Demands in the Middle Years of Schooling. *Australian Journal of Teacher Education, 37*(6), 6.

Murphy, C., Smith, G., Varley, J., & Razi, Ö. (2015). Changing practice: An evaluation of the impact of a nature of science inquiry-based professional development programme on primary teachers. *Cogent Education, 2*(1).

Nichols, K., Burgh, G., & Kennedy, C. (2017). Comparing Two Inquiry Professional Development Interventions in Science on Primary Students' Questioning and Other Inquiry Behaviours. *Research in Science Education, 47*(1), 1-24.

Nichols, K., Gillies, R., & Kleiss, D. (2016). A professional learning model that cultivates primary science classrooms' representational profiles. *International Journal of Educational Research, 76*, 12-33.

Nilsson, P. (2013). What do we know and where do we go? Formative assessment in developing student teachers' professional learning of teaching science. *Teachers and Teaching, 19*(2), 188-201.

Nilsson, P., & Loughran, J. (2012). Exploring the Development of Pre-Service Science Elementary Teachers' Pedagogical Content Knowledge. *Journal of Science Teacher Education, 23*(7), 699-721.

Paige, K., Zeegers, Y., Lloyd, D., & Roetman, P. (2016). Researching the Effectiveness of a Science Professional Learning Programme Using a Proposed Curriculum Framework for Schools: a Case Study. *International Journal of Science and Mathematics Education, 14*(1), 149-175.

Palmer, D. (2011). Sources of efficacy information in an inservice program for elementary teachers. *Science education, 95*(4), 577-600.

Roth, K. J., Garnier, H. E., Chen, C., Lemmens, M., Schwille, K., & Wickler, N. I. Z. (2011). Videobased Lesson Analysis: Effective Science PD for Teacher and Student Learning. *Journal of Research in Science Teaching, 48*(2), 117-148.

Sandholtz, J. H., & Ringstaff, C. (2014). Inspiring Instructional Change in Elementary School Science: The Relationship Between Enhanced Self-efficacy and Teacher Practices. *Journal of Science Teacher Education, 25*(6), 729-751.

Sandholtz, J. H., & Ringstaff, C. (2016). The Influence of Contextual Factors on the Sustainability of Professional Development Outcomes. *Journal of Science Teacher Education, 27*(2), 205-226.

Shymansky, J. A., Wang, T. L., Annetta, L. A., Yore, L. D., & Everett, S. A. (2012). How much professional development is needed to effect positive gains in K-6 student achievement on high stakes science tests? *International Journal of Science and Mathematics Education, 10*(1), 1-19.

Shymansky, J. A., Wang, T. L., Annetta, L. A., Yore, L. D., & Everett, S. A. (2013). The Impact of a Multi-Year, Multi-School District K-6 Professional Development Programme Designed to Integrate Science Inquiry and Language Arts on Students' High-Stakes Test Scores. *International Journal of Science Education, 35*(6), 956-979.

Sinclair, B. B., Naizer, G., & Ledbetter, C. (2011). Observed Implementation of a Science Professional Development Program for K-8 Classrooms. *Journal of Science Teacher Education, 22*(7), 579-594.

Smith, G. (2014). An innovative model of professional development to enhance the teaching and learning of primary science in Irish schools. *Professional Development in Education, 40*(3), 467-487.

Smith, G. (2015). The Impact of a Professional Development Programme on Primary Teachers' Classroom Practice and Pupils' Attitudes to Science. *Research in Science Education, 45*(2), 215-239.

Smith, K., & Lindsay, S. (2016). Building Future Directions for Teacher Learning in Science Education. *Research in Science Education, 46*(2), 243-261.

Smith, P., & Hackling, M. (2016). Supporting teachers to develop substantive discourse in primary science classrooms. *Australian Journal of Teacher Education, 41*(4), 10.

Sullivan-Watts, B., Nowicki, B., Shim, M., & Young, B. (2013). Sustaining Reform-Based Science Teaching of Preservice and Inservice Elementary School Teachers. *Journal of Science Teacher Education, 24*(5), 879-905.

Townsend, A., McKinnon, D. H., Fitzgerald, M. T., Morris, J., & Lummis, G. (2016). Educative Curricula and PCK development driven by STEM professional learning in rural and remote schools: A longitudinal Type IV case study. *International Journal of Innovation in Science and Mathematics Education (formerly CAL-laborate International), 24*(4).

Tytler, R. (2009). School Innovation in Science: Improving science teaching and learning in Australian schools. *International Journal of Science Education, 31*(13), 1777-1809.

van Aalderen-Smeets, S. I., & Walma van der Molen, J. H. (2015). Improving primary teachers' attitudes toward science by attitude-focused professional development. *Journal of Research in Science Teaching, 52*(5), 710-734.

Walan, S., & Mc Ewen, B. (2016). Primary Teachers' Reflections on Inquiry- and Context-Based Science Education. *Research in Science Education*, 1-20.

Watters, J. J., & Diezmann, C. M. (2007). Multimedia Resources to Bridge the Praxis Gap: Modeling Practice in Elementary Science Education. *Journal of Science Teacher Education, 18*(3), 349-375.

Zeegers, Y., Paige, K., Lloyd, D., & Roetman, P. (2012). 'Operation Magpie': Inspiring Teachers' Professional Learning Through Environmental Science. *Australian Journal of Environmental Education*, 28(1), 27-41.

APPENDIX 2B: PROFESSIONAL LEARNING (PL) IN PRIMARY SCIENCE STUDIES 2006–2017

*I=Inquiry; R=rural/remote; O=online component, T=impact measured on teachers; S=impact measured on students; PST=impact measured on pre-service teachers

TABLE 4 PROFESSIONAL LEARNING (PL) IN PRIMARY SCIENCE STUDIES 2006-2017

	Study	Locat-ion	*	PL Focus	PL Strategies	PL duration	Study Method-ology	Study Scale	Data Collection	Reported Outcomes	Recommendations re PL
1.	Albion & Spence, 2013	Aust (Qld)	I, R, T	Self-efficacy for science teaching	*Primary Connections* professional learning and curriculum resources	Short term	Descriptive survey	216 teachers	Online questionnaire - measures of teachers' self-efficacy for teaching science (STEBI-A), information about current science teaching, and teachers' responses to the implementation of *Primary Connections*	Both self-efficacy for science teaching and the amount of science taught we-re higher for teachers who had used *Primary Connections* curriculum materials.	Well supported interventions like the implementation of *Primary Connections* can make a difference to science teaching
2.	Appleton, 2008	Aust (Qld)	I, R, T	PCK	Mentoring	Months	Case study	2 teacher case studies	Interviews with teachers, extensive field notes of lessons, planning documents, some videotaped lessons	Developed science PCK and found that working within teacher context is essential for PL	Mentoring be further investigated as means of facilitating effective change in both elementary science teachers' knowledge base and their science teaching practices
3.	Arias, Bismack, Davis, & Palincsar, 2016	US	T	Learning both the practices and content of science.	Educative curriculum materials—materials explicitly designed to support teacher and student learning	1-hour lesson 3x per week for 2 months	Qualitative case study	2 teachers	Video records, teacher interviews	The teachers regularly interacted with and drew on the educative features to inform their teaching of science practices and content.	Educative curriculum materials have potential in supporting elementary teachers and their students.
4.	Bantwini, 2009	South Africa	T	CPD	Cascading training workshops	ongoing	Survey	88 teachers, 39 schools, 1 district	Questionnaire, interviews, and field notes from classroom observations	Lack of teacher support impacted negatively on implementation of new reforms	PD should be context-based
5.	Baricaua Gutierez, 2016	Philip pines	I, T	Lesson study	PLC	1 year	Qualitative research design	30 teachers	Reflective logs, audio and video-tape recordings, non-structured questions and formal written interviews	Enhanced science content knowledge, improved teaching strategies aligned to inquiry, built collaborative working environment	Lesson study possible PD model for other education systems
6.	Berg & Moore Mensah, 2014	US	T	Coaching	Coaching	1 year	Case study	3 teacher case studies	Transcripts of lessons, teacher meetings, and one-on-one discussions and interviews with teachers	Science coach helped: reconcile tension between spending time on science or other subjects; manage lack of science knowledge and skills; use kit-based curriculum effectively	Providing schools with science coach, who possesses both a science background and expertise in science education, has the potential to be a scalable form of much needed support

7.	Berry, Loughran, Smith, & Lindsay, 2009	Aust (Vic)	O, T	Science teaching and learning - reflection on practice	5 days of workshops over 1 year, online support, 2 school visits (STaL)	1 year	Cases	107 teachers	Teachers author cases studies	Enabled teachers to articulate, share and further develop their knowledge of practice.	Cases enhance quality of science teaching and learning in classrooms and other teacher readers learn through vicarious experiences available through the sharing of the professional knowledge of practice articulated
8.	Bottoms, Ciechanowski, & Hartman, 2015	US	PST	Community of practice	Learning through participation within a community of practice	3 2-week teaching cycles	Descriptive research	19 pre-service teachers in after-school STEM club	Video analysis by PSTs and course artifacts	Participation in iterative cycles contributed to PSTs' confidence in their ability to teach science	Through situated learning and community of practice PSTs come to understand what it means to become a contributing member of a PLC
9.	Buczynski & Hansen, 2010	US	I, T, S	Science content and pedagogical techniques to integrate inquiry-based instruction	Lectures on subject matter, hands-on experiences for teachers as learners, demonstration of inquiry practices	80 hours over 1 year	Qualitative case study	118 teachers, 3450 students, 2 school districts	Pre-professional development focus group, pre/post subject matter exams, teacher surveys, classroom observations, and student achievement scores	Increased science content knowledge and implementation of inquiry practices in classrooms; evidence of student achievement gains; identified barriers to implementation of PL	To maximize the impact of professional development, strategies to mitigate barriers to its implementation need to be a priority in professional development reform.
10	Campbell & Chittleborough, 2014	Aust (Vic)	I, T	Building teacher capacity in teaching science and developing leadership skills to become primary science specialists	15 days of intensive PD (Primary Science Specialists Professional Learning Program), network meetings	1 year	Case study	32 science teacher specialists	Pre and post PD session surveys; focus-group interviews after PD and throughout the year; educator's observations at network meetings; teachers' reports and presentations at network meetings; teacher artefacts.	Data suggested that the formal professional development was only a small part of the external domain that influenced teachers' growth, and that the networking and support among the teachers was a significant influence.	By creating the role of science specialists in primary schools, and investing in science specialists, the subject of Science can be promoted, resources better managed and teachers who are not confident in science, mentored.
11	Cofré et al., 2014	Chile	T	Content knowledge, teacher understanding of NOS	Decontextualized and contextualized NOS activities	6 hours per week for 1 year	Pre-post-test research design	12 teachers	Pre/post NOS test (VNOS), interviews	Most teachers demonstrated enhancement of their NOS understanding. For teachers, the most significant activities for improving NOS understanding were decontextualized activities	Both decontextualized and contextualized NOS activities are effective alternatives to teach NOS

12	Cooper, Kenny, & Fraser, 2012	Aust (Tas)	I, PST	Identify key factors influencing intention of pre-service teachers to use *Primary Connections* to teach science after they graduate	Primary Connections resources	n/a	Pragmatist paradigm, mixed-methods approach	77 pre-service teachers	Online survey and interviews analysed within adapted TPB model framework to elicit how motivations, perceptions and beliefs drive the intentions of individuals	Identified key factors that influenced intentions of pre-service teachers to use *Primary Connections* to teach science after they graduate.	Ethical concerns of promoting particular resources over others in courses, if commercial interests are involved.
13	Cotabish, Dailey, Hughes, & Robinson, 2011 and Cotabish, Dailey, Robinson, & Hughes, 2013	US	I, T, S	Teachers' science process skills	Workshops focused on science content and delivery, specific curriculum units, technological applications, and differentiation of instruction; peer coaching (STEM Starters)	60 hours summer institutes, 60 hours weekly peer coaching over 2 years (120 hours)	Randomized field study	70 teachers from 2 districts	Teachers – Pre and post PD Adapted Fowler Test for assessing science process skills and Perceptual Assessment of Science Teaching and Learning (PASTeL) to assess how teachers perceive their ability to teach, and their students' ability to learn science. Students – pre- post Adapted Fowler Test and pre-post embedded curriculum-based assessments	Improved teacher and student science process skills Teachers - statistically significant gain on the Fowler in science process skills in experimental group. Students - statistically significant gain in science process skills, science concepts, and science-content knowledge in experimental group	Support implementation sustained and targeted teacher professional development focused on improving content-specific science instruction for students.
14	Dalehefte & Rieck, 2014	Germany	O, T	Scientific methods in science instruction	Videos of science classes (SINUS for Primary Schools)	4 years	Video study with control group	13 SINUS and 12 control group teachers (5440 teachers, 870 schools used SINUS)	Video data	Can neither generalize that SINUS instruction differs from regular instruction nor establish a connection between SINUS instruction and student competencies but it is possible to consider scientific methods in science at an early stage in school	More in depth qualitative studies could shed more light on what the use of scientific methods in primary school really means for students' learning
15	Davies, 2010	UK	T, S	Raise pupil attainment in science by developing teachers' skills, knowledge and enthusiasm	Active Learning in Primary Science (ALPS) - centre - based CPD, classroom workshops, in-school consultancy and visits to a hands-on science centre.	6 months	Program evaluation using multi-method approach	40 teachers, 7 schools, 93 students	Documentary evidence, pupil performance data, teacher interviews and observations	Raised questions concerning retrospective evaluation studies relying on perceptions after the event, and the validity of any short-term apparent gains in pupil performance or teacher attitude.	Transmissive elements of formal CPD should be augmented by more informal collaborative school based activities with data collected over a longer period

16	Diamond, Maerten-Rivera, Rohrer, & Lee, 2014	US	I, T, S	Teacher science content knowledge and relationship to student achievement	Teacher workshops, curriculum materials, school site support	1 year	Cluster randomized trial design	223 teachers, 32 experimental and 32 control schools, 1 district	Pre-post science knowledge test, classroom observations	Significant effect on the treatment group teachers' science knowledge test scores and questionnaire responses compared to the control group, but not on the classroom observation ratings. Teachers' scores on the science knowledge test were largest significant teacher-level predictor of student achievement outcomes regardless of participation in the intervention.	This intervention (science curriculum, teacher workshops, and school site support) can be used as an example for curriculum writers and PD providers who wish to improve teacher science content knowledge.
17	Drits-Esser, Gess-Newsome, & Stark, 2016	US	I, T	Provide tools for understanding, accepting and implementing inquiry-based science; enhance teachers' physical science content knowledge	Modelling, lesson adaptations and reflection, inquiry-based kits and training in using these kits - Physical Science Inquiry Academy (PSIA)	88 hours over 2 years (3-day summer institute and 8 1-day sessions during school time)	Longitudinal, mixed-model design	15 teachers from 3 schools	Measures of inquiry practice (RTOP), beliefs about teaching and learning through inquiry (BARSTL), physical science content knowledge (MOSART) classroom observations, interviews	PD impacted teachers' inquiry-based practice, inquiry-based beliefs and physical science content knowledge. Teachers' scores in all three outcome measures rose.	Focus on providing a comprehensive understanding of new strategies; Recognize that belief and practice change take time. Provide materials and supplies, and training in their use. Offer a support structure for same-grade teams. Select schools to participate based on administrative support for science as a subject
18	Falk, 2012	US	T	PCK through formative assessment	Teachers' collaborative analysis of student work	8 3-hour sessions, 1 session per week for 8 weeks	Descriptive case study	11 teachers	Video records of PD sessions, teacher materials, and copies or photos of posters, transparencies, and student work samples	Teachers used and built PCK through their formative assessment practices. Teachers did not show evidence of building new knowledge of instructional strategies	Formative assessment can be a powerful opportunity for teachers to use, integrate, and generate PCK but teachers require additional resources to build knowledge of instructional strategies

19	Fraser, 2010	Scotland	T, S	Science content knowledge, PCK	CPD	ongoing	Descriptive case study, mixed-methods	2 teachers, 40 students	Teachers – pre-post questionnaires, semi-structured interviews and video-stimulated reflective dialogues (VSRD) Students – pre-post questionnaires and focus groups	Capacity of formal CPD to develop science-related content and pedagogical knowledge was constrained by a range of factors within classrooms and schools. Teachers compensate for insecurities in subject knowledge by changing to more secure pedagogies, which lead to negative student attitudes to science.	Develop teachers' capacity to use VSRD within individual schools, and employ internet technology to link groups of teachers or clusters of schools with each other and with 'more expert' others
20	Goodnough, 2016	Canada	I, O, T	Confidence in teaching in STEM subjects and assistance in adopting inquiry-based approaches to teaching and learning	Collaborative action research Teachers in Action (TIA)	2 years	Action research	5 teachers	Teacher interviews and reflections, teacher-created artefacts, and researcher observational notes	Teachers became more confident teachers of science, enhanced their pedagogy, and were able to successfully address some of the contradictions in their activity system.	Activity theory with its focus on the social, collective, and contextual nature of learning offers a comprehensive approach to considering how to design and implement professional learning.
21	Grigg, Kelly, Gamoran, & Borman, 2013	US	I, T	2 PD initiatives on scientific inquiry instruction: Science Immersion and FOSS	Facilitators modeled lessons to teachers assuming the role of students; reflective discussions about implementing the lessons - System-Wide Change (SWC)	3 years	Randomised field trial	96 teachers, 73 schools in 1 school district	Teacher surveys; teacher, principal, and district staff interviews; classroom and professional development observations	Science Immersion and FOSS both resulted in changes in teaching practice but did no expose students to the full cycle of scientific inquiry. Open inquiry (Immersion) seemed to promote the use of evidence, and guided inquiry (FOSS) promoted questioning and connecting evidence to scientific knowledge.	Inquiry approaches may not provide sufficient guidance to students or teachers, and time constraints limit classroom opportunities to complete the cycle of scientific inquiry. Future research should look more closely at differences between open inquiry and guided inquiry curricula and professional development.
22	Hackling, Smith, & Murcia, 2011	Aust (WA)	I, T, S	Building teachers' knowledge, confidence and self-efficacy for managing classroom discourse	Participant action research and design-based research collaboration	4 days over 1 year	Participatory action research and design-based research collaboration	12 teachers	Pre-post questionnaires, lesson videos and interviews	Teachers made significant gains in confidence with science teaching and managing discussions. They also made significant gains in self-efficacy for managing classroom talk and sustaining discussions. Positive impact on students' engagement in whole-class discussions	Further research needed to investigate impact of changes on students' learning outcomes and improve quantity and quality of student-to-student interactions in both whole-class and small group discussions.

23	Harlow, 2014	US	I, T	Physics content with a focus on elementary students' ideas, the nature of science, and learning about how one learns physics	Undergraduate curriculum designed to help practising and prospective elementary teachers develop appropriate physics content (PET)	15 hours over 6 weeks	Qualitative collective case study	5 teachers, 1 district	2 pre and post interviews and videotaped inquiry lessons, pre and post content exams and attitude surveys and artefacts (lesson plans, student work)	Teachers transferred very different things from PET into their teaching practices and only transferred those things they had identified as deficiencies prior to PET	Target-minded learning (knowing what one seeks from a learning context) may increase the likelihood of PD transfer
24	Heller, Daehler, Wong, Shinohara, & Miratrix, 2012	US	T, S	Science content knowledge, PCK	3 different interventions with identical science content: hands-on science investigations; sense-making discussions; and readings but different PCK components: case discussions; looking at student work	24 hours over 14 weeks	Randomized trial	283 teachers (201 intervention and 82 control), 7000 students in 6 states	Pre-post content tests for teachers and students	Significant gains in teachers' and students' scores on selected-response tests of science content knowledge beyond those of controls and effects maintained a year later	Findings suggest investing in professional development that integrates content learning with analysis of student learning rather than advanced content or teacher metacognition alone.
25	Hume, 2012	NZ	I, PST	PCK	Action research, role play and reflection on *Primary Connections* unit	8 2-hour sessions		1 science education teacher as researcher and 11 students in education science course	Participant observation, focus group interview, analysis of documents such as course planning notes and student teachers' reflective journals	Helped student teachers transform the type of knowledge they acquired during course work into the type of knowledge they might need to teach in a primary school context	Simulation allows PSTs to see complexity of science teaching and reflect from both sides of teaching-learning boundary
26	Hume, 2016	NZ	I, T	PCK	Content Representation (CoRe) design – teacher consensus about big ideas for students and identify classroom actions for understanding of big ideas	1 year	Design-based research within case study setting	25 teachers	Surveys, document analysis, videoed teacher workshops, classroom observations, and focus group interviews	Confirmed that collaborative process of CoRe design within a school-based PLC contributed to enhanced teachers' PCK	Research team feel strongly that such experiences and outcomes can be duplicated in other primary schools
27	Johnson & Fargo, 2014	US	I, T, S	Integration of CRP (culturally	TPD (Transformative PD) – immersed participants in study	2 years - summer workshop	Case study	2 schools (1 control), part of 12 school	Criterion referenced assessment (CRT) in science as	TPD supported teachers to transform their practice resulting in a significant impact	Students can learn more, develop deeper conceptual understanding and perform

				relevant pedagogy) and inquiry in science	and discourse of culturally relevant pedagogy and use of problem-based learning (PBL) to design authentic, real-world based learning experiences to support increased student conceptual understanding of science	(2 weeks), academic year release-days (8 total), and monthly grade-level support sessions (20 total).		program, 1 district	measure of student achievement	on traditional state science assessments	significantly better on state standardized assessments through authentic, inquiry-based science learning
28	Karaman & Apaydin, 2012	Turkey	I, T	Teacher NOS	Summer science camp – interactive presentations about NOS, group discussions, communicating with scientists	1 week	Pre-post test survey design	20 teachers	Pre-post test - Student Understanding of Science and Scientific Inquiry (SUSI) scale	Significant difference in pre and post test scores in some NOS aspects	Science summer camps like this might be an alternative pathway for supporting in-service teachers in NOS instruction
29	Kenny & Colvill, 2008	Aust (Tas)	I, T	Inquiry activities	Presentation of resources and hands-on activities	3 half-day workshops	Survey design	10 teacher, 8 schools	Pre-post questionnaire	Teachers valued direct support in the form of curriculum and material resources	Science policies need to be backed up with direct support for teachers
30	Kenny, 2009 and Kenny, 2012	Aust (Tas)	I, O, T, PST	PCK - PST, T and TE collaborate on planning and teaching unit of work	Participant action research – triadic partnership (PST, T, TE)	Plan and conduct 90 minute lesson per week for 6 weeks – program ongoing	Participatory action research	61 teachers in 23 schools	Pre- and post-teaching questionnaires, interviews, emails, phone communications and reflective journals kept by the pre-service teachers	Improved attitudes to and confidence in teaching science for the pre-service teachers and their in-service colleagues	These results indicate triadic partnership approach may be an effective way to support teacher professional learning in science
31	Klieger & Yakobovitch, 2012	Israel	T	Contribution of PD to implementation of science standards and whether seniority together with PD assisted implementation	Lectures, peer learning, analyses of documents and learning materials, experience in constructing test items and standards-based evaluation tasks, and reflection	Teachers reported between 28 and 224 hours of PD	Descriptive, mixed-methods	33 teachers	Questionnaire	PD helped teachers to understand and implement standards in their schools by updating content knowledge and PCK. Seniority in teaching helped in implementation.	In- school support and teacher collaboration are important

32	Koch & Appleton, 2007	Aust (Qld)	I, T	One to one mentoring following PCK workshop	CPD - Mentoring	10 weeks	Case study	2 teachers in 1 school	Case descriptions from pre and post interviews, observations	Despite individual preferences and differences in teaching styles, both case-study teachers experienced professional growth from this mentoring model	Need to tailor PD to individual needs of the teachers
33	Laidlaw, Taylor, & Fletcher, 2009	Aust (NSW)	I, R, T, PST	n/a	Survey to determine how teachers and pre-service teachers perceived the teaching of science and exposure to *Primary Connections* resources	Short term	Mixed-methods survey design	41 teachers, 48 pre-service teachers	Questionnaire, semi-structured interviews	By providing structured and comprehensive lesson plans and lesson sequences that were easy to deliver and adapt, *Primary Connections* materials mitigated issues such as poor resourcing, lack of confidence and conceptual knowledge and limited opportunities for PSTs to observe and teach science	Training DVDs and regional facilitator networks should ensure that all teachers have sufficient training and support to implement the *Primary Connections* program effectively.
34	Lakshmanan, Heath, Perlmutter, & Elder, 2011	US	I, O, T	Inquiry-based science instruction	Online or face-to-face content course, PLCs provided hands-on learning experiences and resource sharing opportunities to enhance classroom practice	PLCs met monthly over a year to review best practices and discuss content and pedagogy	Program evaluation using multi-method approach	79 teachers	Pre-post tests to measure changes in content knowledge, a self-efficacy instrument, an instrument for classroom observations, document review, focus groups, and interviews.	Using a combination of content knowledge courses and professional learning communities over a prolonged period (3 years), this standards-based professional development program was able to positively impact both teacher efficacy and teacher implementation of reformed science teaching in the classroom, and these improvements were sustained for the duration of the program. There was also a positive correlation between the amount of growth in self-efficacy and the extent to which standards-based teaching was implemented.	This study emphasizes the importance of targeting teacher beliefs as well as classroom practice in designing professional development and provides evidence of the benefits gained by sustained professional development over a period of time and of the importance of collaborative forms of professional development

35	Loughland & Nguyen, 2016	Aust (NSW)	I, T, S	Instructional core framework - combined focus on the three areas of content, pedagogy and student learning in an effort to improve student outcomes	Action learning – collaborative planning, teacher mentoring, critical reflective discussion	2 school terms	Exploratory case study	10 teachers, 1 school	Video-taped lesson observations, teacher interviews, field notes and transcripts of the teacher learning sessions	Positive outcomes with reference to the three areas of the instructional core framework: teacher content knowledge, pedagogy and student engagement and motivation and skill outcomes	This research supports the need for designing and delivering professional learning programs that are based on the three areas of the instructional core as well as providing time for collaborative reflection
36	Lowe & Appleton, 2015	Aust (Qld)	I, R, O, T	Implementation of new curriculum and inquiry pedagogy	Participant action research - use of resources and (*Primary Connections* and Curriculum into Classroom) collaborative reflection	PD time span was short term	Nested case studies	6 teachers, 2 schools	Surveys, semi-structured interviews, and field notes	Both case study schools lacked expertise in science professional development, human resources to provide appropriate professional development, and funding to release teachers so they could become familiar with the new curriculum and learn how to implement it in their classrooms. Teachers took the materials (C2C and *Primary Connections*) at face value, unquestioningly accepting the stamp of approval from government authorities	Provide each school with a person with science professional development expertise, who can develop a long-term plan and assist in its implementation, especially in mentoring key teachers
37	Lumpe, Czerniak, Haney, & Beltyukova, 2012	US	I, T, S	Science teacher efficacy	Sessions that focused on inquiry-based instruction, science content knowledge, and science process	100 contact hours – 6 2-week summer sessions and mentoring support over 1 year	Pre-post survey design	450 teachers, 2 districts	Pre-post test of teacher beliefs (STEBI and CBATS), Ohio Proficiency test for student achievement	After 1 year teachers displayed significantly more positive self-efficacy beliefs. Time spent in PD predicted student science achievement	Principles of effective teacher professional development proposed by Desimone (2009) and Loucks-Horsley et al. (2003) could be used as frameworks when designing programs that may impact teacher knowledge, skills, beliefs, and ultimately student learning

38	McKinnon & Lamberts, 2014	Aust (NSW, ACT)	I, T, PST	Self-efficacy beliefs	Hands-on workshops at science centre	Short term - series of 4 workshops	Pre-post test design with 2 further post-tests and mixed methods approach	13 teachers, 8 pre-service teachers	Pre and 3 post self-efficacy measures (STEBI), semi-structured interviews	Enhanced positive science teaching self-efficacy for PSTs in ways beyond teacher training alone. Teachers also reported increased science teaching self-efficacy, but school environment was a major factor in how this increase influenced teaching practice and ultimately effectiveness of the PD.	Science centres, and other informal science education institutions, can produce effective PD opportunities for teachers. Context is important for teacher PD
39	Miller, Curwen, White-smith, & Calfee, 2015	US	I, T, S	PCK	Project SMART – hands-on science experiences from university team, reciprocal peer coaching, collaborative reflection	3 years	Qualitative report	49 teachers, 1,535 students, 1 district	Teacher interviews, classroom observations, surveys, journals, student artifacts, and comments from PD sessions. End-of-year written science content assessment for students	Shifts were evident in: confidence in and knowledge of science content; perceived impact on student learning; collaboration with peers in refining their teaching; perceptions of ''permission'' to teach science	External constraints like high-stakes assessments need to be removed so that primary teachers truly have the ''right'' to teach science and cultivate primary students' scientific thinking, as they were able to do within this project.
40	Mintzes, Marcum, Messerschmidt-Yates, & Mark, 2013	US	I, O, T	Self-efficacy in science teaching	PLCs	Week-long summer institutes and grade level PLCs over 3 years	Mixed research methods, and a non-equivalent control group experimental design	116 teachers (55 experimental, 61 control), 2 districts	Pre and post test of personal self-efficacy and outcome expectancy (TSI); clinical interviews 1 year post project	Teachers with demonstrably low self-efficacy in science teaching grew substantially over a period of 3 years as a result of their participation in a PLC as reflected in significant improvement of TSI scores, and in reported changes in classroom teaching practices and children's behavior.	PLCs offer cost-effective way of engaging teachers in the kind of practice-based, action research that helps build a community of local scholars and enhances teachers understanding of NOS
41	Miyazaki, 2016	Senegal	T	Learner-centred pedagogy	CPD- module based sessions followed by collaborative action research in school (lesson study)	4 hours per month	Multiple case study design	5 teacher case descriptions, 3 schools	Lesson observation and interviews pre immediately post and six weeks after lesson observation	Teachers changed their practices in terms of teaching methods used in the classroom, but the change in pedagogy remained minimal because they understood pedagogy in terms of procedures carried out by teachers rather than as something that engaged pupils in learning.	The recently initiated lesson-study model of training gives a great opportunity for CPD to shift its focus as lesson study compels teachers to reflect upon their teaching practice in a classroom context.

42	Morgan, 2012	Aust (SA)	O, T	Science literacy understanding and teaching and learning	PLC set up in response to survey		Action research	4 teachers in 1 school	Survey of teacher wellbeing and competence in relation to science teaching; school's documents and archives; post-project interviews with the teachers involved	All teachers reported improved levels of satisfaction, which they attributed to collaborative involvement in the project.	The survey used in the project is a tool that could be more widely used in individual schools or hubs to raise awareness of self-efficacy issues
43	Murphy, Smith, Varley, & Razi, 2015	Ireland	I, T	CPD with emphasis on teaching *about* science through inquiry	CPD –workshops, in-school support, Moodle site	18 3-hour workshops over 2 years	Mixed-methods approach	17 teachers, 10 schools	Pre-post questionnaire, post interviews, and reflective journal strategies	Positive impact on teachers' science knowledge and attitudes to teaching and science classroom practice. Aspects of CPD model which teachers perceived to be beneficial at translating inquiry into their classrooms: active, hands-on approaches; collaboration and the duration of the CPD itself.	Need for a more balanced approach between professional development that supports the needs of the individual teacher and that of the system. The results of this study suggest that the model used can lay the fundamentals for effective alternative models of professional development.
44	Nichols, Burgh, & Kennedy, 2017	Aust (Qld)	I, T, S	Community of inquiry (COI) approach to inquiry – based science lessons	2-day workshop on implementing inquiry-based units plus extra day on either COI or collaborative strategic reading	2 years	Longitudinal comparative study with an experimental case-controlled design	18 teachers (8 COI, 10 control), 9 schools, 227 students randomly allocated to COI or control group	Analysis of discourse of videotaped small student groups over 2 years	Learning through a collaborative philosophical inquiry approach to science inquiry improved students' questioning and verbal inquiry behaviours and supported students to transfer and apply these skills across contexts. Provision of inquiry science curriculum resources alone was not sufficient to promote the questioning and other verbal inquiry behaviours predicated by the Australian Science Curriculum.	To implement collaborative philosophical inquiry into science curriculum requires explicit pedagogical-based interventions that support teachers to understand how to teach the content through inquiry and how to engage students in inquiry about science content.
45	Nichols, Gillies, & Kleiss, 2016	Aust (Qld)	I, O, T, S	Self-efficacy and representational practices	Workshop on representational practices and implementation of inquiry science unit	2-day PD and during implementation of unit of work	Before and after convergent mixed methods approach	7 teachers, 3 schools, 122 students	Teacher and student representational and conceptual competency measures, efficacy surveys (STEBI - pre- post PD and post unit) and coding of representational use in the classroom, classroom observations and teacher stimulated recall interviews	Teacher conceptual and representational competencies and confidence to teach science using representations improved. PD was successful in improving students' representational profiles across all classes	Successful elements of PD: teachers learning using inquiry as their students would; a rich source of practical resources; demonstrations and strategies that connect to the curriculum standards; maintaining support for teachers

46	Nilsson & Loughran, 2012	Sweden	PST	PCK	Content Representation (CoRe) lesson preparation, teaching, redo CoRe and reteach	1 semester	Mixed-methods approach	34 pre-service teachers	CoRe pre-test and CoRe post-test, self-assessment, reflection, focus groups	PCK was not a single indicative item—or the same thing for each teacher—but a holistic concept containing (at least) the elements articulated in the CoRe model, which offered a way of assisting student teachers to better understand their ongoing professional learning	Results demonstrate how the CoRe methodology creates real possibilities for understanding PCK development in pre-service teaching in new ways. It has real implications for teacher preparation programs.
47	Nilsson, 2013	Sweden	PST	PCK	Formative assessment – CoRe – videotaped lessons reflected on in group stimulated recall sessions provided formative feedback and lessons repeated	1 semester	Action research	24 pre-service teachers	Analysis of the formative interactions between the student teachers and the teacher educators	Formative interactions together with the CoRe as a tool for problematizing aspects of student teachers' (developing) PCK influenced the way that these student teachers approached their professional learning of teaching science	Need to systematically unpack science teaching AND learning from the point of view of student teachers' needs and concerns
48	Paige, Zeegers, Lloyd, & Roetman, 2016	Aust (SA)	I, T	PCK, action research	Action research, citizen science, interactive workshop modeling pedagogically challenging and engaging practical experiences could be adapted and applied by teachers in their classrooms, action research on aspects of pedagogy, team meetings, mentoring	2 years	Case study	3 teachers	Semi-structured interviews	Teachers in action research-based PL program reported increased confidence to plan and teach units of work that moved away from textbook-orientated approaches to science. PD program's strengths: catered for student interest, meaningful context, topic of local relevance; varied strategies, student agency; teacher PD school-based.	Greater emphasis needed on how to address student-lead inquiry-based investigations in science and give greater prominence to developing teachers' practices in collecting evidence for assessing the science learning of their students
49	Palmer, 11	Aust (NSW)	I,T	Self-efficacy	Workshop, observation (in situ modeling by PSTs), teaching observed by researcher with in situ feedback; inquiry approach	8 weeks	Pre-experimental design - pretest, intervention, immediate posttest, and delayed posttest	12 teachers	Interviews and STEBI prior to, during, after, and two years after the program	Cognitive mastery was most important source of self-efficacy and it was experienced in workshop, observation and teaching phases. In situ feedback also identified as highly effective. Changes in self-efficacy durable for at least 2 years.	Future studies should look at relative impacts of the four sources of self-efficacy and target those with most impact.

50	Roth et al., 2011	US	T, S	Science Teachers Learning from Lesson Analysis (STeLLA) Science content, storyline lens and student thinking lens	Video-based analysis-of-practice	Both groups – 44 hours over 3-week summer session, STeLLA group only - further 58 hours on analysis-of practice activities with a total time of 102 hours in the STeLLA PD program over 1 year	Quasi-experimental design	48 teachers (32 STeLLA, 16 content-only), 1460 students	Teachers - Science content test and lesson video analysis task at three time points: pre-program, mid-program (end of summer institute), and post-program, videotaped lessons of STeLLA teachers Students-written science content test before and after PD	STeLLA PD: improved science content learning for students; provided empirical evidence that teachers can develop meaningful content understandings through analysis-of-practice activities and that learning the science content in isolation of analysis-of-practice work did not support long-term teacher content learning gains; helped teachers become more analytic about science teaching in terms of student thinking and science content issues; helped teachers make significant improvements in science teaching practice in terms of attention to both the science content storyline and student thinking	A carefully designed and implemented one-year science PD program can build elementary teachers' science content knowledge and their pedagogical content knowledge and enhance students' science learning
51	Sandholtz & Ringstaff, 2014	US	I, R, T	Increasing teachers' content knowledge and fostering the use of research-based instructional strategies in science	Intensive adult-level science content instruction; pedagogical training focused on science instruction and how to connect science to language arts and mathematics; training and support to facilitate teacher collaboration	3 years	Mixed-methods design	39 teachers, 16 small rural districts	Self-efficacy assessment (STEBI), teacher survey, interviews, classroom observations	Teachers' overall self-efficacy, personal science teaching efficacy, and outcomes efficacy showed significant gains from pre-program to end-of-program and corresponded with changes in their instructional practice in science from teacher-centred to student-centred but not highly correlated with increased time teaching science	Demonstrates the value of building teachers' confidence and preparedness to teach science in the early elementary grades. Teachers with higher self-efficacy in science are more likely to shift to student-centred pedagogy.
52	Sandholtz & Ringstaff, 2016	US	R, T	Long-term sustainability of professional development outcomes	See above	See above	Case study	See above	Surveys and interviews conducted 2 and 3 years after the end of the professional development program	Contextual factors varied across schools and influenced the sustainability of science instruction after the professional development ended. Administrative (Principal) and collegial supports are particularly important	Ongoing yet modest support for teachers may help maximize the longevity of professional development outcomes in science

53	Shymansky, Wang, Annetta, Yore, & Everett, 2012	US	I, R, T, S	Science concepts, inquiry teaching strategies, and how to adapt science inquiry lessons to teach and reinforce skills in the language arts	ASIL (adapting science inquiry lessons) PD strategy, summer workshops, distance delivery technologies, local leadership team support during the school year	5 years	Quasi-experimental design	1269 teachers, 33 districts	Hours spent on PD, high stakes student science test scores	Significant positive relationship between teacher PD hours and student gains on high stakes test scores. Lower grade teachers may need less PD than upper grade teachers on instructional strategies where focus is on integration of language arts and science inquiry.	Connecting PD to learning as measured by high stakes tests is important for any PD program so that subsequent applications of the strategy can be implemented efficiently and cost effectively.
54	Shymansky, Wang, Annetta, Yore, & Everett, 2013	US	I, O, R, S	See above	See above	5 years	Quasi-experimental design	33 ASIL PD school districts and 20 comparison school districts	Education system test data	High stakes scores across all students in the ASIL strategy schools were significantly higher than those in the comparative schools.	An inquiry adaptation strategy and a combination of regional live workshop and distance delivery technologies with ongoing local leadership and support can serve as a viable PD option for K-6 science
55	Sinclair, Naizer, & Ledbetter, 2011	US	I, R, T	Science content, teacher self-efficacy, classroom teaching performance	Intensive summer institute, 8 monthly follow-up sessions, informal participant-professor mentoring and peer networking	1 year	Pre-post test design with mixed-methods approach	17 teachers in rural districts	Pre- and post-science content knowledge, science teaching self-efficacy (STEBI), classroom teaching performance and informal interviews	Teacher comments and their pre-post test scores revealed the project had a positive impact on their knowledge about science teaching pedagogy as well as their perception of their level of content knowledge.	Need follow-up to investigate lasting effects of PD
56	Smith, K. & Lindsay, 2016	Aust (Vic)	T	Action research to enhance teaching and learning science	Science Teaching and Learning (STaL) and Contemporary Approaches to Primary Science (CAPS) - active learners undertaking critical reflection in relation to their science teaching practice	Both – 1 year duration, 5-day intensive, residential program, STaL - last day case writing CAPS – action	Program evaluation using multi-method approach	STaL – 226 teachers (primary and secondary) CAPS - 55 primary teachers, at least 3 per school	STaL – teacher cases CAPS – pre and post self-evaluation of personal learning, science teaching and student learning	Purposeful, teacher-centred in-service PL that supported them to articulate and share the professional knowledge they have about effective science teaching practice significantly contributed to enabling teachers to think differently about science teaching and learning and become confident pedagogical leaders in science.	Science teachers at all levels benefit from working in partnership, as collaborative researchers, with academics, where they can explore and develop their pedagogical reasoning to explicate expert practice

						research, examines cross curriculum and whole school approaches to planning and teaching					
57	Smith, G., 2014 and Smith, G., 2015	Ireland	I, R, T, S	Teachers' attitudes towards primary science, their confidence and competence in teaching science, and pupils' attitudes towards school science	Ongoing and gives teachers opportunities to collaborate with their colleagues, sharing practices and knowledge, to reflect on their pedagogic practice, to focus on pupil learning and to be involved in decision-making	12 3-hour workshops, ongoing support through Moodle site and school visits over 2 years	Pre-post test design with mixed-methods approach	24 teachers, 15 schools, 281 students	Pre-post PD teacher questionnaires; post-PD teacher interviews; pre-post PD assessment of teachers' understanding of key science concepts; monitoring project development – informal classroom-based observations and reflection sheets	Teachers' instructional practice in science lessons became more inquiry-based and they were engaging their pupils in substantially more hands-on activities in science lessons. All teachers indicated it was their involvement in the PD that brought about changes in their classroom practice and aspects that promoted these changes were content, active participation, collaboration and duration of the PD. Student questionnaire and interview data indicated a positive shift in attitudes to science.	A targeted inquiry-based PD program can have a positive impact on pupils' interest in school science
58	Smith, P. & Hackling, 2016	Aust (WA)	I, T	Action research to develop teachers' capacity to manage discourse in science lessons	Collaborative action research - two cycles of design, enactment, analysis and reflection, and redesign of units including *Primary Connections* units	4 days over 6 months	Participatory action research and design-based research collaboration	3 teacher case studies	Pre- and post-intervention teacher interviews; audio recordings of teacher plenary discussions; lesson observations, field notes, video recordings, and follow-up teacher interviews for five science lessons	Teachers were able to successfully develop their capacity to scaffold productive discourse in their primary science classrooms	The strong and positive impact of viewing one's own practice and sharing practice through the medium of video observed in this study suggests that the use of video should be used more widely in professional learning programs
59	Sullivan-Watts, Nowicki, Shim, & Young, 2013	US	I, T, PST	Influence of a professional development program based	Inquiry teaching through commercially available inquiry science curricula	2 years - science methods course year, and student	Mixed-methods approach	27 pre-service teachers and their 27 cooperating teachers	81 science lessons videotaped in the classroom, as well as various measures of the science content knowledge and preparation of the student teachers and their mentors,	Students assigned to inquiry-based classrooms during their methods course or student teaching year outperformed students without this experience; significant positive	Results support the utility of nationally-developed, commercially available kits used as a foundation for sustained professional development in the process of

				around commercially available inquiry science curricula on the teaching practices		teaching year			and their responses to an oral interview quantitative rubric used to score inquiry elements and use of data in videotaped lesson	effect of multi-year access to the kit-based program on mentor teaching practice	training both pre-service and in-service teachers in inquiry pedagogy
60	Townsend, McKinnon, Fitzgerald, Morris, & Lummis, 2016	Aust (WA, Vic)	I, R, O, T, S	Develops PCK by using approach of CoREs (Content Representations) and PaP-eRs (Pedagogical and Professional-experience Repertoires	Educative curricula, face-to-face sessions, online support and mentoring and direct coaching during school visits initial intense face-to-face professional development session followed by longer term IT-mediated support	1 term	Multiple-case, embedded mixed-methods longitudinal design	15 teachers, 8 schools	Documentary; archival records; interviews of participants; direct observations; physical artefacts; student tests	Educative curriculum improved teachers' science PCK for most teachers. Improved student science learning outcomes.	PCK development takes time and requires a planned and systematic approach with support from employer. Using educative curricula to improve the PCK of rural and remote science teachers, as well as science student learning outcomes, is a strategy worthy of pursuit.
61	Tytler, 2009	Aust (Vic)	O, T	Action planning by schools (SIS)	PD is fundamentally determined and driven by the action planning process that schools undertake	4 years	Program evaluation using multi-method approach	200 schools	A variety of analyses including school reports, field notes of network and consultant meetings, coordinator interviews and questionnaire data	A greater profile for science in the school and the local community; a more coherent and thorough representation of science in the curriculum; increased resources and access to resources; Improved attitudes, particularly confidence, concerning science teaching; evidence of changes to approach in teaching science, particularly towards more hands on, and exploratory approaches	To effect a change in practice we need to consider a range of factors: teacher beliefs concerning the purposes of science education; their pedagogical knowledge and beliefs; broader principles of schooling and community; the operation of science within the wider school; students' lives in relation to contemporary science and its societal and technological links; their lives and perspectives more generally
62	van Aalderen-Smeets & Walma van der Molen, 2015	The Netherlands	I, T	Professional and personal attitudes to science; PCK	Interactive workshops about attitude towards science, scientific attitudes, and inquiry; follow-up assignments;	18 hours of workshops; 35-40 hours of assignmen	Experimental pretest-posttest control group study	61 teachers from 18 schools and 45 control teachers	Pre-post attitudes to science questionnaire (DAS)	Explicitly focusing on teachers' attitude in professional development improved teachers' feeling of being in control over science teaching and their science related behaviour.	Future research is necessary to investigate the contribution of attitude-focused professional development to actual science teaching behavior in the classroom and to changes in

					collaborative reflection	ts over 6 months					teachers' and pupils' scientific attitudes
63	Walan & Mc Ewen, 2016	Swed en	I, T	IC-BaSE (Inquiry- and context- based education) using PROFILES (Professiona l Reflection-Oriented Focus on Inquiry-based Learning and Education through Science) model	CPD - teachers were invited to reflect on IC-BaSE and construct their own teaching modules. These were tested in the teachers' classes during the CPD program.	40 hours over 5 months	Action research	12 teachers	Transcripts of group discussions, teacher portfolios, field notes	Teachers gained new insights about inquiry-based teaching as many had only used inquiry kits before	Teachers and teacher educators can use IC-BaSE as one way to contribute to development of science teaching in primary schools.
64	Watters & Diezmann , 2007	Aust (Qld)	I, T, PST	Inquiry-based practices	Educative curriculum materials		Evaluation	12 pre-service teachers, teachers, 4 tutors	Focus groups, surveys	Multimedia resources provided a window into classrooms in an environment supportive of discussion, debate and reflection	Multimedia resources appear to be a promising approach to complement pre-service elementary science teachers' experiences of teaching and learning
65	Zeegers, Paige, Lloyd, & Roetman, 2012	Aust (SA)	I, T	Develop inquiry based approach	Plan and implement unit based an students collecting real data	Workshop s and 3 2-hour focus groups over 2 school terms	Descriptive case study	13 teachers	Students' work samples, teachers' plans and focus group meeting transcripts	Regular and negotiated support assisted teachers to develop their pedagogical practice; some teachers did not recognise the integral nature of language to school science	By connecting teachers through targeted, sequenced, professional learning activities in which they plan, teach, share and evaluate a unit that involves children interacting with nature, a positive step can be taken in addressing teachers' confidence and pedagogical content knowledge in science

References

Alake-Tuenter, E., Biemans, H. J., Tobi, H., Wals, A. E., Oosterheert, I., & Mulder, M. (2012). Inquiry-based science education competencies of primary school teachers: A literature study and critical review of the American National Science Education Standards. *International Journal of Science Education, 34*(17), 2609-2640.

Albion, P. R., & Spence, K. G. (2013). "*Primary Connections*" in a Provincial Queensland School System: Relationships to Science Teaching Self-Efficacy and Practices. *International Journal of Environmental and Science Education, 8*(3), 501-520.

Arias, A. M., Bismack, A. S., Davis, E. A., & Palincsar, A. S. (2016). Interacting with a suite of educative features: Elementary science teachers' use of educative curriculum materials. *Journal of Research in Science Teaching, 53*(3), 422-449.

Aubusson, P., Griffin, J., & Palmer, T.-A. (2015). Primary Teachers' Professional Learning Preferences in Science and Technology. *International Journal of Teaching and Education, 3*(3), 35-49.

Aubusson, P., Schuck, S., Ng, W., Burke, P., & Pressick-Kilborn, K. (2015). Quality learning and teaching in primary science and technology literature review (2nd ed.). Sydney: Association of Independent Schools New South Wales.

Australian Curriculum Assessment and Reporting Authority (ACARA). (2015). Australian Curriculum: science. Retrieved from http://www.australiancurriculum.edu.au/science/

Australian Science Teachers Association, (2014). *Primary School Science Teaching Survey Report June 2014*. Retrieved from: http://asta.edu.au/programs/assist/primary_science_teaching_survey

Baricaua Gutierez, S. (2016). Building a classroom-based professional learning community through lesson study: insights from elementary school science teachers. *Professional Development in Education, 42*(5), 801-817.

Berry, A., Loughran, J., Smith, K., & Lindsay, S. (2009). Capturing and Enhancing Science Teachers' Professional Knowledge. *Research in Science Education, 39*(4), 575-594.

Bertram, A., & Loughran, J. (2012). Science teachers' views on CoRes and PaP-eRs as a framework for articulating and developing pedagogical content knowledge. *Research in Science Education, 42*(6), 1027-1047.

Borko, H. (2004). Professional development and teacher learning: Mapping the terrain. *Educational Researcher, 33*(8), 3-15.

Borko, H., Jacobs, J., & Koellner, K. (2010). Contemporary approaches to teacher professional development. In E. Baker, B. McGaw, & P. Peterson (Eds.), *International Encyclopedia of Education (part 7, pp. 548–555, 3rd ed.)*. Oxford: Elsevier.

Broadley, T. (2010). Digital revolution or digital divide: Will rural teachers get a piece of the professional development pie? *Education in Rural Australia, 20*(2), 63.

Buczynski, S., & Hansen, C. B. (2010). Impact of professional development on teacher practice: Uncovering connections. *Teaching and teacher education, 26*(3), 599-607.

Bybee, R. (2014). The BSCS 5E instructional model: Personal reflections and contemporary implications. *Science and Children, 51*(8), 10-13.

Campbell, C., & Chittleborough, G. (2014). The 'new' science specialists : promoting and improving the teaching of science in primary schools. *Teaching Science, 60*(1), 19-29.

Capps, D. K., & Crawford, B. A. (2013). Inquiry-Based Professional Development: What does it take to support teachers in learning about inquiry and nature of science? *International Journal of Science Education, 35*(12), 1947-1978.

Cooper, G., Kenny, J., & Fraser, S. (2012). Influencing Intended Teaching Practice: Exploring pre-service teachers' perceptions of science teaching resources. *International Journal of Science Education, 34*(12), 1883-1908.

Cordingley, P., & Bell, M. (2012). Understanding what enables high quality professional learning: A report on the research evidence. *CUREE and Pearson School Improvement*.

Cotabish, A., Dailey, D., Hughes, G. D., & Robinson, A. (2011). The Effects of a STEM Professional Development Intervention on Elementary Teachers' Science Process Skills. *Research in the Schools, 18*(2), 16-25.

Cotabish, A., Dailey, D., Robinson, A., & Hughes, G. (2013). The Effects of a STEM Intervention on Elementary Students' Science Knowledge and Skills. *School Science & Mathematics, 113*(5), 215-226.

Dash, S., Magidin de Kramer, R., O'Dwyer, L. M., Masters, J., & Russell, M. (2012). Impact of online professional development or teacher quality and student achievement in fifth grade mathematics. *Journal of Research on Technology in Education, 45*(1), 1-26.

Department for Education. (2014). National curriculum in England: science programmes of study. Retrieved from https://www.gov.uk/government/publications/national-curriculum-in-england-science-programmes-of-study

Desimone, L. M. (2009). Improving impact studies of teachers' professional development: Toward better conceptualizations and measures. *Educational Researcher, 38*(3), 181-199.

Diamond, B. S., Maerten-Rivera, J., Rohrer, R. E., & Lee, O. (2014). Effectiveness of a Curricular and Professional Development Intervention at Improving ElementaryTeachers' Science Content Knowledge and Student Achievement Outcomes: Year 1 Results. *Journal of Research in Science Teaching, 51*(5), 635-658.

Dickersin, K., & Min, Y. (1993a). NIH clinical trials and publication bias. *The Online journal of current clinical trials*, [4967 words; 4953 paragraphs]-[4967 words; 4953 paragraphs].

Dickersin, K., & Min, Y. (1993b). NIH clinical trials and publication bias. *Online Journal of Cururrent Clinical Trials, Doc No: 50*.

Drits-Esser, D., Gess-Newsome, J., & Stark, L. A. (2016). Examining the sustainability of teacher learning following a year-long science professional development programme for inservice primary school teachers. *Professional Development in Education*, 1-22.

Dwan, K., Gamble, C., Williamson, P. R., & Kirkham, J. J. (2013). Systematic review of the empirical evidence of study publication bias and outcome reporting bias—an updated review. *PloS one, 8*(7), e66844.

Falk, A. (2012). Teachers learning from professional development in elementary science: Reciprocal relations between formative assessment and pedagogical content knowledge. *Science education, 96*(2), 265-290.

Fishman, B., Konstantopoulos, S., Kubitskey, B. W., Vath, R., Park, G., Johnson, H., & Edelson, D. C. (2013). Comparing the Impact of Online and Face-to-Face Professional Development in the Context of Curriculum Implementation. *Journal of Teacher Education, 64*(5), 426-438.

Goodrum, D., Hackling, M., & Rennie, L. (2001). The status and quality of teaching and learning of science in Australian schools: A research report. Retrieved from Canberra:

Hackling, M., Peers, S., & Prain, V. (2007). *Primary Connections*: Reforming science teaching in Australian primary schools. *Teaching Science, 53*(3), 12-16.

Herbert, S., Campbell, C., & Loong, E. (2016). Online professional learning for rural teachers of mathematics and science. *Australasian Journal of Educational Technology, 32*(2), 99-114.

Hume, A. (2012). *Primary Connections*: Simulating the Classroom in Initial Teacher Education. *Research in Science Education, 42*(3), 551-565.

Hume, A. (2016). The CoRe of the matter: Developing primary teachers' professional knowlegde in science. *Teaching Science, 62*(4), 43-55.

Kenny, J. (2009). A partnership based approach to professional learning: Pre-service and in-service teachers working together to teach primary science. *Australian Journal of Teacher Education (Online), 34*(6), 1.

Kenny, J. (2012). University-school partnerships: pre-service and in-service teachers working together to teach primary science. *Australian Journal of Teacher Education, 37*(3), 57-82.

Kenny, J., & Colvill, M. (2008). Primary science: Professional learning and curriculum development in Northern Tasmania. *Teaching Science: The Journal of the Australian Science Teachers Association, 54*(1), 35-38.

Klieger, A., & Yakobovitch, A. (2012). Contribution of professional development to standards implementation. *Teacher Development, 16*(1), 77-88.

Knapp, M. S. (2003). Chapter 4: Professional Development as a Policy Pathway. *Review of research in education, 27*(1), 109-157.

Laidlaw, K.-R., Taylor, N., & Fletcher, P. (2009). Teaching Primary Science in Rural and Regional Australia: Some Challenges Facing Practicing and Pre-service Teachers. *Journal of Science & Mathematics Education in Southeast Asia, 32*(2), 105-130.

Lakshmanan, A., Heath, B. P., Perlmutter, A., & Elder, M. (2011). The Impact of Science Content and Professional Learning Communities on Science Teaching Efficacy and Standards-Based Instruction. *Journal of Research in Science Teaching, 48*(5), 534-551.

Loucks-Horsley, S., Stiles, K., Mundry, S., & Love, N. (2010). *Designing Professional Development for Teachers of Science and Mathematics* Retrieved from http://sk.sagepub.com/books/designing-professional-development-for-teachers-of-science-and-mathematics-3e

Loughland, T., & Nguyen, H. T. M. (2016). Using the instructional core to implement a professional learning programme for primary science teachers in Australia: teacher learning and student skill outcomes. *Teacher Development, 20*(4), 498-520.

Lowe, B., & Appleton, K. (2015). Surviving the implementation of a new science curriculum. *Research in Science Education, 45*(6), 841-866.

Luft, J. A., & Hewson, P. W. (2014). Research on teacher professional development programs in science. *Handbook of research on science education, 2*, 889-909.

Lyons, T., & Quinn, F. (2010). Choosing Science: Understanding the declines in senior high school science enrolments.

McConnell, T. J., Parker, J. M., Eberhardt, J., Koehler, M. J., & Lundeberg, M. A. (2013). Virtual Professional Learning Communities: Teachers' Perceptions of Virtual Versus Face-to-Face Professional Development. *Journal of Science Education and Technology, 22*(3), 267-277.

Mintzes, J. J., Marcum, B., Messerschmidt-Yates, C., & Mark, A. (2013). Enhancing self-efficacy in elementary science teaching with professional learning communities. *Journal of Science Teacher Education, 24*(7), 1201-1218.

Miyazaki, T. (2016). Is changing teaching practice the mission impossible? A case study of continuing professional development for primary school teachers in Senegal. *Compare-a Journal of Comparative and International Education, 46*(5), 701-722.

Murphy, C., Neil, P., & Beggs, J. (2007). Primary science teacher confidence revisited: Ten years on. *Educational Research, 49*(4), 415-430.

Nichols, K., Gillies, R., & Kleiss, D. (2016). A professional learning model that cultivates primary science classrooms' representational profiles. *International Journal of Educational Research, 76*, 12-33.

Nilsson, P. (2013). What do we know and where do we go? Formative assessment in developing student teachers' professional learning of teaching science. *Teachers and Teaching, 19*(2), 188-201.

OECD. (2009). Creating effective teaching and learning environments: First results from TALIS: OECD Publishing.

Office of the Chief Scientist. (2012). *Health of Australian Science*. Canberra Retrieved from http://www.chiefscientist.gov.au/wp-content/uploads/Report-for-web.pdf.

Osborne, J., Simon, S., & Collins, S. (2003). Attitudes towards science: a review of the literature and its implications. *International Journal of Science Education, 25*(9), 1049-1079.

Palmer, D. (2011). Sources of efficacy information in an inservice program for elementary teachers. *Science education, 95*(4), 577-600.

Rivkin, S. G., Hanushek, E. A., & Kain, J. F. (2005). Teachers, schools, and academic achievement. *Econometrica, 73*(2), 417-458.

Roth, K. J., Garnier, H. E., Chen, C., Lemmens, M., Schwille, K., & Wickler, N. I. Z. (2011). Videobased Lesson Analysis: Effective Science PD for Teacher and Student Learning. *Journal of Research in Science Teaching, 48*(2), 117-148.

Rowe, K. (2003). *The importance of teacher quality as a key determinant of students' experiences and outcomes of schooling* Retrieved from http://research.acer.edu.au/research_conference_2003/3

Sandholtz, J. H., & Ringstaff, C. (2014). Inspiring Instructional Change in Elementary School Science: The Relationship Between Enhanced Self-efficacy and Teacher Practices. *Journal of Science Teacher Education, 25*(6), 729-751.

Sandholtz, J. H., & Ringstaff, C. (2016). The Influence of Contextual Factors on the Sustainability of Professional Development Outcomes. *Journal of Science Teacher Education, 27*(2), 205-226.

Shulman, L. S. (1987). Knowledge and teaching: Foundations of the new reform. *Harvard Educational Review, 57*(1), 1-23.

Shymansky, J. A., Wang, T.-L., Annetta, L. A., Yore, L. D., & Everett, S. A. (2012). How much professional development is needed to effect positive gains in K-6 student achievement on high stakes science tests? *International Journal of Science and Mathematics Education, 10*(1), 1-19.

Shymansky, J. A., Wang, T.-L., Annetta, L. A., Yore, L. D., & Everett, S. A. (2013). The Impact of a Multi-Year, Multi-School District K-6 Professional Development Programme Designed to Integrate Science Inquiry and Language Arts on Students' High-Stakes Test Scores. *International Journal of Science Education, 35*(6), 956-979.

Smith, G. (2014). An innovative model of professional development to enhance the teaching and learning of primary science in Irish schools. *Professional Development in Education, 40*(3), 467-487.

Smith, G. (2015). The Impact of a Professional Development Programme on Primary Teachers' Classroom Practice and Pupils' Attitudes to Science. *Research in Science Education, 45*(2), 215-239.

Smith, K., & Lindsay, S. (2016). Building Future Directions for Teacher Learning in Science Education. *Research in Science Education, 46*(2), 243-261.

Smith, P., & Hackling, M. (2016). Supporting teachers to develop substantive discourse in primary science classrooms. *Australian Journal of Teacher Education, 41*(4), 10.

Smith, P. M., & Hackling, M. W. (2016). Supporting teachers to develop substantive discourse in primary science classrooms. *Australian Journal of Teacher Education, 41*(4), 10.

Sullivan-Watts, B., Nowicki, B., Shim, M., & Young, B. (2013). Sustaining Reform-Based Science Teaching of Preservice and Inservice Elementary School Teachers. *Journal of Science Teacher Education, 24*(5), 879-905.

Timperley, H. (2011). A background paper to inform the development of a national professional development framework for teachers and school leaders. *Australian Institute for Teaching and School Leadership (AITSL)*, 1-26.

Townsend, A., McKinnon, D. H., Fitzgerald, M. T., Morris, J., & Lummis, G. (2016). Educative Curricula and PCK development driven by STEM professional learning in rural and remote schools: A longitudinal Type IV case study. *International Journal of Innovation in Science and Mathematics Education (formerly CAL-laborate International), 24*(4).

Tytler, R. (2003). A Window for a Purpose: Developing a Framework for Describing Effective Science Teaching and Learning. *Research in Science Education, 33*(3), 273-298.

Tytler, R., Osborne, J., Williams, G., Tytler, K., & Clark, J. C. (2008). *Opening up pathways: Engagement in STEM across the Primary-Secondary school transition*. Retrieved from

van Aalderen-Smeets, S. I., Walma van der Molen, J. H., & Asma, L. J. F. (2012). Primary teachers' attitudes toward science: A new theoretical framework. *Science education, 96*(1), 158-182.

Zeegers, Y., Paige, K., Lloyd, D., & Roetman, P. (2012). 'Operation Magpie': Inspiring Teachers' Professional Learning Through Environmental Science. *Australian Journal of Environmental Education, 28*(1), 27-41.

APPENDIX 4: FOCUS GROUPS REPORT: AN OVERVIEW

Introduction

This research and evaluation project relates to the implementation of Stage 6 workshops associated with the implementation of *Primary Connections: Linking Science with Literacy* in Australian primary schools. In particular, Stage 6 refers to the 2015-2018 introductory *Primary Connections* workshops targeting pre-service and in-service teachers in regional, rural and remote settings.

As part of this evaluation, data collection involved interviewing focus groups of pre- and in-service teachers from regional areas (rural and isolated) who attended *Primary Connections* workshops in 2017.

This report provides an analytical summary of the findings from six focus groups.

Structure of the Focus Groups Report

The report includes the following sections:

Purpose: Outlines the Research Questions (RQs) that were the focus of the interviews

Procedure: Describes the methods used in collecting and analysing the focus group data

Sample: Summarises the number of interviewees and their background (general, science and familiarity with *Primary Connections*)

Findings: Presents focus group responses related to the each of the RQs. In relation to each RQ a general statement about the findings is provided, followed by detailed evidence from the responses that relate to that RQ.

- In-service teacher responses are usually separated from pre-service responses; if not it will be apparent from the textual context. To amalgamate these responses would be a significant loss of data.
- To indicate the extent to which ideas were held, the number of responses that related to a particular idea (or ideas) is shown using the letter 'R'. Hence, for example, FG 4, 3R means that there were three responses from Focus Group 4 that mentioned a particular idea (or ideas).

(The number of responses does not necessarily equate to the number of teachers who commented, although it would be a reasonable indication).

COMMENT ON REPORTING STYLE

It was decided to include considerable detail from each of the focus group responses (avoiding, where possible, repetition). This was for two main reasons:

- the response data are rich in ideas related to the RQs; and
- it was considered that readers of this report, especially those involved in planning and presenting the Stage 6 workshops, would derive many insights from the teachers' responses.

To avoid use of 'her/his' (as gender was usually not known) the plural was substituted (i.e., 'their' etc.). Double inverted commas are direct quotations from interviewees.

Purpose

The focus groups were one of the data collection methods used to ascertain teachers' pre-service and in-service teachers' perceptions about *Primary Connections* in relation to the following RQs:

Efficiency RQ 2.4 Is training in-service teachers and pre-service teachers in Primary Connections the most efficient way to increase the effective implementation of the program?

Efficiency RQ 2.5 Are there any unintended benefits or disadvantages in providing training in particular ways for in-service teachers and pre-service teachers?

Effectiveness RQ 3.2 To what extent has Stage 6 met the aims and objectives as set out in the funding agreement?

Effectiveness RQ 3.3 What else can the Primary Connections program offer to assist teachers and pre-service teachers to implement the Australian science curriculum?

Procedure

Various members of the *Primary Connections* research and evaluation team led focus group discussions with in-service and pre-service teachers. The focus group interviews immediately followed a Stage 6 *Primary Connections* workshop. The questions used in the interviews are in Appendix 4A and Appendix 4B and are directly related to the above four RQs.

Steps in developing this analytical report

1. Interviews were recorded. Interviewers then prepared summary reports of their focus group (5 to 7 pages). These consisted of a short summary of the overall impression of the focus group interview followed by brief headings and direct quotes from the interviewees. Interviewers often included a summary statement covering a section of the interview.
2. These interview summaries were read and analysed by a member of the research team who had not conducted a focus group. This measure was taken to ensure that no bias towards a specific focus group influenced this report. A content analysis revealed a series of responses that could be coded. Various categories resulted, some of which were guided by the interview questions. In general, these derived categories were identical across in-service and pre-service teachers. This process resulted in an integration of responses; however, as indicated above, responses from each group have been kept separate.
3. The derived categories (from [2]) were then related to the four RQs. Alignment of some of the categories with a particular RQ overlap. This is sometimes mentioned in this report.

Sample

Thirty-seven teachers were interviewed in six focus groups. Interview details are listed (location, date, length of interviews) as is the background of the teachers (e.g. years teaching, secondary science background – where these were available) in the tables below. The interviewees' familiarity with *Primary Connections* is included – virtually all had knowledge of *Primary Connections* and several had taught from *Primary Connections* or were still doing so.

In-service Teachers

Eighteen in-service teachers were interviewed in three focus groups. The characteristics of the three groups are shown in Table 5.

TABLE 5. CHARACTERISTICS OF THE IN-SERVICE TEACHERS' FOCUS GROUPS

Focus Group (FG)	Number in focus group	Time and length of interview	Teaching experience	Familiarity with Primary Connections
FG 4: Mackay (Queensland)	6 (All female)	Immediately following a Qld *Primary Connections* workshop 42 minutes	Not known All live in a regional city; one teaches at an independent school.	All were using *Primary Connections*; one had attended a previous *Primary Connections* professional learning event.
FG 5: South Australia Regional areas	7 (4 females,3 males)	Immediately following a South Australian *Primary Connections* workshop 40 minutes	1-5 years (2; Non-instructional teacher (NIT) and teaching Years 3-7 science specialist); 10-20 years (3; two teach across years 3-7 and 4-5; the other NIT and teaches science R-12); 30+ years (2; principal – secondary science background, not teaching science; Special Needs teaching Years 8-12 with students at R-2 levels).	Five had encountered *Primary Connections*. Two had not (Special Needs; (NIT) (1 year)).
FG 6: NSW regional areas (e.g. Bourke, Brewarrina, Quirindi, Cowra)	5 (4 females, 1 male) [few as many had a distance to travel]	At conclusion of *Primary Connections* workshop [50 attendees] (October); 34 minutes	1-5 years (2); 10-20 years (1 – had been an itinerant, relief from face-to-face, or learning support teacher; this year a K-6 teacher); 20-30 years (2; both distance education- one K-year 1, the other Year 6).	All knew about *Primary Connections*; 4 had taught *Primary Connections* units. The 5th (1 year's experience) studied *Primary Connections* at university (including teaching *Primary Connections* for a day at school and brief contact during professional experience).

Familiarity with Primary Connections: A snapshot

One of the focus groups provided an interesting picture of how in-service teachers expressed their familiarity with *Primary Connections* (this information was not available for other in-service teachers). It is a snapshot that may characterise several in-service teachers and schools (who know of *Primary Connections*).

- A principal had observed teachers using *Primary Connections* by 'cherrypicking' activities rather than understanding and implementing the 5Es teaching and learning model. They wanted this to change, especially as the school had all the *Primary Connections* units (and not many teachers were using them); hence their attendance at the workshop. The intention was to involve the staff in professional learning about *Primary Connections* and the 5Es model and for a graduate teacher (who was "very enthusiastic"), with the principal's assistance, to become a *Primary Connections* "champion for the school".
- One teacher had used *Primary Connections* for 5-6 years and was "comfortable with it" while another had used *Primary Connections* in an ad-hoc manner and wanted a more coherent approach to science teaching; a third thought she does not do the units "credit", especially in being able to implement collaborative learning in a multi-grade class. A fourth has taught using many *Primary Connections* units without experiencing any *Primary Connections* professional learning and, therefore, hoped to consolidate their learning (by attending the workshop).

PRE-SERVICE TEACHERS

Twenty pre-service teachers were interviewed in three focus groups. The characteristics of the three groups are shown in Table 6.

TABLE 6. CHARACTERISTICS OF THE PRE-SERVICE TEACHERS' FOCUS GROUPS

Focus Group (FG)	Number in focus group	Time and length of interview	Enrolment status	Secondary science background	Professional Experience (Practicums)	Familiarity with Primary Connections
FG 1: Regional University (coastal)	6	Immediately following a Qld *Primary Connections* workshop 30 minutes	BEd Primary Year 1 (4) Year 2 (1) Year 3 (1)	None had completed senior secondary science during their schooling	Year 3 had completed a practicum	Years 1/2 knew *Primary Connections* from a science unit; 2 had completed an assessment task related to *Primary Connections*. Year 3 had not encountered *Primary Connections* in first 2 years.
FG 2: Regional University (inland)	7 (6 females; 1 male)	Immediately following a Qld *Primary Connections* workshop 33 minutes	BEd Primary (6) Early Childhood (1) Year 4 (3) Year 3 (2) By distance (3)	Not known	Assumed all had professional experience	All had encountered *Primary Connections* in (their two) science units; two through professional experience.
FG 3: Regional University (inland)	6 (All female)	Immediately following a Qld *Primary Connections* workshop (August) 35 minutes	BEd Primary All Year 3 or 4 By distance (3)	Not known	Assumed all had professional experience	Five had encountered *Primary Connections* in their science unit(s) or elsewhere (1; no science unit to date); 5 through assessments; one through professional experience.

Findings: Response to research questions

The following discussion provides ample evidence that the focus groups have 'shed light' on the (four) research questions to which they were related (see Purpose).

RQ 2.4 Is training in-service teachers and pre-service teachers in Primary Connections the most efficient way to increase the effective implementation of the program?

The focus groups cannot directly compare (with other possibilities) whether the 'training... in *Primary Connections*' is 'the most efficient way to increase the effective implementation of the program'. However, focus group responses directly and indirectly indicate that these participants thought that the Stage 6 workshops were 'efficient' and 'effective' and that they intended to 'implement the [*Primary Connections*] program'. These aspects are reinforced in the sections related to RQ 3.2 (see especially Objective 1) with its reference to 'teacher confidence' and 'intentions to implement *Primary Connections*'. They are also reflected in comments below about 'The general delivery of the workshop and its contents'.

The participants' expectations about the workshop and whether they were met are another indication of how 'efficient' (or valuable) they perceived the workshops to be. In-service teachers found that the workshops addressed many of their needs and most pre-service teachers were surprised at how relevant the workshops were, and the engaging way in which they were presented.

When asked about aspects that were not included in the workshops, the following were identified: assessment; STEM (integration of science, technology and maths); Information and Communication Technology (ICT)/technology enhanced teaching and learning; differentiation of science to cater for needs of all students; and catering for small schools.

In-service teachers: detailed evidence relating to RQ 2.4

The general delivery of the workshop and its contents

These teachers (FG 4) appreciated:

- the science-literacy "bent" as well as the program's coverage of numeracy (e.g. "graphing") and its potential links with history and geography. They (3R) indicated they took advantage of these links. This was significant for them (to address concerns about time) as they now appreciated more time was needed to implement *Primary Connections* in an effective way.

- having presenters with recent classroom experience "who were still connected to the real world" as they were able to answer particular questions and tailor the workshop to the teachers present.

Expectations about the workshop

Teachers (FG 4, 5) definitely appreciated the content in the workshops, and sometimes (as in FG 6, 3R) had no expectations. For one private school teacher (FG 4) the *Primary Connections* units were invaluable as her school did not have access to "departmental (unit) resources".

They had expected:

- "more in assessment" as it is "foremost on teachers' minds today"; there is a need to collect "evidence for assessment" to describe students' progress. (FG 4, 2R).
- STEM to be discussed – its meaning, implementation (including whether *Primary Connections* addresses STEM concerns and asking to what extent does *Primary Connections* exemplify STEM 'integration'). One teacher posed the question:

…is …STEM… about; a way of thinking; (and is not) Primary Connections … already; that way of thinking; and if that's the case, how do we get that across?" (FG 5; grew out of an extended discussion).

- (in hindsight; FG 6, 1R) minimal focus on *Primary Connections* "catering for small schools", especially in "multi-stage" classes (and situations where there is only one student within a particular stage).

Pre-service teachers: detailed evidence relating to RQ 2.4

Expectations about the workshop and its general delivery and contents

Although some students (all in FG 1, several in FG 2) indicated they did not have expectations about the workshop, their responses implied that they thought it would be boring, content heavy, and that they would have to listen and take notes. There was the feeling there would be an emphasis on the content of *Primary Connections* units and using them (but they were not disappointed that this did not eventuate). Others did expect it to be interactive because of the promotional posters of children doing activities (FG 1, 2R, but general agreement).

By way of contrast:

- FG 1 found it "interesting", engaging, active and requiring participation.
- FG 2 were similar, expressing surprise at how engaging and relevant the workshop was (compared to, for example, 'watching a screen'). Many responses indicated the different effects the workshop had on these respondents - they included:
    - now feeling confident to "even (teach) physics… because I'm not a physicist"
    - starting with the "engage phase… learn(ing) with the kids" which was thought to be "a very good thing"; another similarly added "you're more a leader… leading the direction of where it's going… learning with them (the students)" (2R);
    - that the workshop leaders appreciated they were soon to be teachers and did not talk "down to them" (FG 2, 1R) and talked to them "about pedagogies" and "learning to teach science by inquiry" rather than "learning about science" (3R). Hence, as one said, the workshop "gave us what we needed to do our job well".
- The third focus group held several different expectations. They thought there would be:
    - Examples of how to integrate ICT into their science teaching, referring to possibilities such as digital photographs, computerised graphs, use of iPads to collect data (FG 3, 2R but agreement from others): ICT integration "wasn't really even touched upon" and they wished it had been.
    - More emphasis on STEM (FG 3, 1R), although they were ambiguous as to whether STEM needed to be included.

In contrast to the other focus groups, a few FG 3 pre-service teachers thought there would be more ways shown of how to do it (i.e., the *Primary Connections* approach) and hence for them (as pre-service teachers) to have the opportunity to "teach' aspects of the various phases (in the 5Es model)" (e.g. "to a (small) group") (FG 3, 3R). One of these pre-service teachers thought "it was chalk and talk most of the time".

These reactions are the opposite of the experiences reported by all those in FGs 1 and 2.

RQ 2.5 Are there any unintended benefits or disadvantages in providing training in particular ways for in-service teachers and pre-service teachers?

The overwhelming response of all the participants was that face-to-face workshops are much preferred to online or related delivery mechanisms (or, for that matter, any other modes, e.g. hearing from a colleague who has been to a workshop). Many reasons/benefits were given for face-to-face workshops:

- interacting with other teachers/pre-service teachers;
- having 'time-off' to complete professional learning and to be out of the classroom ('clears [one's] head');
- immediate clarification of issues;
- modelling of the teaching and learning approaches and strategies;
- enhancement of deeper learning (e.g. about 5Es model);
- ensuring that participation in hands-on experiences occurs and with follow-up reflection;
- learning from other colleagues (especially if an external university student); and
- the flow-on effect of appreciating the impact of many workshop participants going out to implement *Primary Connections* and 'spreading the word'.

(It was also considered advantageous to have hard and digital copies of the *Primary Connections* units.)

There were no disadvantages for those who had attended workshops; although, when asked what else could be done, a few suggestions were made – but these were not perceived as 'disadvantages' of face-to-face workshops. However, they advised that some teachers (not those in focus groups or at workshops) may not be able to, or may not want to, attend face-to-face workshops. Participants commented that professional or personal circumstances, such as carer responsibilities, or travel logistics, such as the workshop being too distant or difficult to get to, could inhibit participation by some.

When asked what else could *Primary Connections* do to assist their professional learning (related to teaching primary science) several suggestions emerged that may have relevance for future professional learning initiatives.

In-service teachers suggested:

- follow-up processes of various types (e.g. a forum; communication networks; email contact to respond to emerging questions);
- feedback mechanisms to assist in follow-up implementation (e.g. *Primary Connections* members visit their schools);
- a follow-up workshop 'a year later';
- 'interactives' linked to the online units;
- video extracts of experienced *Primary Connections* teachers teaching (for later, and ongoing, reflection);
- other workshops/processes to assist with science content; and
- additional workshops in isolated areas.

When asked for 'workshop improvements' some of the above were expanded, but the following were also mentioned:

- include ideas for 'special needs' students and 'fast workers'; and
- ensure all units are free.

Pre-service teachers suggested:

- follow-up processes of various types (e.g. communication networks; email contact of latest *Primary Connections* developments);
- feedback mechanisms to assist in follow-up implementation (e.g. *Primary Connections* members visit their schools);
- video extracts of experienced *Primary Connections* teachers teaching (for later, and ongoing, reflection);
- additional workshops on science content; and
- all *Primary Connections* resources freely available.

When asked for 'workshop improvements' some of the above were expanded upon, but the following were also mentioned:

- make more reference to use of ICT;
- extend length of the workshops; and
- have 'resources' to 'take away (from the workshop).'

In-service teachers: detailed evidence relating to RQ 2.5

Benefits of face-to-face workshops

All FG 4(7R) and FG 6 (8R, but general agreement) teachers thought there were no disadvantages associated with presenting *Primary Connections* professional learning in a workshop format. Its benefits included:

- "opportunities to interact… and share practice" with teachers from other schools ("hear their stories" [e.g. "this is how we teach it" or about how they organise science time]) and leaving feeling "refreshed" (about teaching science).
- simply being given time and "be taken out of the classroom" so that you are "present in your head" (during the professional learning).

For FGs 4 and 6 the face-to-face workshop was definitely more preferable, and effective, than:

- having a colleague come back from the workshop and sharing with staff (as the workshop was "much more hands-on and practical");
- "doing modules online". Teachers (FG 6, 5R) referred to putting online professional learning "on the back burner", not being given time for completing, or not being "present" because other things are on your mind (low level engagement was mentioned).
- involvement in a "webinar" (the latter still requiring *Primary Connections* resources to be available; you would not get "engaging… activities like sticky notes, sticky dots, jigsaw"). As one teacher expressed it:

I've done over 100 hours of online PD this year and I found that workshop was more invigorating than the 100 hours PD I have done online. And I will retain that information much easier than the other work that I've done.

Face-to-face workshops were also preferred by most of FG 5. Some variations were mentioned:

- a "blended" approach: "do the theory online and the come together to do the practice part later face-to-face";
- as suggested elsewhere, online "videos of good practice" could be helpful (also referred to by FG 6, 4R, even lesson segments, especially for recent graduates).

What else could Primary Connections do to assist your professional learning/implementation of Primary Connections? (including possible improvements)

There was generally a high level of satisfaction with the workshop and all (FG 4, 5) said they would recommend it to their peers.

Suggestions were (FG 4, 7R; FG 5, 4R):

- having a contact *Primary Connections* person (or "point") to email about a unit if they had any questions or to "help teachers to put what they learned (at the workshop) in context";
- a follow-up workshop a year later;
- "a forum to discuss implementation of units and share experience and … tips and tricks, maybe a Q & A with an expert on a unit"; this could be an ongoing collaborative initiative as well to "get the best out of each unit";
- availability of "quality 'interactives' that link specifically to each published unit (and be regularly up dated "in conjunction with units") as many "good resources are often loosely (associated) to… unit(s)";
- observing other teachers who are effectively using *Primary Connections*;
- having additional "online training videos" available for personal viewing as well as an "online course for those who could not attend" (FG 5 tempered this possibility by adding that "disengagement online… does not allow you to pick up on how people are feeling");
- running *Primary Connections* workshops in isolated/rural areas (especially in SA). This would encourage several teachers from one school to attend, although the value of having teachers from different schools attend such workshops was noted.
- using the 'train-the-trainer' model and having a 'champion';
- having the *Primary Connections* booklets available (as a "backup", to prepare for and "enrich" teaching and to assist teachers with limited science background). However, the booklets were not seen as an alternative to the *Primary Connections* workshop; it was reiterated that online professional learning was not a recommended approach – for reasons stated elsewhere (see 'Benefits of face-to face workshops'). (FG 6, 10R)
- (for teaching science effectively) provide avenues that will enhance primary teachers' science knowledge (FG 6, 3R). One teacher did say that the "*Primary Connections* resources provide good background"; other suggestions included increased time within university pre-service science education units, universities "connecting with small schools networks to help teach science in schools" and a science day with a local secondary school. Specialist science teachers were, in general, not supported as a way forward; "silos" would be formed and cross-curriculum initiatives would flounder.
- (for some Queensland teachers) the need for stronger alignment with the Year 7 Queensland science curriculum (e.g. inclusion of a "prac report" to aid "flow" and transition into secondary school science; consistency in how "science literacy follows through" and that "primary teachers follow the same processes" as secondary science teachers) (FG 4; 2R).

Suggestions for improvements to the workshop

- Make workshops more relevant for 'special needs' students (FG 5, 1R).
- Include additional tasks for "fast workers" (FG 5, 1R, but consensus).
- Have follow-up workshops (perhaps in a year); for example, to "confirm or re-affirm what you have done from this workshop" so that "your understanding in teaching science in this format keeps moving forward" (FG 5, 3R, but consensus).
- Review units at school before attending the workshop (FG 4, 1R).
- Make units free (FG 4, 1R).

Pre-service teachers: detailed evidence relating to RQ 2.5

Benefits of face-to-face workshops

- All pre-service teachers (FG 1, FG 2, FG 3) agreed that face-to-face was definitely preferable ("without a doubt") to online workshops or use of DVDs because they would not be as engaging. The face-to-face workshops also provided:
    - immediate clarification of issues about which these respondents were uncertain. As one pre-service teacher said:

Everything they did, they did in a way that it was scaffolded towards what we needed to learn in the end (FG 1).

An external student (FG 3) told of the frustration of not being able to clarify issues immediately (using asynchronous online communication) as well as the difficulty of "explaining things in an email" and not always being aware of the "body language" that helps engagement in a face-to-face situation. This pre-service teacher had watched online "live lectures" and commented that "you get so much more interaction [in face-to-face situations]".

- the opportunity for participants to learn from each other (as distinct from learning from the presenters):

… (to) bounce ideas off each other, it's not the same being in an online forum. Even just talking to someone and seeing the reaction on their face when you discuss things, and having that instant reaction time is so different to just… speaking in a microphone to someone who's like a thousand kilometres away (FG 2; also supported by other comments).

This was supported in FG 3 (1R) because "you can verbalise your own thoughts better" (and it is easier than written approaches, including emails).

- instances of 'modelling' how to teach using the 5Es model: as one respondent said: "If I'm going to learn how to teach then you need to see people teach". Another added we learn the "theoretical stuff" (at university) but "we don't learn how to teach" – 'collaborative learning' was given as an example where they had been introduced to it, and its value, in their university science unit, "but we don't get to nut it out and work with people and collaborate, especially external students" (FG 2, 4R including an exchange).

Another FG 2 response disagreed, in part, with this view, indicating how much they had learnt from 'external lecture delivery', but this did not lead to "confidence to teach". They then added they had learnt to "teach" while on professional experience placement, "but they didn't realise how effective (they) could be (until they did this workshop)". Hence, this respondent was also praising the value of the face-to-face *Primary Connections* workshop.

- "real hands-on" (FG 3, 1R).

- External students especially appreciated "the difference in being able to talk to someone, and physically…" (FG 2, 1R, but agreement by another external student).
- Face-to-face was very effective for several students (FG 2) in establishing a deeper meaning of the 5Es. As one respondent said (and others concurred):

so I can't say exactly what it was and how they did it, but all of a sudden, I understood it. I never fully understood 'elaborate', I didn't understand; I knew the order, I knew how to put things in, but I really didn't understand the whole concept. And now I do.

- The view was expressed that it was problematic as to how effective hands-on investigations are when professional learning is offered at a distance (e.g. online), as is the case when you are an external pre-service student (FG 2); as one respondent said it depends on your "dedication".
- An interesting contribution about the impact of face-to-face workshops was the "flow-on effect". The realisation that "50 pre-service teachers" will be entering the workforce having experienced this *Primary Connections* professional learning workshop had a 'felt' impact for a FG 3 respondent who could envisage how it could inspire many primary students to be "investigative scientists and engineers and teachers themselves".

Limitations of face-to-face workshops

There were no clearly stated disadvantages when this mode of presentation was used (but see Suggestions for improvements to the workshop) where some respondents referred to travel issues as well as having an even longer *Primary Connections* face-to-face workshop).

Primary Connections units: hard copy or digital

There were mixed feelings about whether the units should be available in hard copy, with a leaning towards digital (because of [a] the search function; [b] links to other resources; and [c] personal preference). The consensus was to have both versions available (FG 3, 3R but there was general discussion).

Primary Connections, professional learning and implementing primary science: What else could Primary Connections do to assist your professional learning?

- Make all the resources available on Scootle (FG 2) or free (FG 3).
- Ensure that the *Primary Connections* team keep attendees up to date with latest changes (FG 2).
- Create a "space for teachers to communicate" (about implementing *Primary Connections*) (FG 3, 1R).
- Have available brief video extracts of *Primary Connections* team members teaching in classrooms, showing various ways they might implement the phases in a unit, showing what the "students are doing…(and) what the teachers are doing" (FG 3, 1R).
- Have 'master teachers from *Primary Connections*' visit attendees and provide them with feedback on how they are progressing in their implementation of *Primary Connections* (consistent with the workshop) (FG 2, strong consensual response; it would be "fantastic"; FG 3). This aspect was discussed at length in FG 3. When expense was raised it was opined that: (a) lessons could be uploaded, for example on the *Primary Connections* website; and (b) for others (*Primary Connections* leaders, maybe trusted colleagues) to provide online feedback. Despite a genuine desire to obtain feedback, constraints were raised about such an approach (e.g. time for various people involved; trust issues about putting "themselves out there" [i.e., online]).
- Have additional workshops focussing on science concepts, even though it was appreciated that there were online resources addressing this aspect; this was because "some teachers may not fully understand the concepts" and hence confuse their students (FG 3, 1R).

Suggestions for improvements to the workshop

When specifically asked this question, few suggestions were offered, by groups 1 and 2, there being a very high level of satisfaction with the workshop. All said they would use *Primary Connections*, one adding to the exclusion of all other approaches (FG 1). Across all focus groups, the following possible improvements emerged:

- The location of the workshop and its timing were mentioned, with individual respondents referring to extended travel issues; even so, most found it worked well (FG 1).
- Integration of ICT into the *Primary Connections* activities would assist (FG 3; see earlier).
- It could have been longer (a week was mentioned). This FG 2 respondent (and another) "loved all the information" but would have liked more time "looking at each unit, learning how to teach it to a class…". Another FG 3 pre-service teacher would have liked "another day to practise what we have been learning… so that we can remember".
- Have a "vignette, like a video" (e.g. of teachers using *Primary Connections* in their classroom) to take away and return to, to further reflect upon approaches used (FG 2, 2 R); another (FG 3, 1R) also wanted "some tangible things" to leave with to remind themselves of the workshop (even the "coloured wristbands… to spark memories (of the workshop activities)".

RQ 3.2 To what extent has Stage 6 met the aims and objectives as set out in the funding agreement?

Stage 6 workshops targeting pre-service and in-service teachers in regional, rural and remote settings have been held from 2015-2018.

The Stage 6 objectives are:

1. To increase the uptake of Primary Connections: Linking Science with Literacy in schools;
2. To support primary school teachers and pre-service primary school teachers to teach science through inquiry; and
3. To ensure primary school teachers, pre-service primary teachers and school educators are informed about *Primary Connections*.

The focus groups provided teachers' reactions to Stage 6 professional learning workshops held during 2017. The data gathered:

- give an indication as to whether these pre- and in-service teachers will implement, or continue to implement, *Primary Connections*. In-service teachers also shared their intentions as to what they would do when they returned to their schools, while pre-service teachers expressed what they thought could be done at the school level (i.e., Objective 1).
- indicate the support the workshop provided so that teachers could implement primary science using the 5Es model. This model incorporates 'guided', and where appropriate, 'open' inquiry processes. Hence, teachers' responses when referring to the 5Es sequence either are explicitly or implicitly referring to the implementation of inquiry teaching and learning processes. On occasions, teachers mentioned 'learning through inquiry' per se (i.e., Objective 2).
- identify the many ways that these teachers were informed about the nature of the Stage 6 *Primary Connections* initiative. Their responses also answer whether they would recommend *Primary Connections* to others, including back at their own schools. Furthermore, responses indicate how some teachers became aware of the *Primary Connections* workshop (i.e., Objective 3).

Research Question 3.2 is, therefore, organised under each of the Stage 6 objectives, although teachers' responses may often apply to more than one objective. Where appropriate, readers are referred to other sections of this report.

RQ 3.2 Objective 1: To increase the uptake of Primary Connections: Linking science with literacy in schools

IN-SERVICE TEACHERS

The in-service teachers emphasised their desire to implement *Primary Connections* (or continue to implement it, as several were already using *Primary Connections*). As with pre-service teachers, one of the most significant realisations related to the value of the 5Es approach and the underpinning pedagogy of the 5Es model (see Clarification about the implementation of the 5Es model for sequencing learning).

In-service teachers commented on useful features of *Primary Connections* but also spoke about 'planning' matters. Features (including realisations) were:

- toolkit of strategies;
- collaborative learning emphasis; and
- unit planning across science, literacy and numeracy: ways forward using *Primary Connections* units

(See In-service teachers: Intentions to implement *Primary Connections* as a result of the workshop).

In-service teachers, especially from very remote areas, also shared how the uptake of *Primary Connections* is dependent, in part, on their teaching context, whether that be:

- a K-6 multi-grade teacher;
- a distance education teacher; or
- a relief from face-to-face teacher or similar.

(See In-service teachers: Intentions to implement *Primary Connections* as a result of the workshop).

PRE-SERVICE TEACHERS

The pre-service teachers clearly reported their increased confidence to teach science and their definite intention to implement *Primary Connections* when they entered the teaching profession. Reasons for this increased confidence could be inferred from their comments. Confidence increased because issues of concern (to them as pre-service teachers) were addressed by the *Primary Connections* workshop, namely:

- self-perceived deficits in science content knowledge;
- inappropriate perceptions of what 'learning science' involves; and
- provision of specific teaching tools and strategies (for details see Confidence to teach science increased)

Related to this increased confidence to teach science (and implement *Primary Connections*) were features of *Primary Connections* that attracted these pre-service teachers' attention. Some of these features were clarifications and/or realisations they noted about either *Primary Connections* or teaching science generally. One of the most significant realisations related to the 'value of the 5Es approach' and the underpinning pedagogy of the 5Es model (see Clarification about the implementation of the 5Es model for sequencing learning).

Other features (including 'realisations') were:

- availability of 'complete' teaching and learning units and flexibility to adapt them;
- ease of integration with other curriculum areas;
- advantages of 'backward planning';
- collaborative learning guidance;
- toolkit of strategies; and
- indigenous perspectives advice (for details see Intentions to implement in future teaching career as a result of workshop).

In-service teachers: detailed evidence relating to RQ 3.2 Objective 1

As a result of the *Primary Connections* professional learning workshop, in-service teachers indicated that there were several realisations and/or approaches that they intended to act upon or implement (and these also suggested their confidence was raised). Some in-service teachers shared how their intentions to implement *Primary Connections* depended on their teaching context (see Intention to implement *Primary Connections* depends on context).

Intentions to implement Primary Connections as a result of workshop

Value of the general Primary Connections 5Es pedagogy

There was a realisation by some teachers (FG 4, 3R; FG 6, 2R) that they had not been implementing the 5Es model effectively. They had not been "explicit" about the 5Es phases. One had been using the books but

today everything around the book…and those 5Es make sense… it's a cohesive document now in my brain.

The use of a 'puzzle' that "broke down the expectations for the *student* and the *teacher* for the 5Es" (italics added here and below) was "really beneficial" (FG, 6, 1R):

…sometimes I think I'm doing the wrong thing in that certain phase but it was good to see, that is, what you are supposed to do and this is what the student does.

Others (FG 4, 3R) found the 5Es model to be a helpful guide in implementing an inquiry approach ("more structured and guided" avoiding a "loose" approach with minimal "parameters").

In a concluding comment a FG 6 teacher said: they liked *Primary Connections*

… because of how easy they make it. I like how you can pretty much pick it up and go. It's structured".

Clarification about the implementation of the 5Es model for sequencing learning

Those teachers who had used *Primary Connections* previously now appreciated that their practice needed to be altered. Examples mentioned were:

- Previous ways in which the *Primary Connections* units had been implemented were now seen to be inappropriate (e.g. only "select(ing) and us(ing) parts of it"; not following the sequence; following the sequence but combining parts of different phases [e.g. due to time]; leaving components out [now realising that all phases are important]) (FG 4; 3R).
- Not correcting students "to start off with… let them make mistakes…(rather) accept every answer now". This was "the biggest thing" one FG 6 teacher learnt:

… because it's never been said to me in that way before. Where you just accept it, don't change it, write them up word for word and then we work the change into a paraphrase later.

- Appreciating the value of discussion, especially towards the end of a sequence, and that such discussion can be seen as an assessment process in its own right (rather than, say, using paper and pencil assessment). Also the significance of key language (within discussions) had been overlooked such as students making and evaluating their "claims" (FG 4, 2R).

Primary Connections provided useful 'strategies'

A FG 4 teacher said the demonstrated 'strategies' (examples were not provided) were "very effective". Some in FG 6 (4R) were more specific. They:

- reflected on their use of the TWLH and now appreciated the significance of displaying its contents throughout a unit so that students could "look at it and think 'Oh, that's what we're doing in science'"; another indicated their science displays need to be as obvious as their literacy displays.
- "really liked the thinking tools" (could readily see how they could use them in their class), for example the "Hot potato".

Collaborative learning

These teachers appreciated the emphasis on students collaborating throughout a *Primary Connections* unit (FG 4, 2R).

Primary Connections was research-based and trialled

Responses (FG 4; 3R) clearly indicated an appreciation that the *Primary Connections* approach to teaching and learning was based on research findings (e.g. even down to the "design" of the "questions"); furthermore, units were repeatedly trialled in classrooms.

Unit planning using Primary Connections: addressing science, literacy and numeracy outcomes

In contrast to the pre-service teachers, these in-service teachers raised, as a discussion point, 'unit planning'. They saw real advantages in blending science with literacy and numeracy (but different groups of teachers offered variations on this theme).

Meeting outcomes in science, literacy and numeracy: concurrent or otherwise?

In FG 6 (17R) an extended discussion considered how literacy and numeracy could be planned in an integrated manner with science in *Primary Connections*. Some responses indicated that the literacy and numeracy outcomes covered in a *Primary Connections* unit could be deleted from their literacy and numeracy curriculums, and then focus only on those outcomes remaining in these two curriculums. A key variation was to ensure the learning outcomes in literacy and numeracy are encountered at the appropriate depth within their respective curriculums (e.g. bar graphs may be met in *Primary Connections*, but other (graphing) aspects may need to be learnt in mathematics *or* graphs would be encountered in mathematics but students could apply them in *Primary Connections*, say, to show data records – you could even have students "discover" an appropriate graph to use).

Number of Primary Connections units in a year

In FG 6 (8R) another lengthy discussion concerned whether four *Primary Connections* units could be taught within a year. All thought it would be desirable, but only one teacher said it occurred and another added some schools do 4 units over two years. Others thought it would be difficult, if not impossible, especially for distance education, multigrade (here K-6), and relief from face-to-face teachers, who all indicated challenges (e.g. [in a K-6 context] making *Primary Connections* unit choices and avoiding 'science' gaps, together with timetabling issues; ensuring coverage was feasible [within a distance education context]; and [for 'relief from face-to-face teachers] only having access to students one day a week). Some of these 'difficulties' meant *Primary Connections* units were not completed:

I might only get to the Explore stage or you don't even get to the Evaluate (stage) and those kids are missing out on a massive part of the syllabus.

Intention to implement Primary Connections depends on context

Responses from FG 5 indicated a willingness to use (or continue to use) *Primary Connections*. Several issues raised were specific to each teacher and their background, experience and needs. They implied that how they would be implementing *Primary Connections* in their classrooms depended upon their teaching context, namely:

- One teacher, being familiar with *Primary Connections* and its 5Es model, said the workshop "confirmed they were on the right track". Implementing *Primary Connections* meant that collaboration was emphasised, "open-ended questioning" was used, lessons were "student-led" and learning was "much deeper".
- The multi-grade (years 3 to 7) teacher felt they could now implement *Primary Connections* across two year levels, but was still uncertain about its use across four year levels. It was also indicated that students' "mindsets", that is their perceptions of science learning, would need to change from "blow things up" to "more thinking".
- A graduate teacher said they would avoid "cherry picking" in order to "focus on one concept…and follow the structure precisely". To teach *Primary Connections* "well", this teacher and another, felt behavioural issues would need to be "managed", especially when students did not have particular skills, such as working collaboratively in groups, sharing ideas respectfully and taking responsibility in student-led investigations.
- The non-instructional teacher felt that the (5Es) structure underpinning *Primary Connections* would mean that, in teaching across year levels (and at varied times), a coherence could be developed in their science teaching.
- The special needs teacher reflected that the level of each student would need to be considered and hence "use the *Primary Connections* resource accordingly" (e.g. use a Year 1 unit for a student 'assessed' at that level). In their school 'questioning' was a focus and a workshop session "on how to question, what sort of questions (e.g. probing)" was valued.

To effectively fulfil some of the above, and address stated concerns, it was felt by all FG 5 teachers that "a whole school approach" would be the best way forward (as *Primary Connections* may not "work" if teachers use it in isolation). As one said:

So if you start at Reception you build on it over the years so by the time they get to Year 4, they know what their roles are and you don't need to keep going back all the time.

They all agreed that "if (*Primary Connections* is) taught properly" student achievement would improve.

Pre-service teachers: detailed evidence relating to RQ 3.2 Objective 1

Confidence to teach science increased

Increased confidence to teach science was a general and very strong feeling that was expressed by these pre-service teachers (FG 1,2,3). This was irrespective of whether they had completed a university science unit or not (FG 3, 1R, now "pretty confident") or even if they still lacked such confidence in their final degree year (FG 3, 1R, now "100% confident" and will use *Primary Connections* on "internship").

Even if respondents said they were 'confident' before the workshop, they were "much more confident" after it; in part, this was because they now felt they understood "why (they) should use it… there really is a method to the madness" (FG 3, 2 R).

These pre-service teachers would be more than willing to recommend *Primary Connections* to their peers and, in some instances, already had shared how valuable it had been (FG 2, FG 3). The workshop "changed your confidence" and "made you want to stay". A FG 1 pre-service teacher who had experienced practicum and had avoided science would "now be happy to teach it". This feeling of increased confidence (especially in applying the 5Es model) was pronounced in FG 2; for example, one pre-service teacher expressed their enthusiasm for the *Primary Connections* 5Es approach by saying they were going to try it with their son at home.

This added confidence appeared, in part, to be related to how *Primary Connections* addressed:

Self-perceived deficits in science content

> One now appreciated that they do know "quite a lot (about science)" and another that "chemistry and stuff like that…is a lot easier than I thought". It was a relief to be told that "if you don't know (some science) it's not bad"; you do not "have to be scientists to teach it (science)". Furthermore, the *Primary Connections* online resources were seen as bridging "gaps in (their science) knowledge" which they can "expand (on) before teaching (a) unit". They appreciated the reliability of these *Primary Connections* science content resources compared to, say, Google (FG 1, 5R; FG 2 in general). Focus Group 1 shared how various *Primary Connections* workshop activities revealed gaps in their knowledge.

Inappropriate perceptions of learning science

Learning science can be "engaging and fun" rather than "boring (with) lots of notes" which is what one respondent believed her peers thought learning science was like (FG 1, 1R).

A need for specific teaching tools and strategies

The range of generic *Primary Connections* tools and strategies (not just for science) was seen as practical advice for future teachers (See *Primary Connections* provided a toolkit of strategies).

Intentions to implement in future teaching career as a result of workshop

As a result of the *Primary Connections* workshop, these pre-service students indicated there were several realisations and/or approaches that they intended (or implied they intended) to act upon or implement. It is inferred that appreciating these features added to their confidence to teach science (and implement *Primary Connections*). The features were:

Value of the general Primary Connections 'pedagogy'

There was the positive perception that the *Primary Connections* workshop was mainly about a pedagogical approach not "what to teach" (FG 2, 1 response). In this vein, assessing primary students' prior knowledge, hands-on activities and 'play' were mentioned; as one said:

Even in year 6, play is important. It's not about standing and delivering information. They (the students) are figuring it out for themselves (FG 2).

Clarification about the implementation of the 5Es model for sequencing learning

These pre-service teachers were aware of the 5Es model (FG 1; all 6R; FG 2 most responses; FG 3 all responses). One (FG 1) said that it had been "pumped at us", while the Year 2 pre-service teacher (FG 1) indicated they had only experienced the 'engage' and 'explore' phases in their university science unit. The FG 2 pre-service teachers (4R, but general consensus) said they had completed university assignments where the 5Es model 'framed' their learning (also for 5 FG 3 students), but for FG 2 respondents (and a FG 3 response who "had no idea of the structure from it"), it was at the *Primary Connections* workshop that it "absolutely clicked" because "we've never had it broken down for us" or had as much time devoted to the nature of the 5Es model. They now felt confident to implement the 5Es model.

Responses suggested that there were several misunderstandings/misconceptions about implementing the 5Es model. Clarifications were:

- that the 'engage' phase could be more than one lesson (FG 1, 1R);
- ensuring students "express(ed) their ideas first and allow them to make connections and then to introduce science ideas afterwards" and not "too soon in the learning sequence" (FG 3, 2R). Another, realised that if you "build students up from the bottom" then the 5Es steps will assist in students learning "the outcome you want them to";
- all five phases did not have to be included in one lesson – a pre-workshop conception (FG 1, 1R);
- an appreciation that each 5Es phase required certain types of activities/tasks to meet the purposes of that phase (FG 3, 1R); and
- the units cannot be "cherry-picked"; to do so can be a "big flop".

This confounded one student as she and her mentor (in a professional experience placement) had followed the *Primary Connections* instructions. Both had not "realise(d) that you need to do everything (in the *Primary Connections* sequence) for it (the activity) to be meaningful" (FG 2, 1R). In an insightful exchange three interviewees displayed the quality of their understanding of this aspect of using the 5Es sequence. They appreciated that each phase needed to be completed in a sequential manner, but that not all the activities or tasks in a *Primary Connections* unit needed to be encountered by their students. This is illustrated in the following (partial) exchange:

Pre-service teacher A: You don't have to do every single experiment but you do have to do every single stage and actually immerse yourself into it.

Pre-service teacher B: Like you can't just jump, say to (the) explain (phase), you have to start off with the engage, then explore.

This was a 'key moment' from the workshop for these three interviewees: "So that was what I got the most, out of all of it (the professional development workshop)". It was also mentioned by a FG 3 respondent; they had previously chosen "bits and pieces" but now understood that following all the 5Es steps would result in "kids… gain(ing) a lot more".

The above interchange engaged others in the conversation. This lead to further support for this realisation, i.e., that teachers need to appreciate the underlying rationale of the 5Es model. The pre-service teacher, recounting her professional experience, said her mentor teacher had simply been given a *Primary Connections* unit and "told to use it"; he did not appreciate its rationale and hence how to use the resource. This interviewee hence strongly saw the need for the *Primary Connections* professional development workshops. Another respondent (FG 2) added a similar comment:

That's why I wanted to come (to this professional learning workshop), because I'd looked at a book (Primary Connections Unit) last semester for an assignment, and thought, 'What in the world is this?!'

- even after encountering the 5Es model still having a "mentality" that teaching science was to "do a fun activity"; this pre-service teacher "hadn't realised…had no idea" what the 5Es actually involved. Another indicated the workshop emphasised "this is literally how to do it (plan a sequence of science lessons)" (FG 2, 2R).

Availability of 'complete' units was an attractive feature

The *Primary Connections* teacher unit guides were perceived by these pre-service teachers as a most useful aid in helping them implement science in their classrooms:

…you can just pick them up and teach from (them) (FG 1, 1R)

why change something that isn't broken… apart from differentiation… (they said not to tamper with the 5Es structure) (FG 3, 1R),

For one FG 3 pre-service teacher, the units' progression from "investigating things… to showing …explanations" was a reason not to deviate from the 5Es structure. For "those who are not very science literate" following the unit structure was seen as especially helpful (FG 1, 1R).

Flexibility to adapt units

In contrast to the above, others appreciated that the units could be "adjust(ed) to your teaching style" and varied through using a "backwards plan" (FG 1, 3R). Adapting units was also seen (by one student) as a way to follow students' ideas in "an effective way" in order to keep them "interested…(and) more engaged in their learning" but it was added not to "deviate too far".

It was also noted that, at times, various constraints (e.g. time) may mean that the units could not be taught as described (even when this was the desired approach), or as a teacher you could envisage a more effective way forward (FG 3, 2R).

Science can be readily integrated with other curriculum areas

There appeared to be 'relief' with the realisation that science could be integrated with other curriculum areas (literacy and mathematics were mentioned). An example was appreciating that data collection was "wow, it's like…maths". This relief was, in part, due to perceived time constraints (in meeting the curriculum outcomes from a range of subjects). The workshop indicated how integrating curriculum areas could be achieved (FG 1, 3R).

'Backward planning' was an approach seen to have advantages

Planning in this way was seen as adding flexibility for these pre-service teachers. They saw it as a method that helped identify if a unit was not moving towards its learning outcomes and hence make adjustments that would "make it more effective for the students" (FG 1, 2R; also mentioned in FG 2).

Collaborative and/or cooperative learning group guidance and roles were appreciated

Having group roles (director etc.) was seen as helping classroom management when groups were used, and was positively received, especially as they were reinforced within workshop activities (FG 1, 1R; FG 2, 1R).

Workshop guidance related to group sizes contrasted with earlier experiences while on professional experiences (practicum), although one student felt reasons for smaller groups were not provided (FG 1, 2 responses). Specific details about group sizes were described - from their group work in the workshops (e.g. value of focused discussion/conversation in smaller groups; increased direct involvement in the set tasks; more engaged and less noise) (FG 2, 2R, but some general agreement).

Primary Connections provided a 'toolkit of strategies'

The 'strategies' (e.g. 'parking lot chart', question box, TWHL) were very much appreciated by these pre-service teachers (all of FG 1; several FG2, 3R). Most agreed that they were not familiar with many of them; actually being involved in experiencing them (FG 3) added to their appreciation. These strategies were considered a valuable workshop component.

When asked 'what they would take into their future (science) teaching', specific strategies were mentioned; e.g. 'barometer' and 'spectrum' strategies were seen as ways for primary students to share their thinking about science phenomena in a non-threatening and engaging way, which valued students' experiences and considered a collective view. These strategies were also experienced in the workshop and clearly had an impact; as one pre-service teacher said:

…and then when you did speak out (in the workshop tasks), you didn't feel intimidated because it was taking the group's view. (FG 2, implied by many other responses).

Indigenous perspectives allayed concerns

The *Primary Connections* indigenous perspectives supplement provided guidance for some pre-service teachers who may have indigenous students in their class; it allayed concerns as, at least one (FG 1) was hesitant about including indigenous perspectives because they may 'offend'.

RQ 3.2 Objective 2: To support primary school teachers and pre-service primary school teachers to teach science through inquiry

As indicated under 'Clarification about the implementation of the 5Es model for sequencing learning' above, the underpinning pedagogy of the 5Es model implies students learning through 'guided inquiry'. At various times teachers made comments that implied using (guided or more open) inquiry rather than transmission/exposition approaches. A selection of comments illustrating these attributes include:

In-service teachers

- (FG 4, 3R) found the 5Es model to be a helpful guide in implementing an inquiry approach ("more structured and guided" avoiding a "loose" approach with minimal "parameters").
- For a FG 5 teacher there was the understanding that primary science (and *Primary Connections*) involves "simple things that are evidence-based" with "kids doing the work" (meaning inquiry) not the teachers.
- Implementing *Primary Connections* meant that collaboration was emphasised, "opening questioning" was used, lessons were "student-led" and learning was "much deeper" (5Es).

Other related comments are implied throughout this report.

Pre-service teachers

- Appreciated the workshop talking to them "about pedagogies" and "learning to teach science by inquiry" rather than "learning about science" (FG 2, 3 responses).
- Made reference to (or hinted at) students making 'investigative decisions':
  Even in year 6, play is important. It's not about standing and delivering information. They (the students) are figuring it out for themselves (FG 2).
- Ensure students "express their ideas first and allow them to make connections and then to introduce science ideas afterwards" and not "too soon in the learning sequence" (FG 3, 2R).

RQ 3.2 Objective 3: To ensure primary school teachers, pre-service primary teachers and school educators are informed about Primary Connections

There are various ways this objective can be interpreted. These are implied in the following comments.

- The extent to which these focus group teachers were informed about *Primary Connections* is amply illustrated by their responses in various sections of this report. Their comments were often detailed, indicating the depth of understanding some of them displayed about *Primary Connections*. The headings (and the associated details) in various sections of this report exemplify this 'understanding', e.g. see 'Intentions to implement *Primary Connections* as a result of the workshop' for in-service teachers and pre-service teachers.
- This objective could also be interpreted as asking how teachers (pre- and in-service) first learnt about *Primary Connections*. Table 5 and Table 6 indicate that virtually all these participants were familiar with *Primary Connections*: some through their university science units, others through, e.g. professional learning, *Primary Connections* networks and/or their school's purchase of *Primary Connections* units.

- Concerning how these teachers became aware of these Stage 6 workshops, in FG 5 (7R) four were notified by their principal; two had *Primary Connections* subscriptions, while two found out by 'Googling' for professional development.
- To assist in informing others, these teachers all agreed they would 'spread the word' among their colleagues and schools with which they have contact. Below are their responses about what they would need to do next at school (in-service teachers) or their current hopes for implementing *Primary Connections* in schools (pre-service teachers).

In-service teachers:

- The main issue for the FG 4 (4R) teachers was to 'find time' to plan and implement what they had learned. To that end it was suggested that 'in-school' time would need to be provided to review year-level planning and to "enhance" the teaching of *Primary Connections*, as well as to "work in cohort groups to look at the *Primary Connections* website". Apart from these aspects, FG 4 responses also indicated that (back at school):
  - they would now be "more comfortable" collecting "evidence of learning in science" (becoming more of a priority);
  - the feasibility of providing a journal for each student would be investigated.
- For a FG 5 teacher the issue would be "up-skilling the teachers". This was because many teachers saw science as "whizz-bang stuff" rather than "simple things that are evidence-based" with "kids doing the work" (meaning inquiry) not the teachers. There needs to be, as emphasised in the workshop, "intentionality" behind the science.
- Two FG 6 teachers indicated they would either urge colleagues to attend future *Primary Connections* workshops or encourage their school to develop a "whole school approach" to *Primary Connections* (because teachers vary in the use of *Primary Connections*). At least three said it was an expectation that they share their learning from the *Primary Connections* professional learning workshop (with others at their school) but previous experience suggested this would not happen; one said there were no other teachers (at their school) with whom to share.

Pre-service teachers:

- Related to this objective (and also to Objective 1) were these pre-service teachers' thoughts about how schools might become more aware of *Primary Connections* and its effective implementation. FG 1 (4 responses) suggestions were:
  - the use of staff meetings to increase awareness, and argue the value, of *Primary Connections* (e.g. by persuasion through an exchange of views while emphasising the research behind the *Primary Connections* approach, watching DVD clips of *Primary Connections* in action);
  - more *Primary Connections* professional learning workshops be implemented in more (all) schools. This seems imperative, as schools may have *Primary Connections* units but are not familiar with how to implement them (as illustrated by the mentor teacher with one of the FG 2 pre-service teachers: see Clarification about the implementation of the 5Es model for sequencing learning). This view was very enthusiastically supported by five other FG 2 responses, which made reference to the value of actually experiencing how to use the *Primary Connections* resources. Having an in-school *Primary Connections* "champion" was suggested as an alternative to attending the workshops.

Reasons for non-attendance at the workshop

Also associated with Objective 3 is an awareness of why some people could not attend. Reasons given included: distance; children to care for; and concurrent university classes (pre-service teachers).

In-service teachers made the following suggestions to overcome these difficulties:

- Stream or podcast the workshop (FG 4, 1R).
- FG 6 (1R) said an online approach may assist some teachers (however this group did not recommend it – see comments related to RQ 2.5).

Suggestions made by pre-service teachers included: having university lecturers attend the *Primary Connections* professional learning workshops so that they are more familiar with the *Primary Connections* approaches or the *Primary Connections* team offering the workshops at university (including the possibility that they be part of university science units – hence no students would miss the opportunity (that these pre-service teachers had) (FG 2, 2 responses; FG 3, 1 response).

RQ 3.3 What else can the Primary Connections program offer to assist teachers and pre-service teachers to implement the Australian science curriculum?

Not all focus groups made direct reference to the *Australian Curriculum: Science*. Pre-service teachers were relieved that *Primary Connections* had included explicit connections to the *Australian Curriculum: Science,* while in-service teachers did not elaborate on this issue – most took it 'on-trust' that *Primary Connections* covered the outcomes in the *Australian Curriculum: Science*. They expressed appreciation that *Primary Connections* units were updated so that they were consistent with the latest versions of the *Australian Curriculum: Science*. They saw no need for additional emphasis on the *Australian Curriculum: Science* in current or future *Primary Connections* professional learning.

In-service teachers did make passing comments that implied that *Primary Connections* helped with implementation of the *Australian Curriculum: Science*, for example, its consistent approach to learning through inquiry processes.

In-service teachers: detailed evidence relating to RQ 3.3

Primary Connections and Implementing the Australian Curriculum: Science

These in-service teachers (FG 4) did not feel that the workshop focused on the *Australian Curriculum: Science, per se.* They took it "on trust" that *Primary Connections* complied with the *Australian Curriculum: Science*. They did not think additional information on the *Australian Curriculum: Science* was required in workshops. One teacher commented that the updated units had responded to the *Australian Curriculum: Science* and also noted that other curriculum areas did not have similar resources to *Primary Connections* but that other curriculum areas would benefit from the development of similar resources (FG 4, 1R).

FG 5 made minimal reference to the *Australian Curriculum: Science* but agreed that the *Primary Connections* resources were consistent with it. However, a special needs teacher felt "there is no consideration for special needs students" in the curriculum and was equivocal as to whether *Primary Connections* assisted teachers to implement the *Australian Curriculum: Science* (in special needs situations).

Pre-service teachers: detailed evidence relating to RQ 3.3

Primary Connections and Implementing the Australian Curriculum: Science

There was general agreement that there was consistency between *Primary Connections* and the *Australian Curriculum: Science* (FG 2). When one student commented how "thorough(ly)" the workshop addressed the connections between the *Australian Curriculum: Science* (and it was implied to other curriculums as well, such as Mathematics) and the *Primary Connections* units, others readily agreed.

Having these 'connections' made explicit was the "biggest relief" because meeting the requirements of the *Australian Curriculum* was seen as "overwhelming". A FG 3 respondent wondered "how am I going to do all this (i.e., meet *Australian Curriculum: Science* expectations)" – they felt the *Primary Connections* 'connections' "takes a lot of pressure off". Another response, for example, was that although they already had a sound knowledge of the *Australian Curriculum: Science*, the *Primary Connections* workshop "improved my knowledge of how to teach it (i.e., the *Australian Curriculum: Science*) in a fun and engaging way". The workshop "made me feel so much better… in this area" (FG 2, 1R). A similar feeling, appreciating how valuable were the 'connections' that *Primary Connections* made to the *Australian Curriculum: Science,* was expressed as follows:

[Pre-service teachers] now feel like they're able to teach science, not "escape" it, approach it in a way that they didn't feel they could when they looked at the [Australian] curriculum for science – not knowing what to choose, where to start – hard when you don't have a science background.

Conclusion

The conclusion highlights key findings, based on the focus group data, related to each of the research questions.

Efficiency RQ 2.4 Is training in-service teachers and pre-service teachers in Primary Connections the most efficient way to increase the effective implementation of the program?

Teachers reported that the Stage 6 workshops were efficient and better than expected. Following the workshop, they stated that they intended to implement the *Primary Connections* program.

In-service teachers also found the workshops addressed many of their needs for teaching science. Most pre-service teachers were surprised as to how relevant the workshops were and at the engaging way in which they were presented.

When asked about aspects they had expected to be included in the workshops but were not, some teachers identified digital learning/ICT; STEM (with an emphasis the integration of science, technology, engineering and mathematics); and differentiation (adapting *Primary Connections* to meet the needs of the diverse range of students in their classes).

Efficiency RQ 2.5 Are there any unintended benefits or disadvantages in providing training in particular ways for in-service teachers and pre-service teachers?

Focus group teachers reported that face-to-face workshops are much preferred to online or related delivery mechanisms (or, for that matter, any other modes, e.g. hearing from a colleague who has been to a workshop).

They noted that some teachers (not those in focus groups or at workshops) may not be able to, or may not want to, attend a face-to-face workshop. Therefore, we recommend that the AAS continue with face-to-face workshops but that consideration be given to meeting the *Primary Connections* professional learning needs of those for whom attendance at workshops, as currently delivered, is difficult. More detailed information can be found in the Recommendations section of this report.

Focus groups provided suggestions related to further workshops for professional learning in *Primary Connections*, including follow-up support. Recommendations related to this matter are included in that section of this report.

Effectiveness RQ 3.2 To what extent has Stage 6 met the aims and objectives as set out in the funding agreement?

Evidence from the focus groups supports the conclusion that Stage 6 has met the objectives as set out in the funding agreement.

For example:

Objective 1: To increase the uptake of Primary Connections: Linking science with literacy in schools.

After the workshop, in-service teachers indicated their desire to implement or to continue using *Primary Connections*. Many had not implemented it in full previously. Most expressed a commitment to implement *Primary Connections* in full, with greater fidelity, in future – subject to school based constraints.

Pre-service teachers reported that, after the workshop, they had increased confidence to teach science and that many intend to use *Primary Connections*, and use the 5Es, when they enter the teaching profession.

Many in-service and pre-service teachers reported that they had not realised or fully understood the importance of the 5Es model for *Primary Connections*. The improved understanding of *Primary Connections* and the 5Es that resulted from the workshops seems to have influenced their determination to implement *Primary Connections* with greater fidelity.

Objective 2: To support primary school teachers and pre-service primary school teachers to teach science through inquiry.

Following the workshop, teachers and pre-service teachers expressed commitment to implementing inquiry, which, by implication from other data, emphasises the 5Es.

Objective 3: To ensure primary school teachers, pre-service primary teachers and school educators are informed about Primary Connections.

Most pre-service and practicing teachers appeared to know about *Primary Connections*. Participants in workshops all indicated that they had learnt a lot about *Primary Connections* from the workshops and indicated that this would influence their teaching of science.

Effectiveness RQ 3.3 What else can the Primary Connections program offer to assist teachers and pre-service teachers to implement the Australian science curriculum?

Teachers took it 'on-trust' that *Primary Connections* covered the outcomes in the *Australian Curriculum: Science.* They expressed appreciation that *Primary Connections* units were consistent with the latest versions of the *Australian Curriculum: Science.* The only request for additional support related to addressing special needs. This is consistent with the request for support with differentiation noted above.

APPENDIX 4A: FOCUS GROUP GUIDING QUESTION SCHEDULE [VERSION USED IN EARLY INTERVIEWS]

Focus group guiding question schedule

(RQs 2.5, 3.1, 3.2, 3.3)

Focus groups and interviews will be held with pre-service teachers immediately following their participation in a two-day professional learning workshop.

Focus group duration: 30 minutes.

Probing questions commence with '…'

INTRODUCTION

My name is _________________ and I am part of a research team from the University of Technology Sydney (UTS). This research is to evaluate the implementation of the primary science teaching program - *Primary Connections*. The research is being led by Professor Peter Aubusson from the UTS and is funded by the Australian Academy of Science.

Please take a moment to read the information sheet and consent form. If you agree to participate, please sign the disclosure and indicate your willingness to be audio recorded.

DEMOGRAPHICS:

Please tell me…

First name

University

Degree you are completing

Year you will complete their degree

Know about or used *Primary Connections* before today

QUESTIONS

What will you use?

1. What did you do or learn during today's workshop that you intend to implement in your future teaching (pre-service)?

….What aspects of this two-day workshop did you find particularly helpful? (RQ 2.2, 3.1)

… Do you think using *Primary Connections* will improve student achievement in line with the expectations of the *Australian Curriculum: Science*?

(Focusing on unit planning/delivery/evaluation – gauging fidelity of implementation of units and using an inquiry approach) (RQ 2.2, 2.3)

What can be improved?

2. Was there anything that you were expecting would be included in today's professional learning that wasn't?

… What improvements could be made to the workshop?

…Can you think of any other benefits or disadvantages in providing training in *Primary Connections* as a workshop?

(What could be done to improve the workshop, to help you more effectively teach the Australian science curriculum?) (RQ 3.1, 3.3)

How else could we provide professional learning for *Primary Connections*?

3. Thinking about other pre-service primary teachers that you know and what might appeal to them, how else might professional learning for *Primary Connections* be offered?

…Is a workshop the most efficient way to conduct professional learning about *Primary Connections*?

…What else do you think the *Primary Connections* program can offer to assist teachers and pre-service teachers to implement the *Australian Curriculum: Science*?

(What do you think are some of the advantages of face-to-face delivery? Disadvantages? How would you prefer this professional learning to be delivered?

How could Primary Connections improve their professional learning options?)

(RQ 2.4, 2.5)

Final questions

Intention to use *Primary Connections* based on workshop?

4. Do you think this workshop will increase the likelihood of you comprehensively implementing the program in your teaching?

… Would you recommend this workshop to other pre-service teachers? Why

(Focusing on unit planning/delivery/evaluation – gauging fidelity of implementation of units and using an inquiry approach) (RQ 2.2, 2.3) …. Again to ensure a positive end to the FG.

Overflow question

5. What further professional learning support do you anticipate you will need for teaching science once you begin your career?

CLOSE

Thank you for your participation in this research.

APPENDIX 4B: FOCUS GROUP GUIDING QUESTION SCHEDULE [UPDATED VERSION USED IN LATER INTERVIEWS]

Focus group guiding question schedule (RQs 2.5, 3.1, 3.2, 3.3)

Focus groups and interviews will be held with in-service teachers immediately following their participation in a one-day professional learning workshop.

Focus group duration: 30 minutes.

Probing questions commence with '…'

INTRODUCTION

My name is ________________ and I am part of a research team from the University of Technology Sydney (UTS). This research is to evaluate the implementation of the primary science teaching program - Primary Connections. The research is being led by Professor Peter Aubusson from the UTS and is funded by the Australian Academy of Science.

Please take a moment to read the information sheet and consent form. If you agree to participate, please sign the disclosure and indicate your willingness to be audio recorded.

DEMOGRAPHICS:

Please tell me…

- First name
- Years of teaching/current role or position, grade
- To what extent did you know about or have you used Primary Connections before today?

QUESTIONS

What will you use?

1. What did you do or learn during today's workshop that you intend to implement in your future teaching (pre-service)?

….What aspects of this two-day workshop did you find particularly helpful? (RQ 2.2, 3.1)

… Do you think using Primary Connections will improve student achievement in line with the expectations of the Australian Curriculum: Science?

(Focusing on unit planning/delivery/evaluation – gauging fidelity of implementation of units and using an inquiry approach) (RQ 2.2, 2.3)

What can be improved?

2. Was there anything that you were expecting would be included in today's professional learning that wasn't?

… What improvements could be made to the workshop?

…Can you think of any other benefits or disadvantages in providing training in Primary Connections as a workshop?

(What could be done to improve the workshop, to help you more effectively teach the Australian science curriculum?) (RQ 3.1, 3.3)

How else could we provide professional learning for Primary Connections?

3. Thinking about other pre-service primary teachers that you know and what might appeal to them, how else might professional learning for Primary Connections be offered?

…Is a workshop the most efficient way to conduct professional learning about Primary Connections?

…What else do you think the Primary Connections program can offer to assist teachers and pre-service teachers to implement the Australian Curriculum: Science?

(What do you think are some of the advantages of face-to-face delivery? Disadvantages? How would you prefer this professional learning to be delivered?

How could Primary Connections improve their professional learning options?)

(RQ 2.4, 2.5)

FINAL QUESTIONS

Intention to use Primary Connections based on workshop?

4. Do you think this workshop will increase the likelihood of you comprehensively implementing the program in your teaching?

… Would you recommend this workshop to other pre-service teachers? Why?

(Focusing on unit planning/delivery/evaluation – gauging fidelity of implementation of units and using an inquiry approach) (RQ 2.2, 2.3) …. Again to ensure a positive end to the FG.

5. What follow-up would you like to receive?

(eg. preferences for online or hardcopies of Primary Connections units and other resources; what should be free, what should be paid for?

Overflow question

6. What further professional learning support do you anticipate you will need for teaching science effectively?

CLOSE

Thank you for your participation in this research.

APPENDIX 5: EXPERT ADVICE ON *PRIMARY CONNECTIONS*

The Expert Advice evaluation sought to answer the following research question in relation to the *Primary Connections: Linking Science with Literacy – Stage 6 Project*:

Effectiveness RQ 3.3 What else can the Primary Connections program offer to assist teachers and pre-service teachers to implement the Australian science curriculum?

Advice from a small group of experts in science education on potential developments for *Primary Connections: Linking Science with Literacy,* with particular emphasis on Stage 6, was sought. One of the main functions of this data collection was to inform the design of surveys to be conducted in the evaluation. However, the advice is valuable in its own right and has been reported separately here.

Method

Selection of Experts

Four experts were identified for interview. Three were available for interview. The interviewees were two professors and one associate professor in education. Each was located in a different state or territory in Australia. All had extensive experience in researching primary science and in conducting science professional learning with primary school teachers. The experts all had extensive knowledge of *Primary Connections*, though for some the experience with *Primary Connections* was more recent than for others. Two of those interviewed had conducted and reported research on *Primary Connections*. Two of the experts had extensive experience in working in and conducting research in regional, rural and remote settings. Further detail on the characteristics of those interviewed is not provided in order to protect their anonymity.

Data Gathering and Analysis

Interviews ranged from approximately 35 minutes to 60 minutes. The interviews were audio recorded. The interview protocol consisted of the interviewer explaining the purpose of the research and reminding the interviewee that the interview was part of a research project focused on *Primary Connections* Stage 6. This was followed by a brief statement about Stage 6 before confirming that the experts understood what the research was about.

Each expert was then asked what else *Primary Connections* could do beyond what it was already doing. The intention was to follow up with a more specific question related to the *Australian Curriculum: Science* but all experts commented on this without prompting. Further prompting questions and comments were then used throughout the interview to encourage the respondents to elaborate further on views expressed. All respondents were asked specifically about the extent to which professional learning in relation to *Primary Connections* might be facilitated online. The interviews were free flowing with the experts expressing diverse views with little prompting from the interviewer.

Notes were taken during the interview. Content from interviews pertaining to the research question were checked and notes corrected by updating with verbatim records from recordings. A thematic analysis was conducted by the *Primary Connections* Stage 6 evaluation's lead researcher. The transcriptions were analysed to identify themes using open coding. The analysis was carried out while listening to digital recordings of the interviews to take into account the tone and oral expression of the spoken word.

The themes identified in the open coding were used as the basis of reporting the findings (see below). Some similar themes were collapsed, forming fewer overall themes in the reporting than in the original coding.

Some responses were specifically related to regional, rural and remote provision of professional learning. These are reported first. Other advice pertained to *Primary Connections* more broadly, e.g. professional learning, resources, and ongoing evaluation.

Findings

ADVICE

All experts spoke very highly of *Primary Connections.* Comments on the overall merit of the program included statements that it has been 'excellent' and 'outstanding'.

All experts commented favourably on the role *Primary Connections* is playing in supporting the *Australian Curriculum*. More specifically, they noted that the resources clearly identify the ways in which they facilitate the implementation of the *Australian Curriculum: Science* Foundation Year to Year 10. Particular comments were made on how the implementation of the *Curriculum* could be supported further by members of the *Primary Connections* team monitoring learning outcomes through ongoing evaluation. Some advice was also provided on the development of inquiry skills, as emphasised in the *Australian Curriculum*. Comments on these matters are noted below.

REGIONAL, RURAL AND REMOTE SETTINGS

Involve secondary science teachers in the Primary Connections Stage 6 workshops

One expert explained:

If going face-to-face in rural and regional areas to deliver programs to primary teachers then they [the primary teachers] also need to work with secondary teachers. Given that secondary teachers may be primary teachers themselves, early career, overseas trained, teaching out-of-field [then] they all need to know what is happening in primary science. And they need to be able to manage transition to secondary. If you're going to do a single thing, then they [the Primary Connections team members] need to work with a broad range of teachers [in rural settings].

Work with groups of teachers and schools that are relatively close to each other

Most rural and regional areas have a feeder high school or they are a district high with a primary. Could bring feeder schools to centre, and do not just do one-off workshops. Need to build a community of practice – a professional learning community. And these require constant input to maintain.

If you are trying to get change within a school, you need a critical mass for people to talk and share with each other about how something is going. There should be two or more teachers from the one school and as many teachers as possible from a regional area within one hour's travel of each other to allow for ongoing collaboration after the initial workshop.

Modify workshops to meet needs of different contexts

One expert argued that doing the same workshop in varied contexts was less than ideal and proposed that the workshops take into account the contexts of teachers attending the workshops.

You need to know about the areas and the needs and the different mix that exists in remote areas. So, doing the same thing [an identical workshop] in each place is not likely to work. It needs to be adapted for the needs of different contexts.

Need to understand the culture, teacher turnover, teacher trauma in those [remote and disadvantaged] schools [and adapt PD accordingly].

Professional Learning

The prevailing view appeared to be that *Primary Connections* has, and could continue to have, a role in supporting the *Australian Curriculum: Science*. However, effective support depends as much on supporting teacher professional learning as it does on the production of resources. The experts commented extensively on ways in which the *Primary Connections* professional learning program could be enhanced.

- Focus professional learning on groups of teachers not individual teachers

All three experts argued that *Primary Connections* currently tends to focus on individual professional learning. To be more effective, they proposed that it should focus on workshops for groups of teachers (as noted above) and promote collaboration among these teachers for the long-term implementation of *Primary Connections*. The group could be from a school, from a cluster of schools, or from an area where the members of the group are within a reasonable driving distance of each other.

What the [Primary Connections] team do is essentially is a 'train the trainer' model, a cascade model. The focus is on individual teachers. Now the research is very clear that teachers working together over a period of time will result in better sustained professional learning.

While primary schools have a number of disciplines upon which to focus, it is possible for a school to select science at a given time. When the school makes the decision to focus on science, then the teachers at that school can work together. The principle of teachers working together is more powerful than individual teachers trying to improve learning by themselves. So, the focus has to shift to teams rather than individuals. They [the Primary Connections team] need to contact and work through schools rather than individuals.

They could work through the principal so that we make science a priority for a year. The school would set up a school plan with support from Primary Connections. It should be broader than just implementing Primary Connections. The professional learning could revolve around a school plan that meets their perceived need. The Primary Connections resources could contribute to meeting this need.

- Ongoing professional learning beyond workshop

All interviewees were emphatic that ongoing professional learning beyond the *Primary Connections* workshop is essential if the goals of *Primary Connections* are to be achieved.

After the initial workshop teachers need to be encouraged to teach a unit or units over a year and provide reflections and feedback. A lot of positives come from this follow up [such as] teaching the units and reflecting on the teaching through a feedback questionnaire. It [is] like ongoing teacher development. To get changes that are sustained there has to be some sort of longer term involvement of the teachers with Primary Connections materials in the classroom preferably with them being able to talk with people involved in Primary Connections. Longer involvement in professional development will pay off.

- Blended model of professional learning

All interviewees proposed a blended model of professional learning. They all asserted the value of face-to-face workshops but argued the benefits of the face- to-face workshop could be leveraged with online professional learning activities and/or additional face-to-face sessions.

Learning is a social experience so operating on face-to-face wherever possible but electronic systems can be used for face-to-face. It doesn't work as well but it could be used. The preference is always face-to-face but using technology to enhance the face-to-face dimension makes sense. It's not either/or.

Should use video [of teachers using Primary Connections in classes] with at least two videos of teachers implementing and working with Primary Connections [and this should be] shared and feedback provided so that they get ongoing advice on Primary Connections in practice.

There needs to be follow up ongoing PD and follow-up investigating [researching of] the teaching and learning [of Primary Connections in practice]. There need to be incentives to encourage teachers to use Primary Connections resources and to use the 5Es. They need to come back together to share experiences and ideas *about teaching with Primary Connections and the 5Es and to work with each other. They need the opportunity to come back to work together, face-to-face or online, to talk to each other about how things are going [and this could be] facilitated by a Primary Connections team member. It would be ideal if these follow up workshops could be run in different parts of the state to bring people together to talk about things and to talk about what Primary Connections could do to support them.*

Target Audience for Professional Learning

There were varied views among experts on the optimal target audience for *Primary Connections*. One expert expressed the view that the current pre-service teacher audience was appropriate. Others recommended different target groups, identified below.

- Early career teachers after 2 years

One expert recommended that professional development in *Primary Connections* should be aimed at early career teachers after they had had a few years of experience as teachers.

The pre-service teachers are a captive audience but those in the first years of teaching are least able to bring about change. A better audience to tap into would be those just out of the first two or three years of teaching when they have a long career ahead of them. They are discerning and can determine what will work in their school with their students.

- University lecturers

Another recommendation was that the target audience for a *Primary Connections* professional development program ought to be primary science teacher educators rather than university students. It was also suggested that the *Primary Connections* team should seek to work in close collaboration with teacher educators to facilitate the use of *Primary Connections* in primary teacher education programs.

Primary Connections stage 6 is delivered directly to pre-service teachers. Those pre-service teachers have to attend a workshop that is voluntary. This is a huge negative. Most pre-service teachers are time poor with work, family, university demands. This disadvantages too many pre-service teachers. Parents with children to look after on Saturday for example, they have to make the decision on whether to go the extra mile on Saturday. It would be so much better if we could make it [Primary Connections] part of the main course.

Focus should be on university [primary science teacher educator] staff, not pre-service teachers. The expectation would be that university staff would integrate Primary Connections back into their [teacher education] standard courses. This would be a much better investment. It could become part of the pre-service teachers' assessment work and built into the work they do at university. As it is, it is an add on. It needs to be integral to their teacher education program.

Need to bring together teacher educators and Primary Connections people. Then determine how Primary Connections can help teacher educators. You could develop resources, not for but with, teacher educators to enhance the work that they do. Develop [professional learning] resources so each group [Primary Connections developers and teacher educators] can help each other.

Focus on the Later 5Es in Future Professional Development

One expert proposed that professional learning in *Primary Connections* should concentrate on the more challenging, the last three, of the 5Es. The expert also stressed that fidelity to the program sequence is not an end in itself. Consequently, *Primary Connections* professional learning should help teachers to understand and assess the science learning they were trying to bring about.

Teachers are very good at 'elicitation' and 'engagement' but have mixed capabilities with the explain phase and [limited] understanding of the elaborate and evaluate phases. For example, [among teachers] evaluate is focused on what was learned without dealing with reflecting on how it was learned. [There is a] need to ensure that [there is] effective implementation of the 5Es scheme and that all of the phases are used most of the time. Not that the scheme is sacred and that you must always have all of the components. Once you have evidence *that they have understood and learnt, the scheme isn't important. But teachers have to get to the evaluate stage or they will not know whether and what the students have learnt. Need to ensure that PD leaders are pushing the full scheme and need to gather data to determine whether the 5E scheme is being implemented with fidelity.*

Primary Connections and the 5Es: Emphasis on the 'key idea' While Enacting the 5Es with Flexibility

There is also a need to ensure that teachers are aware that they are working towards students developing an understanding of a key idea and it's not just about following the program.

… the teachable moment and professional noticing. The 5Es steps are guides and they are all important but you need the flexibility where the 5Es are a guiding principle and the Primary Connections program provides a plan of action but teachers need to be able to use teachable moments that arise and this may cause teachers to move in and out of the precise steps.

Resources

- Provide *Primary Connections* in differentiated forms

One expert argued that *Primary Connections* is primarily serving the needs of the top 50% of the primary school student population. This expert recommended varying the program resources to meet needs of the lower 50% of the population.

Primary Connections [has] a very middle class top 50% feel – the extension, the challenges are absolutely fantastic but it is catering for the top 50% and the research [data] seems to be mostly coming from the top 50% with the assumption you can generalise to the lower 50%. So, there is a need for study of implementation and adaptation to meet the needs of the lower 50% of population.

- Serve needs of disadvantaged

[There is a need to serve] the disadvantaged more broadly: refugees, low SES and NESB students. It would be a big challenge but developing a plan to target these groups [would be useful]. Some of these disadvantaged groups have never met anyone with a science degree or a science-related career. Maybe Primary Connections could embed more about careers in science to raise awareness and aspirations.

- Strengthen 'wonder of science', maintain literacy and numeracy emphasis

Continue to build on literacy and numeracy and also strengthen the wonder of science.

Paper-based or Digital Resources

There were divergent views on whether *Primary Connections* should be available as a paper-based resource or an online digital resource or both. One expert recommended that all resources should only be available online and that no hard copy documents should be provided. Another expert indicated that hard copy resources for teachers were likely to be attractive to the current population of teachers. A third expert said that in the current regional, rural and remote environment, paper based resources are essential until schools get reliable internet and adequate bandwidth.

Improving Scientific Inquiry: Gradually Removing Scaffolding

One expert argued that the scaffolding of inquiry in *Primary Connections* should be gradually reduced in some units and across the program as a whole.

There is a need to determine what teachers think it means to engage students in scientific inquiry and how they might gradually remove the scaffolding that is evident in Primary Connections to move responsibility from what students are doing more and more to them [the students] and to do so by gradually, removing scaffolding over time. So, Primary Connections needs to elaborate on, and work with teachers on, how they can gradually do this. And the Primary Connections team needs to be able to work over time with teachers on how they do this and this will require working on teacher beliefs.

Focus Primary Connections Resources on Primary School Students Not Teachers

One argued that *Primary Connections* resources should be digital and that these should be fundamentally primary school student resources.

The digital focus has to be on the students. At the moment, the resources are focused on and produced for the teacher. They need a digital mechanism that functions much as the student booklet used to. The digital resource can be interacting and dynamically visual. The core of the Primary Connections activities still was hands on but the digital student resource can help the student undertake hands on activities in a simpler way. The teacher resource or teacher guide is then built around the student resource. The professional learning has to be built on current [professional learning] research. Primary Connections is a tremendous brand and well-recognised by teachers. By embracing digital technology, Primary Connections can become even better.

Make Primary Connections Free

One expert argued that the resources had to be free to increase penetration and ensure wider access and use.

Stop selling materials. It has to be free. Give away any leftover materials at the cost of postage and make all resources digital. The hard copy is a big cost and money should not be expended on publishing more hard copies.

Ongoing continuous evaluation by the Primary Connections team

One expert suggested that there is a need for continuous evaluation by the *Primary Connections* team of teachers' use and understanding of the 5Es [as mentioned earlier] as well as their implementation of the [national] curriculum. This was in addition to periodic independent evaluations that have been conducted.

The national curriculum is embedded in Primary Connections but [as part of the work of the Primary Connections team] there needs to be follow up to determine the extent to which teachers are teaching and students are learning the curriculum.

Teacher Beliefs

One expert argued that there is a need for *Primary Connections* to:

conduct research into teachers' initial beliefs [prior to workshops] about teaching and learning in science and then gather data progressively about how these beliefs change and develop [as they use Primary Connections].

Conclusion

The experts provided a range of advice on what else *Primary Connections* could do. The underlying position expressed was that *Primary Connections* provides support for the implementation of the *Australian Curriculum: Science* Foundation Year to Year 10 (particularly Foundation to 6).

Recommendations specific to the *Australian Curriculum: Science* included:

- gradually reducing scaffolding to enhance the development of students' capability for increasingly independent scientific inquiry;
- emphasising the latter three Es in the 5Es model, including strengthening teachers' understanding of explain, elaborate (application) and evaluate phases; and
- ensuring teachers focus on student learning of key ideas expressed in *Primary Connections* (which are entirely consistent with the *Australian Curriculum: Science)* rather than the implementation of the *Primary Connections* program of study per se. (That is, recognise that the 5Es and *Primary Connections* program are a means to an end, not the end in and of themselves.)

With regard to *Primary Connections* Stage 6, some of the advice is broadly consistent with current *Primary Connections* endeavours, e.g. providing professional learning workshops in local areas to attract relatively closely located teachers.

Advice on adapting workshops to meet the needs of local contexts and attracting secondary teachers to *Primary Connections* workshops to ensure that they are well informed about *Primary Connections* could also be considered.

Acting on advice that *Primary Connections* resources should be adapted to meet the needs of a more diverse range of learning and learners could contribute to broader uptake of the resources.

There was agreement advising that:

- the focus of professional learning should shift from individual teachers to groups of teachers who can work together after and between professional learning events;
- one-off Primary Connections workshops need to be expanded with the provision of follow up professional learning activities which could include virtual and face-to-face interactions, and sharing and feedback among teachers as well as with the Primary Connections lead facilitators; and
- face-to-face workshops are valuable and critical but opportunities for on-going professional learning, including online activities, should be explored and implemented.

The only points of significant disagreement among experts were on whether teacher and student *Primary Connections* resources and units should be accessed online or provided as hard copy, and the extent to which online professional learning could be implemented now. It is as if *Primary Connections* is on the cusp of needing to move from being primarily available as hard copy to being primarily available online but two of the experts doubted that this action should be taken immediately. It seems that the fundamental difference in opinion is not whether resources should be online or hard copy; rather, some experts are concerned that internet access is poor for some teachers. This makes online resources unattractive until access improves. It seems that access to online primary science education resources in schools may be inadequate, suffering from connectivity or bandwidth limitations. Similarly, in addition to face-to-face workshops, online professional learning may offer some benefits, not least being flexibility of access, but currently internet access in schools is perceived to be inadequate for the task.

Addressing this broad problem related to internet access is beyond the scope of the *Primary Connections* program and this evaluation. Nevertheless, it is important to take into account the quality of internet access available to regional, rural and remote teachers in considering future developments of *Primary Connections*. With this in mind, the attractiveness of various modes of professional learning, including face-to-face workshops, online activity and blended learning, is discussed further elsewhere in the evaluation when reporting on focus groups and survey findings.

APPENDIX 6: REPORT ON BEST-WORST SCALING (BWS) AND PROGRAM PERCEPTIONS

This report was commissioned by the Australian Academy of Science and prepared by researchers from the University of Technology Sydney (UTS). The assistance of members of UTS' Centre for Business Intelligence and Data Analytics (BIDA) is acknowledged, particularly the role of Dr Edward Wei.

Executive Summary

This report examines perceptions of the *Primary Connections* program as nominated by in-service and pre-service teachers. The research was undertaken to identify perceptions of the program, its outcomes, and improvements that can be made in terms of its delivery and content.

Several rounds of consultation were undertaken with key stakeholders (teachers, consultants, administrators, academics) as well as reviewing existing literature to identify a list of areas of investigation to improve the *Primary Connections* program. Following this, primary school teachers completed a survey to assess the perceptions of the program and its outcomes. A set of questions was also included to inform the improvement of the content areas of the program. To do so, teachers completed a Best-Worst Scaling (BWS) task within the survey. The BWS task asked teachers to consider small subsets of 25 topic areas over several iterations. On each occasion, teachers ranked the presented topic areas in order of importance as appropriate for including in the *Primary Connections* program. From the data obtained, a predictive model was developed. The predictive model quantifies the probability that a topic area will be nominated as more important in their professional learning relative to the other potential topic areas examined in the study.

Both in-service and pre-service teachers indicate an interest in science, they enjoy teaching science, and are confident in doing so. The interest and level of comfort in teaching science was more pronounced among in-service teachers. Just over 55% of pre-service teachers indicated that the teachers at their schools have good background knowledge in the area and more than a third have colleagues who lack the confidence and skills to teach primary science competently or understand the syllabus. On the other hand, almost 80% work at schools where teachers report having a positive attitude to the teaching of primary science.

Schools are somewhat supportive of professional learning with 75% reimbursing in-service teachers for such activities, 59% of teachers suggested their school had a strong emphasis on primary science and 64% suggested their school was well resourced for primary science teaching. Almost a third of teachers work at schools where teachers are not given the opportunity to receive ongoing professional learning in primary science.

Almost two thirds of in-service teachers have accessed *Primary Connections* resources through printed booklets, whilst half use Scootle. Only 41% access the resources through the *Primary Connections* website. The vast majority of in-service teachers were interested in professional learning that provides annotated videos demonstrating how to teach *Primary Connections*, but less open to receiving feedback from experts on their own *Primary Connections* lessons.

In-service and pre-service teachers prefer workshops that are face-to-face or a combination of online and face-to-face delivery. The majority of in-service teachers opposed the use of online only workshops. Only a third of in-service teachers are likely to attend workshops that take place on a weekend or during school hours. On the other hand, close to 70% of pre-service teachers are likely to attend workshops at these times.

The top 10 areas nominated by in-service teachers as being relatively more important for inclusion in *Primary Connections* professional learning were (in order of importance):

- Investigation-based science
- Science teaching strategies
- Guiding inquiry in science
- Adapting *Primary Connections* for multi-stage classes
- Understanding the *Primary Connections* approach

- Various ways of teaching each 5Es phase
- Differentiating *Primary Connections* for student diversity
- Activity-based science
- Doing hands-on science activities
- Implementing *Primary Connections* units

Pre-service teachers were largely in agreement with these being the most important topic areas, with the exception of *Understanding the Primary Connections approach* and *Adapting Primary Connections for multi-stage classes,* which they ranked lower in importance.

At the other extreme, both pre- and in-service teachers agree the following four areas were the least important for inclusion in the *Primary Connections* program:

- Developing *Primary Connections* professional learning networks
- Collaboration with fellow teachers or pre-service teachers
- Management and organisation of science equipment and materials
- Argument-based science

The impact of the *Primary Connections* workshops has been to increase confidence among teachers in a number of areas, particularly in terms of understanding the aims of the program, the 5Es teaching and learning model, and the relationship between science and literacy. Both in-service and pre-service teachers were less likely to nominate that the workshops improved their confidence in being able to apply the research that *Primary Connections* is based on. More than 97% agreed that they would recommend the *Primary Connections* workshop to other teachers and a similar number of teachers indicated that it would increase the likelihood of implementing the program in their teaching.

Study Participants and Experiences with *Primary Connections*

The survey was completed by 126 in-service teachers and 171 pre-service teachers during the summer holiday period (December 2017 to January 2018). The survey was undertaken with the approval of UTS Human Research Ethics Committee (HREC ETH17-1280). The survey was completed online following an invitation sent by email by the AAS to in-service and pre-service teachers who had completed a *Primary Connections* workshop. Teachers took a median of 14.8 minutes to complete the survey.

There were 184 pre-service teachers who commenced the survey. Among them, 20 respondents did not qualify for various reasons (e.g. did not agree to participate or had not taught within the last five years). Of the qualified 166 respondents, 126 respondents completed the survey. This resulted in a response rate of 76.8% of the total qualified in-service teachers. In the case of pre-service teachers, there were 224 respondents who commenced the survey. Among them, only one respondent did not agree to participate. Of the qualified 223 respondents, 171 respondents completed the survey in full. This resulted in a response rate of 76.7% of the total qualified pre-service teachers.

All participating in-service teachers had taught in the last five years. Several had additional experience in teaching at high school, with 16% having taught in Years 7 to 10 and 6% having taught in Years 11 and 12. With the exception of kindergarten, there was a uniform representation of experiences in teaching across the primary year levels, both in terms of current and recent teaching experiences.

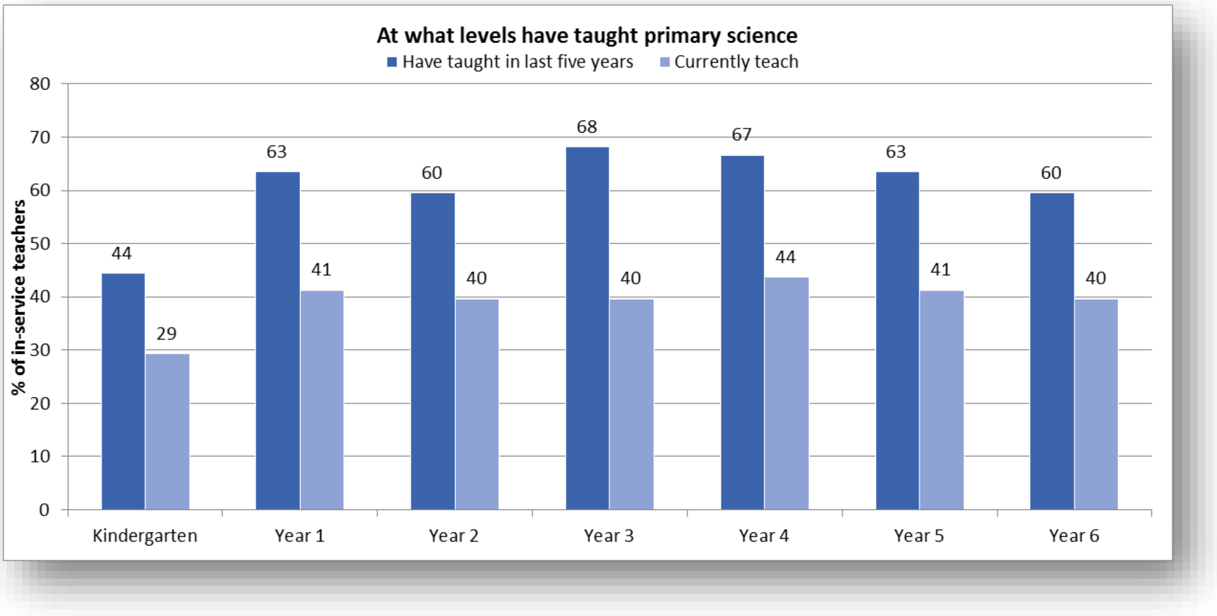


FIGURE 7. EXPERIENCES IN PRIMARY TEACHING (BY YEAR)

Teachers were represented from all states and territories. In-service teachers were asked to report upon the school at which they were working. The majority of in-service teachers surveyed came from small cities or towns, particularly those located in the country rather than coastal areas. Only 6% of teachers were from a capital city.

Pre-service teachers were asked to indicate the location of the university at which they were studying their teaching degree. Pre-service teachers were more likely to be from larger cities or towns, including those located in the country (23%), coast (23%) or the capital (40%).

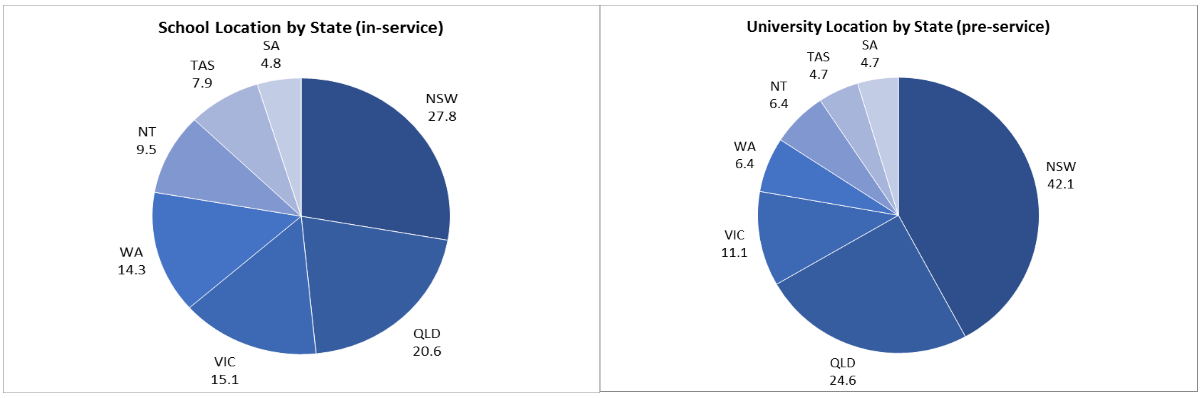


FIGURE 8. LOCATION OF RESPONDENT (BY STATE)

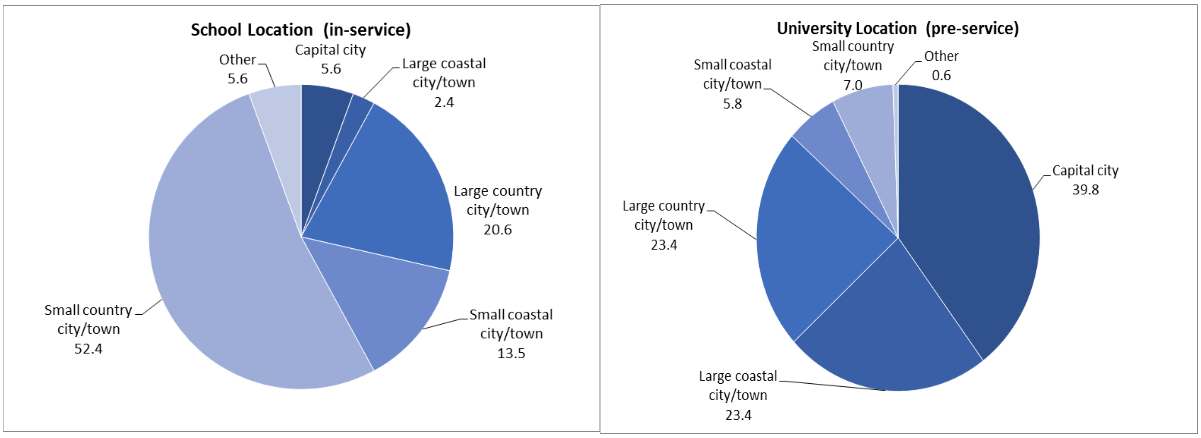


FIGURE 9. LOCATION OF RESPONDENT (BY REGION)

Experiences in using *Primary Connections* varied across the in-service and pre-service teachers surveyed. In the case of in-service teachers, 81% had previously used *Primary Connections* in their classrooms. Of these, around two-thirds had used less than 10 units, and half had used six or less units. With respect to usage, 60% had taught entire units.

The majority of access to *Primary Connections* resources was via printed booklets and Scootle. In contrast, only two out of every five teachers were utilising the *Primary Connections* website for resources.

TABLE 7 EXPERIENCES IN USING PRIMARY CONNECTIONS IN THE CLASSROOM (IN-SERVICE TEACHERS)

	%
Previously used Primary Connection units in classroom	81.0
Number of Primary Connections units used:	
1 to 3	14.7
4 to 6	35.3
7 to 9	13.7
10 to 13	16.7
14 to 16	7.8
16 to 19	0
20 or more	10.8
Usage:	
Taught entire units	59.8
Used parts of units	40.2
Accessing resources:	
Primary Connections website	40.5
Printed booklets	65.1
Scootle	50.8
Other	6.3

The support of the school with respect to teachers' experiences of professional learning varied. Three out of four in-service teachers were reimbursed for their professional learning activities. Around the same number volunteered to undertake the workshop, with 18% being nominated by executive staff to do so.

School and Teacher Capabilities in Science Teaching

Perceptions of school capabilities with respect to primary science teaching also varied. Less than 60% of in-service teachers agreed that their school places a strong emphasis on primary science and almost a third indicated that their school is not well resourced for the teaching of primary science. In-service teachers indicated that the majority of their colleagues had a positive attitude to the teaching of primary science. On the other hand, just over half agreed that the background knowledge of teachers in the area of primary science was good. Around 62% indicated that teachers had the confidence and skills and understanding of the syllabus to teach primary science competently. Among in-service teachers, 31% indicated that teachers have the opportunity to receive ongoing professional learning in primary science.

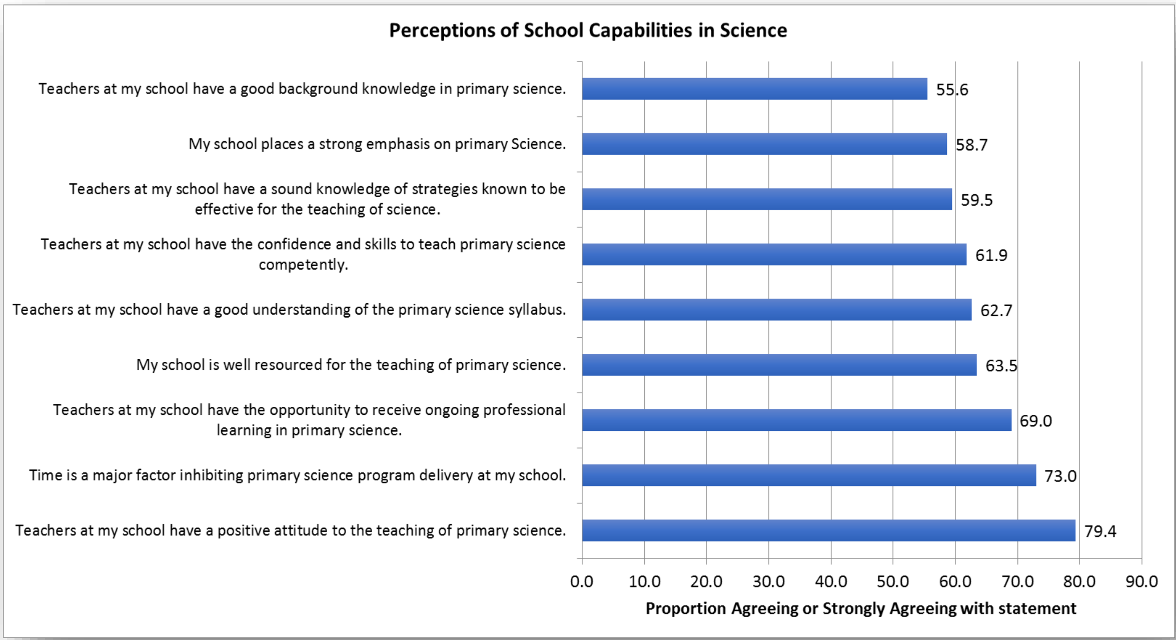


FIGURE 10. PERCEPTION OF SCHOOL CAPABILITIES IN PRIMARY SCIENCE TEACHING

Teachers in the current study were much more confident in their colleagues' capabilities in science than has been indicated by other studies examining teacher and school capabilities in other areas. For example, Burke et al. (2017) report that in a study of those working in NSW Independent Schools, only 39% agreed that their colleagues had the confidence and skills to teach the subject of primary Science and Technology competently, whilst 35% agreed that other teachers had sound knowledge of strategies for effective teaching in this area. Similarly, teachers participating in the current study were more positive about the general attitudes of teachers to the subject area. Burke et al. (2017) reported that 59% agreed that other teachers had positive attitudes to the teaching of Science and Technology (59%), whilst a similar level of agreement had been reported in a study by Aubusson and Griffin (2011), which focused on teachers of Science and Technology in NSW government schools. In the current study, 63% reported confidence in their understanding of the syllabus as compared to a figure of 41% and 43% for the two comparative studies conducted by Aubusson and Griffin (2011) and Burke et al. (2017) respectively.

In Burke et al. (2017) similar questions were asked of teachers regarding perceptions of the schools' capabilities. With respect to resources, 39% of NSW AIS teachers agreed that their school was well resourced for the teaching of primary Science and Technology, and 51% of teachers agreed that they worked at schools that provided opportunities for other teachers to receive ongoing professional learning in primary Science and Technology. In the current study, it appears that teachers feel their schools are better resourced for science teaching, with 64% agreeing that they perceive this to be the case.

The experiences and attitudes to science and primary science teaching were largely positive among pre-service and in-service teachers. The overwhelming majority of in-service teachers (95%) disagreed that they were not interested in science, whilst 93% indicated that they enjoyed teaching the subject. Experiences with respect to studying science whilst at high school were mixed, with 28% indicating that they had a negative experience. The experiences of in-service teachers were more positive with respect to science teaching. Significant differences were detected with respect to interest, enjoyment and comfort in teaching science. However, there were no detectable significant differences across the two teacher groups with respect to confidence in science teaching.

The levels of confidence and enjoyment in teaching science are higher relative to teachers surveyed in other settings. For example, Burke et al. (2017) report that 88% of NSW AIS teachers surveyed agreed that they enjoyed teaching primary Science and Technology and only 83% of those teachers agreed that they were comfortable teaching the subject.

TABLE 8 ATTITUDES TO SCIENCE TEACHING (IN-SERVICE AND PRE-SERVICE TEACHERS)

	In-service (n=126)		Pre-service (n=171)		
Statements regarding science and science teaching	Mean	S.D.	Mean	S.D.	
I am not that interested in science (R)	9.22	1.47	8.85	1.68	*
I enjoy teaching science	8.65	1.73	7.98	1.73	**
I am not that confident in teaching science (R)	8.09	2.28	7.69	2.12	
I'm quite comfortable teaching science	7.98	1.84	7.35	1.69	**
I had negative experiences at high school with respect to science (R)	7.14	2.91	5.91	3.04	**

Items were measured on a 10-point scale with 1=strongly disagree to 10=strongly agree.

(R) = items are reverse coded.

*/** Significant difference across two groups at the p <.05/.01

Perceived Value of *Primary Connections* Workshops

Teachers were extremely positive about *Primary Connections* workshops. Almost all in-service teachers would recommend the workshop to other teachers. The majority of teachers strongly agreed that the workshops increased the likelihood of implementing the program in their teaching. Among in-service teachers, 98% agreed that *Primary Connections* helps in their ability to implement the *Australian Curriculum: Science* and more than half strongly agreed that *Primary Connections* would improve student achievement in this regard.

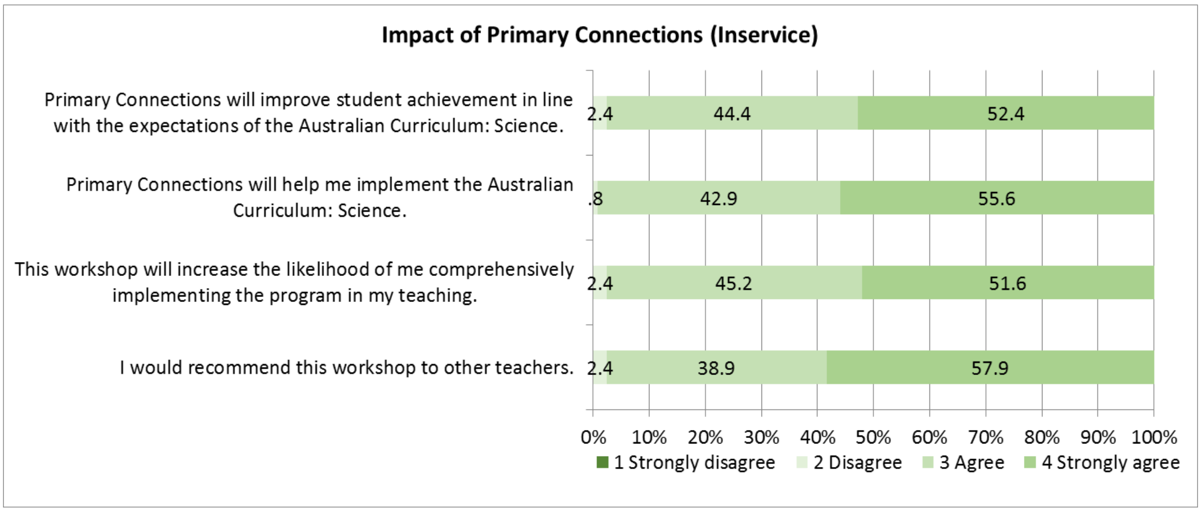


FIGURE 11. PERCEIVED VALUE OF *PRIMARY CONNECTIONS*

The impact of having completed a *Primary Connections* workshop increased teachers' confidence in a number of different areas. More than four in five teachers agreed that the workshops increased their confidence in their ability to use the range of *Primary Connections* resources, increased their understanding in relation to the major principles of *Primary Connections* and the 5Es teaching and learning model, as well as increasing their confidence in understanding the relationship between science and literacy. Around three in four teachers indicated that the workshops increased their confidence to use *Primary Connections* tools to enhance student learning in science and literacy. There were no significant differences in the level of agreement amongst the pre-service and in-service teachers in relation to these outcomes reported in the Figure below.

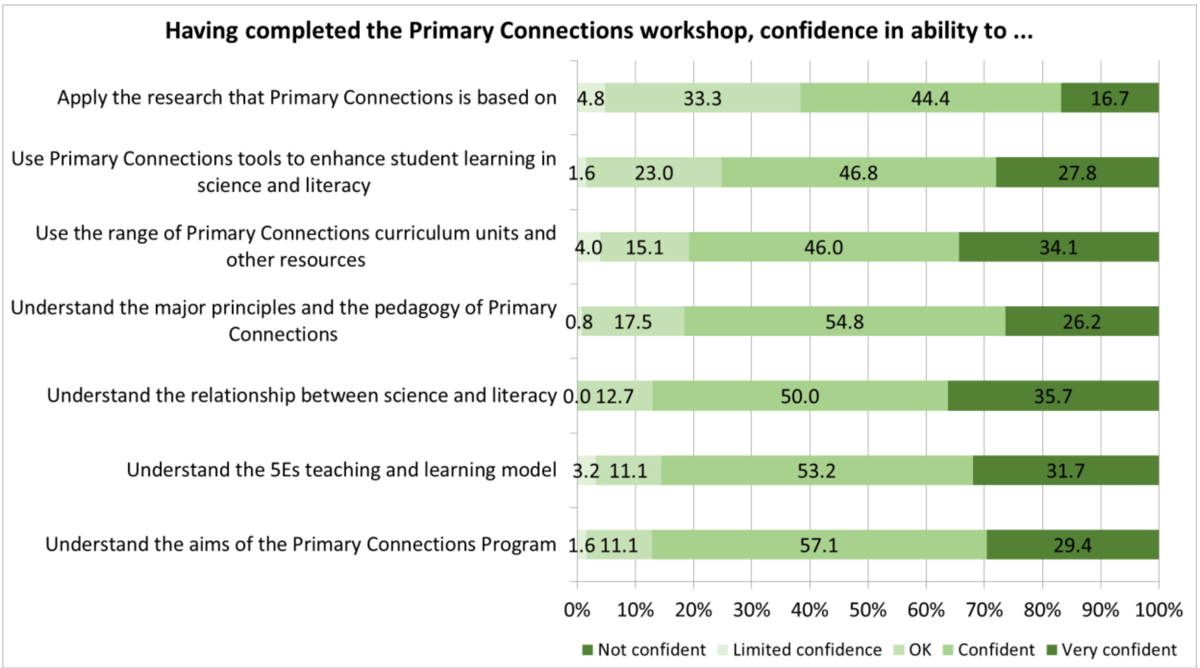


FIGURE 12. IMPACT OF *PRIMARY CONNECTIONS* WORKSHOPS ON CONFIDENCE OF IN-SERVICE TEACHERS

Preferences relating to *Primary Connections* workshops

Teachers were asked to express their preference for variations in the *Primary Connections* workshops in terms of delivery mode, location, timing, costs, facilitation and supporting resources.

In relation to delivery mode, both pre-service and in-service teachers overwhelming preferred workshops that were face-to-face only. Around three in four teachers indicated that they would to attend a workshop in which a combination of online and face-to-face delivery was offered. In the case of workshops that were delivered entirely online, less than half of in-service teachers agreed that they were likely to attend. Pre-service teachers were more open to online-only delivery, with 53% expressing that they would be likely or very likely to attend a workshop delivered in this manner.

Participants were also asked about their likelihood of attending workshops if the location of the learning site varied with respect to travel time. Not surprisingly, almost all teachers agreed that they would be likely to attend if the travel time was 30 minutes or less. Workshops involving travel time of more than four hours or involving a flight were agreeable to around a third of in-service teachers and less than a sixth of pre-service teachers. In comparison, more in-service teachers were in favour of an overnight stay, however, only 45% were in support of workshops offered in this way. Pre-service teachers were less receptive to workshops involving overnight stays, with only 22% of such teachers indicating that they would be interested in attending.

Among in-service teachers, workshops taking place during school hours were much more preferable relative to professional learning activities taking place after school, on the weekend or during school holidays. In contrast, pre-service teachers preferred workshops run on a weekend or during school holidays.

Not surprisingly, teachers preferred free workshops. Around 17% of in-service teachers would not attend if the workshop cost $100 and only 39% would consider a workshop that cost between $100 and $400. The overwhelming majority would not consider attending workshops costing more than $400. The sensitivity to costs of participating in workshops was more pronounced among pre-service teachers than in-service teachers.

Teachers were largely indifferent to the workshop facilitator's experience, but in-service teachers were more in favour of someone with recent teaching experience as compared to a science education expert.

TABLE 9 PREFERENCES AMONG WORKSHOP FORMATS

	Likelihood of attending workshop (In-service teachers)					In-service	Pre-service
Delivery mode:	Very unlikely	Unlikely	Neutral	Likely	Very likely	Likely or very likely	
Face-to-face only	0.8	2.4	4.8	31.0	61.1	92.1	95.9
Online only	13.5	23.8	18.3	28.6	15.9	44.4	52.6
Combination of online/face-to-face	3.2	9.5	15.1	42.9	29.4	72.2	74.3
Location of learning site (travel time):	Very unlikely	Unlikely	Neutral	Likely	Very likely	Likely or very likely	
30 minutes travel	4.8	0.8	2.4	15.9	76.2	92.1	99.4
2 hours travel	15.9	11.9	11.9	27.8	32.5	60.3	36.3
4 hours travel	24.6	24.6	15.9	17.5	17.5	34.9	13.5
A flight	37.3	20.6	10.3	15.9	15.9	31.7	15.2
Overnight stay	30.2	14.3	10.3	23.8	21.4	45.2	22.2
Timing of professional learning:	Very unlikely	Unlikely	Neutral	Likely	Very likely	Likely or very likely	
After school	10.3	11.9	17.5	35.7	24.6	60.3	69.6
During school hours	0.8	2.4	1.6	40.5	54.8	95.2	62.6
On a weekend	18.3	27.0	19.0	19.0	16.7	35.7	75.4
During school holidays	26.2	22.2	19.0	18.3	14.3	32.5	69.6
Cost of participation:	Very unlikely	Unlikely	Neutral	Likely	Very likely	Likely or very likely	
Free	0.0	0.8	0.8	10.3	88.1	98.4	100.0
$100	0.8	4.0	11.9	39.7	43.7	83.3	65.5
Between $100 and $400	11.1	25.4	24.6	27.8	11.1	38.9	14.0
Greater than $400	51.6	27.8	15.1	3.2	2.4	5.6	1.2
Facilitator:	Very unlikely	Unlikely	Neutral	Likely	Very likely	Likely or very likely	
Has recent teaching experience	0.0	0.0	3.2	31.0	65.9	96.8	94.2
Is a science education expert	0.0	1.6	11.1	34.1	53.2	87.3	92.4

Teachers were also asked about their likelihood of attending workshops depending on the support that was offered outside of the workshops. In-service teachers were least receptive to support coming in the form of feedback from experts on their own *Primary Connection*s lessons. Around four in five were likely to participate in workshops if they were supplemented with online spaces to share ideas or to ask questions of experts. The most popular professional learning support came in the form of annotated videos demonstrating how to teach with *Primary Connections*. The level of support for all these initiatives was much higher among pre-service teachers, with more than 90% in agreement that they would be likely or very likely to attend if these resources were available.

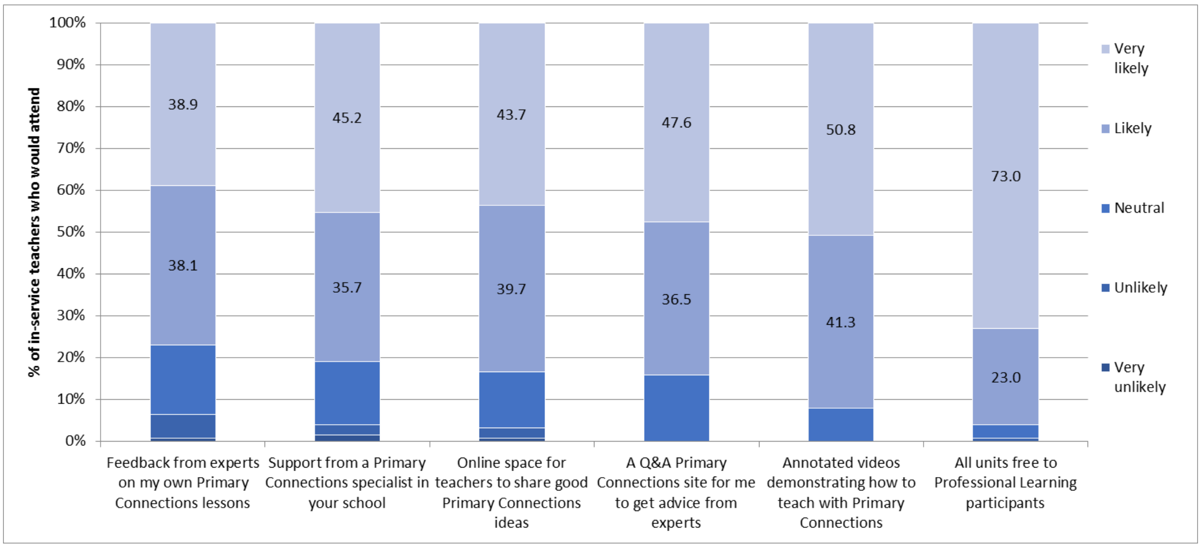


FIGURE 13. PREFERENCE FOR PROFESSIONAL LEARNING SUPPORT RELATING TO *PRIMARY CONNECTIONS*

Developing the list

A comprehensive list of factors was generated initially by drawing from the data gathered in six focus groups following *Primary Connections* professional learning workshops. Three of these were undertaken with pre-service teacher participants and the other three were conducted with in-service teacher participants. The list was refined and focused through discussion amongst science education experts on the research team in a two-stage meeting process. In the first meeting, the list was extended through adding items that were consistent with the stated goals and aims of the *Primary Connections* professional learning workshops that were not evident in the focus group data. In the second meeting, the number of items was reduced through categorising similar factors and with a concern for clarity.

The final list of factors used in the study is presented in Table 10. The next stage of the research was to understand which of the listed items were perceived by teachers to be more important to their professional learning than others. To do so, an instrument using Best-Worst Scaling (BWS) was developed.

TABLE 10 STATEMENTS TEACHERS WERE ASKED TO CONSIDER IN BWS STUDY

List of topics included in study
Science pedagogy
Science content knowledge
Australian National Science Curriculum
Argument-based science
Evidence-based science
Investigation-based science
Activity-based science
Guiding inquiry in science
Literacy in science

Science concepts in *Primary Connections* units
Collaboration with fellow teachers or pre-service teachers
Developing *Primary Connections* professional learning networks
Implementing *Primary Connections* units
Implementing the 5Es
Science teaching strategies
Doing hands-on science activities
Understanding the *Primary Connections* approach
Student collaborative learning in science
Differentiating *Primary Connections* for student diversity
Adapting *Primary Connections* for multi-stage classes
Various ways of teaching each 5Es phase
STEM in primary schools
Integration of digital technologies in science
Condensing *Primary Connections* units to the available time
Management and organisation of science equipment and materials

The Best-Worst Scaling Methodology

An extensive list of 25 topics in *Primary Connections* professional learning was derived.

The overarching objective of the current research undertaking was to understand which topics are more significant in terms of their importance to in-service and pre-service teachers in relative terms. For instance, is it more preferable to teachers to learn about adapting *Primary Connections* for multi-stage learning or to manage and organise science equipment and materials?

One approach that could be useful to understand which topics are perceived to be more important than others would be to ask questions about each topic and ask teachers to rate each on an appropriate scale, such as one that ranges from 1=not at all important to 7=very important. This approach, however, does not entice teachers to directly consider which topic is perceived as more important than another, because each topic is considered one-at-a-time. In this way, a teacher could, in fact, nominate that all topics are a '7' because they are all relevant to their teaching in some way or another. That is, rating each topic one at a time may not reveal which barrier matters more because respondents have no clear incentive or instruction to make any trade-offs when asked about items in isolation, and may simply indicate that everything matters (Carson et al., 2000). And, knowing that "everything matters" does not help understand where to focus strategic efforts and resources to help develop professional learning resources. What can be more revealing is to place teachers in a situation that forces them to nominate which topic is more relevant than another, in relative terms. Best-Worst Scaling is an approach that was selected as a means of doing this.

Best-Worst Scaling (BWS), also known as Maximum Difference Scaling (or simply, 'maxdiff'), was developed by Louviere & Woodworth (1990) and first published in 1992 (Finn & Louviere, 1992). Formal mathematical proofs are offered by Marley & Louviere (2005). BWS is a relatively straightforward response elicitation method that asks people to choose the two items from a listing of several items that most and least match a given criterion. To briefly overview how it was used in the current setting, teachers were provided with five topics barriers and then asked to nominate which of the five was most important to include in professional learning in *Primary Connections*. A variation of BWS was used in which teachers were asked to consider topics from most to least important rather than switching from considering the most, then the least, then the 2nd most, as has been used in other studies. Instead, following the nomination of the most important topic, this item was removed from consideration, leaving just four topics. Teachers were then asked to nominate the next most relevant topic. This continued until we had a complete ordering of factors in terms of their relative importance for professional learning.

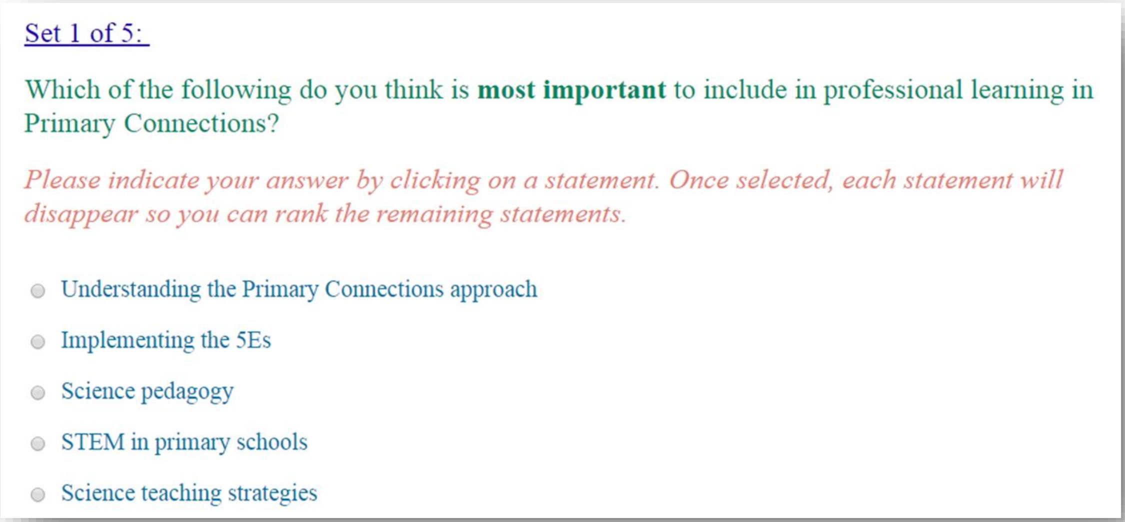


FIGURE 14. EXAMPLE OF BWS TASK

In the BWS task, respondents evaluated five of the 25 barriers at a time. Teachers were asked to nominate the one item that was most important. To do so, the respondent clicked on the corresponding radio button. Upon doing so, this nominated statement disappeared, leaving four topic areas. Teachers continued to nominate topics that mattered more in this way until all five statements in this sub-set were fully-ranked from most to least important. A "none of these are barriers" option was trialed, but found to disrupt the cognitive flow of the task. Instead this item was taken account of with a Likert scale question about the importance of a sub-set of barriers. After a practice set, each teacher completed five tasks nominating the importance of items. The selection of which statements to display was determined by a design that over a large enough sample would reveal which factors, on average, presented themselves as more relevant to respondents as a topic for inclusion in *Primary Connections* professional learning.

The use of BWS is attractive as it forces respondents to discriminate among objects (in this case, barriers) in terms of their relative importance (Louviere and Islam, 2008). Another key characteristic of BWS is that the response scale provided to respondents is a discrete outcome (choice) rather than continuous (e.g. rating on 1 to 7 scale). In doing so, several response style biases can be avoided that have been found in prior research using such scales (e.g. Baumgartner & Steenkamp, 2001; Harzing, Köster, and Zhao, 2012; Van Vaernebergh & Thomas, 2013). For example, some respondents have a tendency to avoid the extreme ends of the rating scales, whilst others have a tendency to remain neutral. BWS is also advantageous because it is cognitively easy for respondents: there is no allocating of points or percentages to items, or a need to rank a lengthy list of items simultaneously (Louviere & Islam, 2008). This choice of scale was motivated by our ambition to make the task easier for respondents to complete, to reduce overall response times, and supported by growing evidence that the use of such indicators does not compromise measurement reliability (e.g. Dolnicar, Grün, & Leisch, 2011; Dolnicar & Grun, 2007; Driesener & Romaniuk, 2006; Grassi, Nucera, Zanolin, Omenaas, Anto, & Leynaert, 2007; Preston & Colman, 2000).

It is worth noting that by its very nature, Best-Worst Scaling purposely minimises inter-item correlation rather than maximises it. That is, our intention was to maximise discrimination in measuring which topics are important to teachers across the 25 areas included for study. Whilst BWS is preferable in cases where one wishes to maximise discriminate validity between items (as in this setting), by its very design it becomes weaker in identifying consistency or correlations within the data, such as those captured by various measures of reliability, including Cronbach alpha.

BWS has been applied in various contexts, including studies in marketing and consumer behaviour (e.g. Auger et al., 2007; Burke et al., 2013; Burke et al., 2014; Louviere & Islam, 2008; Massey et al., 2013), personality research (Lee et al., 2007, 2008), health economics (Lancsar et al., 2007; 2013), and to understand the public's views on climate change (Carson, Louviere & Wei, 2010).

In education, BWS has seldom been used. The first study to introduce the method to education was undertaken by Schuck, Aubusson, Burke, and others (Schuck et al., 2012) to understand which factors impact early career teachers more in their decisions about staying in the profession. Results of the study showed, for example, the importance of collaboration with colleagues in shaping teachers' commitment to the profession relative to other factors, such as class size or support of parents. A more recent relevant application has been undertaken by Palmer et al. to examine the reasons given by school students to reject or to undertake study of a subject, offering fresh insights into ways of stimulating demand for science subject uptake (Palmer, 2015; Palmer et al., 2017).

Best-Worst Scaling Results

The BWS approach allows a score to be determined for each of the 25 statements referring to importance as a topic for professional learning.

The score can be interpreted as an index describing whether a teacher will nominate the barrier as more important relative to another factor, averaged across its co-occurrence with all other factors. The score is best interpreted as a relative measure of importance rather than an absolute measure. Statements with scores that are higher in magnitude are reflective of statements that teachers are more likely to nominate as important to their professional learning. Statements with lower scores are issues that teachers are less likely to nominate as important. To aid interpretation, each score has been standardized with respect to the least and most important topic, scored 0 and 100 respectively. Items scored closer to 100 have been nominated by teachers in the sample as topics that are more relevant in professional learning, whilst items with scores closer to zero are relatively less important in this regard.

The top 10 areas nominated by in-service teachers as being relatively more important for inclusion in *Primary Connections* professional learning were (in order of importance):

1. Investigation-based science
2. Science teaching strategies
3. Guiding inquiry in science
4. Adapting *Primary Connections* for multi-stage classes
5. Understanding the *Primary Connections* approach
6. Various ways of teaching each 5Es phase
7. Differentiating *Primary Connections* for student diversity
8. Activity-based science
9. Doing hands-on science activities
10. Implementing *Primary Connections* units

Pre-service teachers were in agreement with these being the most important topic areas, with the exception of *Understanding the Primary Connections approach* and *Adapting Primary Connections for multi-stage classes*, which they ranked lower in importance.

At the other extreme, both sets of teachers agreed the following four areas were the least important for inclusion in the *Primary Connections* program:

- Developing *Primary Connections* professional learning networks
- Collaboration with fellow teachers or pre-service teachers
- Management and organisation of science equipment and materials
- Argument-based science

The scores sorted by score are presented in Figures 15 and 16 below.

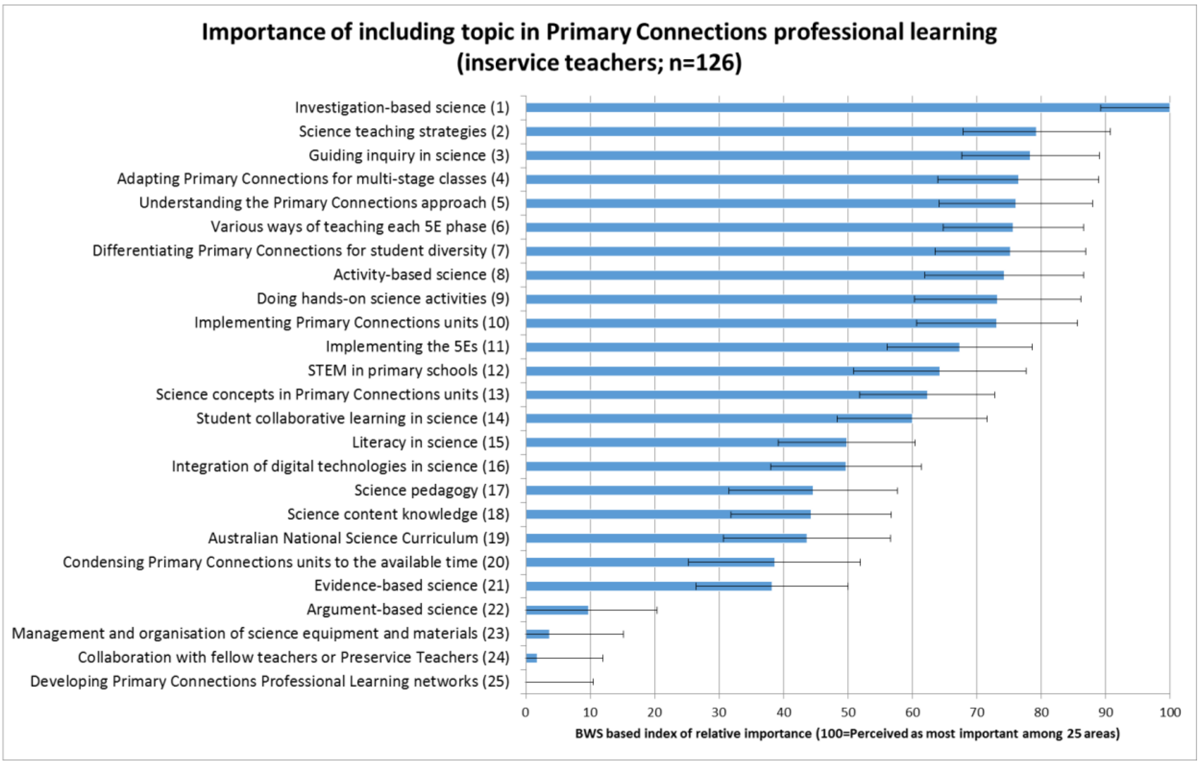


FIGURE 15. RANKING AND SCORES OF IMPORTANCE OF PROFESSIONAL LEARNING TOPIC AREAS (IN-SERVICE TEACHERS)

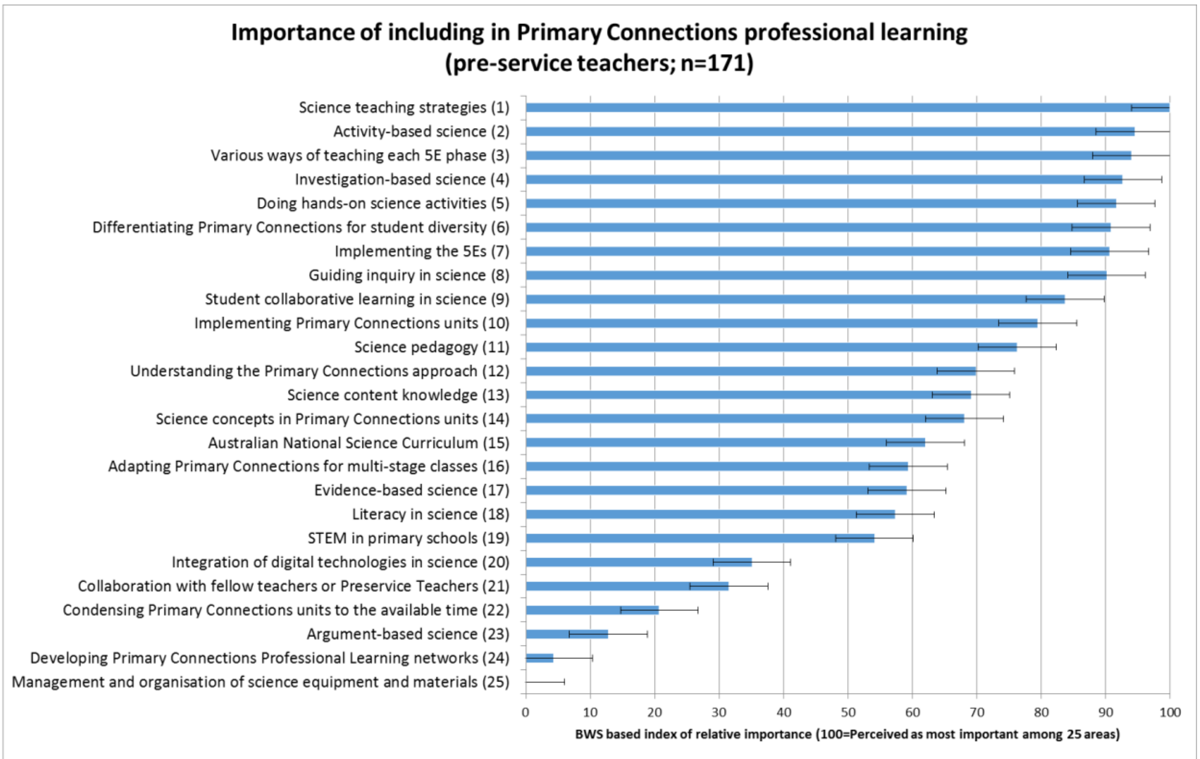


FIGURE 16. RANKING AND SCORES OF IMPORTANCE OF PROFESSIONAL LEARNING TOPIC AREAS (PRE-SERVICE TEACHERS)

A comparison of the two sets of results shows general agreement on the topics of importance, with some exceptions. For example, in-service teachers are more interested in professional learning that deals with adapting *Primary Connections* for multi-stage classes and understanding the *Primary Connections* approach more broadly. In-service teachers are also more interested in the topic of STEM in primary schools than pre-service teachers are. Interestingly, pre-service teachers are much more interested in collaboration with other teachers relative to in-service teachers. Pre-service teachers are also more interested in student collaborative learning in science, implementing the 5Es and science pedagogy.

TABLE 11 BWS-SCORES AND RANKINGS OF TOPICS IN-SERVICE V PRE-SERVICE

Item	BWS Score In-Service	BWS Score Pre-Service	Rank (In)	Rank (Pre)
Investigation-based science	100.0	92.7	1	4
Science teaching strategies	79.3	100.0	2	1
Guiding inquiry in science	78.3	90.1	3	8
Adapting *Primary Connections* for multi-stage classes	76.4	59.4	4	16
Understanding the *Primary Connections* approach	76.0	69.8	5	12
Various ways of teaching each 5E phase	75.6	94.0	6	3
Differentiating *Primary Connections* for student diversity	75.2	90.8	7	6
Activity-based science	74.3	94.5	8	2
Doing hands-on science activities	73.2	91.6	9	5
Implementing *Primary Connections* units	73.1	79.5	10	10
Implementing the 5Es	67.3	90.6	11	7
STEM in primary schools	64.2	54.1	12	19
Science concepts in *Primary Connections* units	62.3	68.1	13	14
Student collaborative learning in science	59.9	83.7	14	9
Literacy in science	49.8	57.4	15	18
Integration of digital technologies in science	49.7	35.1	16	20
Science pedagogy	44.6	76.3	17	11
Science content knowledge	44.3	69.1	18	13
Australian National Science Curriculum	43.6	62.0	19	15
Condensing *Primary Connections* units to the available time	38.6	20.7	20	22
Evidence-based science	38.2	59.1	21	17
Argument-based science	9.7	12.8	22	23
Management and organisation of science equipment and materials	3.6	0.0	23	25
Collaboration with fellow teachers or Preservice Teachers	1.7	31.5	24	21
Developing *Primary Connections* professional learning networks	0.0	4.3	25	24

100= most important; 0 = least important topic relative to other topics listed

References

Aubusson, P., Burke, P., Schuck, S., Kearney, M., & Frischknecht, B. (2014). Teachers Choosing Rich Tasks: The Moderating Impact of Technology on Student Learning, Enjoyment, and Preparation. *Educational Researcher*, *43*(5), 219-229.

Aubusson, P., Schuck, S., Ng, W., Burke, P.; & Pressick-Kilborn, K. (2015). Literature review. Quality Learning and Teaching in Primary Science and Technology. Sydney: Association of Independent Schools New South Wales. Available at: https://www.aisnsw.edu.au/Services/EducationResearch/Latest%20Research%20Documents/Primary%20Science%20and%20Technology%20Literature%20Review%202015_FINAL.pdf

Aubusson, P. & Griffin, J. (2011). Science & Technology teaching & professional learning preferences. A report on research conducted for NSW Department of Education and Training.

Auger, P., Devinney, T., & Louviere, J. (2007). To What Extent Do Consumer Ethical Beliefs Differ Across Countries? A Cross-Country Investigation Using Best-Worst Scaling Methodology. *Journal of Business Ethics*, *70*(3), 299-326.

Baumgartner, H., & Steenkamp, JEM (2001). Response styles in marketing research: A cross-national investigation. *Journal of Marketing Research, 38* (2), 143-156.

Burke, P. F., Aubusson, P. J., Schuck, S. R., Buchanan, J. D., & Prescott, A. E. (2015). How do early career teachers value different types of support? A scale-adjusted latent class choice model. *Teaching and Teacher Education*, 47, 241-253.

Burke, Paul F., Peter Aubusson, Sandy Schuck, Tracey-Ann Palmer, Kimberley Pressick-Kilborn and Wan Ng (2017). Barriers to effective teaching in primary Science and Technology. A study using Best-Worst Scaling. Association of Independent Schools New South Wales (AISNSW), Sydney: Australia. Retrieved from: http://ow.ly/xYh5307QtsS

Burke, P. F., Eckert, Christine & Davis, Stacey (2014). Segmenting Consumers' Reasons For and Against Ethical Consumption, *European Journal of Marketing,* 48(11/12), 2237-2261.

Burke, P.F., Louviere, J.J., Wei, X., MacAulay, G., Quail, K. & Carson, R. (2013). Overcoming challenges and improvements in best-worst elicitation: Determining what matters to Japanese wheat millers', International Choice Modelling Conference 2013, Sydney, Australia, July 2013 in *Proceedings of International Choice Modelling Conference 2013*, Ed (Anon), Open Conference Systems, Sydney, Australia, pp. 1-19.

Burke, P. F., Schuck, S., Aubusson, P., Buchanan, J., Louviere, J. J., and Prescott, A. (2013). Why do early career teachers choose to remain in the profession? The use of best–worst scaling to quantify key factors, *International Journal of Educational Research*, Vol. 62, pp. 259-268.

Carson, R. T., Groves, T., & Machina, M.J. (2000). Incentive and informational properties of preference questions. Working paper, San Diego: University of California, San Diego

Carson, R. T., Louviere, J. J., & Wei, E. (2010). Alternative Australian climate change plans: The public's views. *Energy Policy*, 38(2), 902-911.

Dolnicar, S. (2013). Asking good survey questions. *Journal of Travel Research, 52*(5), 551-574.

Dolnicar, S., & Grün, B. (2007). How constrained a response: A comparison of binary, ordinal and metric answer formats. *Journal of Retailing and Consumer Services, 14*(2), 108-122.

Dolnicar, S, Grün, B, & Leisch, F. (2011). Quick, simple and reliable: forced binary survey questions, *International Journal of Market Research, 53*(2), 231-252.

Finn, A. & Louviere, J.J. (1992). Determining the appropriate response to evidence of public concern: The case of food safety. *Journal of Public Policy and Marketing*, 11(1), 12-25.

Grassi, M., Nucera, A., Zanolin, E., Omenaas, E., Anto, J. M., & Leynaert, B. (2007). Performance comparison of Likert and binary formats of SF-36 Version 1.6 across ECRHS II adults populations. *Value in Health, 10*(6), 478-488.

Harzing, A., Köster K., and Zhao, S. (2012). Response style differences in cross-national research. *Management International Review 52*(3), 341-363.

Lancsar, E., Louviere, J.J., & Flynn, T.N. (2007). Several methods to investigate relative attribute impact in stated preference experiments. *Social Science & Medicine*, 64 (8), 1738-1753.

Lee, J. A., Soutar, G.N., & Louviere, J. (2007). Measuring Values Using Best-Worst Scaling: The LOV Example. *Psychology & Marketing*, 24(12), 1043-1058.

Lee, J. A., G. Soutar, and J. Louviere. (2008). "The Best-Worst Scaling Approach: An Alternative to Schwartz's Values Survey." *Journal of Personality Assessment*, 90(4): 335-347.

Louviere, J., & Islam, T. (2008). A Comparison of Importance Weights and Willingness-To-Pay Measures Derived from Choice-Based Conjoint, Constant Sum Scales and Best-Worst Scaling. *Journal of Business Research*, 61(9), 903-911.

Louviere, J.J. and Woodworth, G.G. (1990). "Best-Worst Scaling: A Model for Largest Difference Judgments," working paper, Faculty of Business, University of Alberta.

Palmer, T. A., 2015. Fresh Minds for Science: Using marketing science to help school science (Doctoral dissertation), University of Technology Sydney (UTS), Australia.

Palmer, T. A., Burke, P. F., & Aubusson, P. (2017). Why school students choose and reject science: a study of the factors that students consider when selecting subjects. International Journal of Science Education, 39(6), 645-662.

Preston, C. C., & Colman, A. M. (2000). Optimal number of response categories in rating scales: reliability, validity, discriminating power, and respondent preferences. *Acta Psychologica, 104*(1), 1-15.

Romaniuk, J. (2008). Comparing methods of measuring brand personality traits. *The Journal of Marketing Theory and Practice, 16*(2), 153-161.

Schuck, S., Aubusson, P., Buchanan, J., Prescott, A., Louviere, J., & Burke, P. (2012). Retaining effective early career teachers in NSW schools. Report for the NSW DEC.

Van Vaerenbergh, Y., & Thomas, T.D. (2012). Response styles in survey research: A literature review of antecedents, consequences, and remedies. *International Journal of Public Opinion Research, 25* (2), 195-217.

APPENDIX 7: DISCRETE CHOICE EXPERIMENT

Primary Connections: Shaping the Future of In-Service and Pre-Service Teacher Programs – A Discrete Choice Experiment Approach

Executive Summary:

- Nine out ten teachers would highly recommend professional learning workshops in *Primary Connections* to in-service and pre-service teachers.
- A Discrete Choice Experiment was designed to examine the preferences for future workshops and how demand would be affected by variation in timing, location, costs, content, duration and follow-up.
- Discrete Choice Experiments offer several advantages such as

a) allowing alternatives to be considered without concerns that they are correlated and therefore difficult to evaluate in terms of what features are driving demand;

b) forcing trade-offs to be made with respect to these features to reveal relative importance rather than an indication that all features are important; and

c) examining alternatives that have not been offered before with respect to professional learning.

- A total of 270 teachers completed an online survey, with 30% of respondents being pre-service teachers. Just fewer than 20% were living in remote locations, 32% in small towns, 31% in larger towns and the remaining 18% living in a capital city.
- The most important driver of choices relating to attending a future *Primary Connections* workshop was fees. Seven out of ten in-service teachers indicated that they would be reimbursed for such activities, with 39% indicating that a workshop of $400 would be borne at their own expense.
- The remaining drivers of choice, in order of importance, were travel time, the timing of the workshop, additional follow-up, duration and content.
- Teachers prefer workshops to be held during the school term and on a weekday. Pre-service teachers in large cities and in-service teachers in small or remote towns also show interest in workshops held on a Saturday. All teachers are unlikely to attend workshops held in the evening. There is a strong preference to hold workshops on Mondays and Fridays during school hours.
- Workshops requiring more than two hours travel are much less likely to be attended.
- For workshops held in capital cities, 41% of teachers would have to travel less than two hours to attend, 64% would stay in a hotel or serviced apartment and around a third with friends or family, with the vast majority (72%) travelling alone.
- The content of the workshop was of less concern relative to other workshop features.
- Teachers were most interested in accessing 24/7 videos or an expert online discussion after workshops, and less welcoming of receiving a phone-call from an expert as a form of follow-up to a *Primary Connections* workshop.
- Teachers much prefer face-to-face workshops, particularly pre-service teachers. The strongest preference is for face-to-face workshops held during term.

Background and Objectives

An external independent evaluation and research for *Primary Connections* Stage 6 (2014 – 2018) has been conducted by researchers from the University of Technology Sydney (UTS).

The evaluation project was commissioned by the Australian Academy of Science (AAS) with particular reference to work undertaken under the 6th stage funding agreement with the Australian Government.

The purpose of the Stage 6 Evaluation was to:

- provide a summative evaluation of the work completed under the current funding agreement through an assessment of outcomes against the Stage 6 objectives; and
- assess the impact of the program more broadly in order to enable program improvement.

The Stage 6 objectives are:

- to increase the uptake of *Primary Connections* in schools.
- to support primary school teachers and pre-service primary school teachers to teach science through inquiry.
- to ensure primary school teachers, pre-service primary teachers and school educators are informed about *Primary Connections*.

As such, the purpose of this research component was to evaluate aspects of the program in terms of identifying important considerations that participants may use in evaluating a potential invitation to participate in more professional learning activities relating to *Primary Connections*.

Background to Discrete Choice Experiments and Choice Modelling

Every day people make trade-offs as they make decisions. For instance, when choosing a cereal, a consumer may consider whether it has a five-star health rating against whether it is a cereal that they think is tasty or good value for money. In purchasing a car, a consumer may evaluate whether it has good mileage against the car's make and model. Essentially, decision makers must consider each alternative in terms of its attributes and judge whether these attributes are important to them or not, to make a holistic evaluation of the alternative. This allows them to then judge each alternative against each other alternative, and choose the one option that is right for them based on all these trade-offs.

A Discrete Choice Experiment (DCE) is a method that is used to understand how decision makers make trade-offs between the various features or attributes of options about which they must make a choice. A choice experiment is used to quantify which features of an option are more or less attractive to decision makers, or whether such features are ignored entirely when other features are in play. To do so, a choice experiment involves observing choices among alternatives when the features of the alternatives are systematically altered. For example, if a decision maker consistently chooses a red car over a blue car or a yellow car, regardless of the price of the car, we learn that colour is important to this decision maker, more so than price. We also learn that the decision maker prefers red cars to cars that are blue or yellow in colour.

In the current study, the focus is on understanding the preferences of pre-service and in-service teachers for potential professional learning workshops that *Primary Connections* may conduct in the future. For example, *Primary Connections* may offer workshops at various times of the year (e.g. during school holidays), days and times of the week (e.g. Friday evening), at different locations (e.g. requiring three hours travel time), with different types of content being focused upon (e.g. multi-age classes). The purpose of the research is to consider how teachers evaluate potential professional learning workshops. If teachers are consistently observed to choose workshops that are held in school holidays rather than during term, regardless of the content being focused upon, we learn that teachers focus on timing more than content when evaluating potential workshops, and teachers are more likely to attend a workshop offered during term, all else being equal.

There are a number of ways data can be gathered to observe how teachers respond to variation in workshops and their willingness to attend a workshop. In the current context, examining how teachers responded to past programs may make it difficult to account for several things. First, a teacher's choice to attend a workshop in the past may have been impacted by one or more factors that are difficult to separate with just one observation. Even over multiple observations, certain attributes may always co-occur (e.g. a workshop was always held on a particular day in a particular location) and it would be difficult to understand what the critical attribute of the workshop is (e.g. the location or the day the workshop is held). Second, the design of future workshops may result in opportunities that have never been evaluated by teachers – as such, it is difficult to know the demand for workshops that may be held on different occasions of differing length, with different content or differing levels of follow-up support from workshops held in the past.

Another way of evaluating which attributes of workshops matter is to survey teachers and ask about the importance of each attribute one-at-a-time on a suitable scale (e.g. Likert scale of most to least important). Unfortunately, teachers are likely to indicate that every attribute of a workshop is important, since there is no incentive not to, nor ability to consider each attribute against each other (Carson & Groves 2007).

A survey conducted using a Discrete Choice Experiment provides opportunities to present options that are entirely hypothetical and may not already occur in a person's environment of study. It also allows the impact of various factors, particularly those relating to multicollinearity, to be controlled and minimised. It allows the observation of teachers' preferences to go beyond what they have already experienced to date and to observe what happens when some elements are removed, introduced or varied from what is currently offered. It is done in a way that some elements can be held constant to observe what happens when other features are varied. A choice experiment asks respondents to consider an environment where they must trade-off various solutions, thereby revealing which solution component is more valued relative to another.

With respect to scholarly works, the earliest accounts of choice experiments can be traced as far back as research undertaken by Thurston (1927), who was interested in describing how decision makers undertake pairwise comparisons (i.e., selecting one option out of a pair of options). Similarly, work by Luce (1959) in mathematical psychology and McFadden (1974) in economics are seminal works in these respective areas. The field of choice modelling and choice experiments gained traction when applications began to appear in transport and marketing (e.g. Ben-Akiva and Lerman 1985; Louviere & Hensher 1982; Louviere & Woodworth 1983). Since then, other fields including health economics have benefited (e.g. Train 2009). To date, much of the work in choice experiments in education has been introduced by researchers at UTS in areas such as teacher retention, technology adoption and student learning (Aubusson et al., 2014; Burke et al., 2013; Burke et al., 2015; Burke et al., 2018; Schuck et al., 2010; Palmer et al., 2018).

Survey Instrument and Design of Discrete Choice Experiment

A DCE was used to understand how teachers make trade-offs between potential workshops conducted by *Primary Connections* with respect to a number of factors including location of workshops, timing, duration, content, follow-up and fees.

Following a series of screening questions, teachers were provided the following background to the task:

Workshop Scenarios

Primary Connections conducts professional learning workshops throughout the year that aim to enhance primary school teachers' confidence and competence for teaching science. These workshops and training materials focus on developing students' knowledge, understanding and skills in both science and literacy.

We would like you to imagine that you have decided to undertake some *further* professional learning to develop your skills as a primary school teacher.

The next part of the survey will present several alternative professional learning workshop scenarios. Please compare the alternatives presented and indicate which one you prefer.

Teachers were then presented the following information about the task and the features that they would be evaluating:

Workshop Scenarios

Three options will appear on the next screen. Each of the options will be described by several attributes.

Location: Workshops are described as being conducted face-to-face or as a webinar. Face-to-face options are described in terms of the number of hours it will require you to travel to the workshops. This may require you to drive, take a train, bus or a plane. Please consider your current situation in terms of what it would mean to travel to multiple workshops or those requiring more than 2.5 hours of travel (e.g. accommodation arrangements).

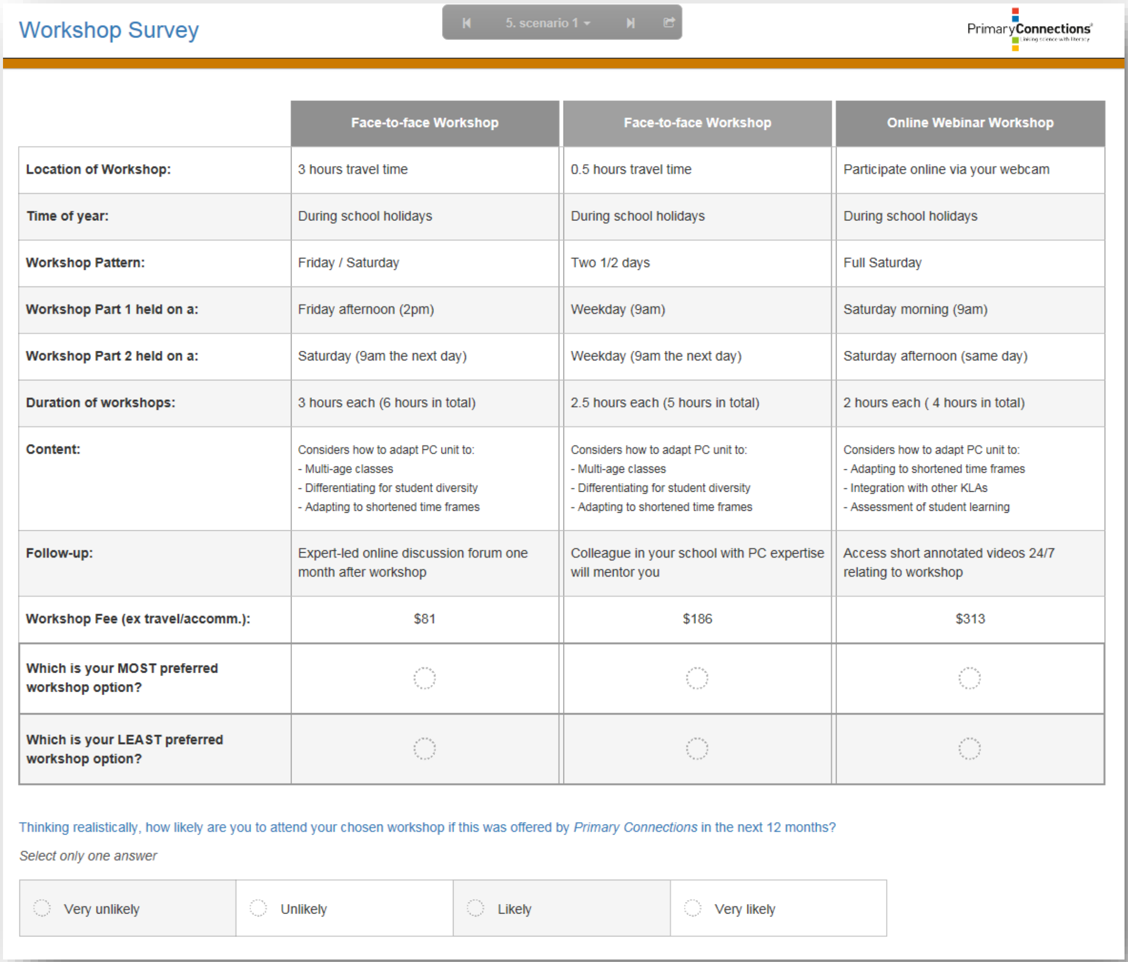
Timing and Duration: Workshops may be held on weekdays, evenings or on the weekend and occur during the school term or holidays. Starting times are shown in brackets. Workshops are held on one day or spread over two days.

Content: Workshops cover several topics relating to adapting *Primary Connections* units.

Follow-up: Alternatives are described in terms of possible follow-up support that you may be provided after completing the workshop.

Workshop Fee (excluding travel or accommodation costs): A fee is shown for each professional learning option. This covers the resources described and catering for any face-to-face workshop, but does not include any costs associated with travelling to the workshop or accommodation. Later in the survey, we will ask you about travel and accommodation arrangements, including whether you have costs reimbursed by your school or are able to stay with friends when attending one of these workshops.

The first of ten choice scenarios was then presented to respondents. An example of the task is presented in Figure 17.



Workshop Survey

5. scenario 1

PrimaryConnections

	Face-to-face Workshop	Face-to-face Workshop	Online Webinar Workshop
Location of Workshop:	3 hours travel time	0.5 hours travel time	Participate online via your webcam
Time of year:	During school holidays	During school holidays	During school holidays
Workshop Pattern:	Friday / Saturday	Two 1/2 days	Full Saturday
Workshop Part 1 held on a:	Friday afternoon (2pm)	Weekday (9am)	Saturday morning (9am)
Workshop Part 2 held on a:	Saturday (9am the next day)	Weekday (9am the next day)	Saturday afternoon (same day)
Duration of workshops:	3 hours each (6 hours in total)	2.5 hours each (5 hours in total)	2 hours each (4 hours in total)
Content:	Considers how to adapt PC unit to: - Multi-age classes - Differentiating for student diversity - Adapting to shortened time frames	Considers how to adapt PC unit to: - Multi-age classes - Differentiating for student diversity - Adapting to shortened time frames	Considers how to adapt PC unit to: - Adapting to shortened time frames - Integration with other KLAs - Assessment of student learning
Follow-up:	Expert-led online discussion forum one month after workshop	Colleague in your school with PC expertise will mentor you	Access short annotated videos 24/7 relating to workshop
Workshop Fee (ex travel/accomm.):	$81	$186	$313
Which is your MOST preferred workshop option?	○	○	○
Which is your LEAST preferred workshop option?	○	○	○

Thinking realistically, how likely are you to attend your chosen workshop if this was offered by *Primary Connections* in the next 12 months?

Select only one answer

○ Very unlikely ○ Unlikely ○ Likely ○ Very likely

FIGURE 17 EXAMPLE DISCRETE CHOICE EXPERIMENT TASK

The design of the choice experiment was based on focus group data, survey results from the previous Best-Worst Scaling exercise, expert discussions, including those involved in workshop design, and multiple discussions and workshopping with *Primary Connections* staff. These discussions were used to identify the scope of the decision task, the attributes and levels to describe alternatives, and constraints around these.

An experimental design was created which allows alternatives to be presented such that each attribute can be evaluated in terms of its impact on choice, without being correlated with any of the attribute. A considerable number of combinations of workshops could have been presented to respondents. For example, in the present context, with 16 locations x 2 time of year variations x 4 durations x 8 timings of workshops x 8 content x 4 follow-up patterns that could occur, a total of 32768 possible alternatives could be considered. The number of combinations increases when a continuous variable such as workshop fee is introduced. In choice experiments, the alternatives are chosen in a way that systematically spans the multi-dimensional space that describes possible options to gather the greatest amount of trade-off information and learn about preferences in the most statistically efficient manner possible. One such strategy would be to use an orthogonal main effects plan (OMEP) to reduce the number of combinations to just a sub-set (i.e., fractional factorial). In the aforementioned problem, a choice experiment involving just 256 alternatives may be suitable, thereby reducing the demands on sample size to learn about teachers' preferences. Unfortunately, such a design approach using OMEP was unsuitable owing to the anticipation that each feature would not be independently evaluated by simple decision rules described by a main effects model, but rather require potential interaction terms between levels of some features to better describe teacher's decision making. Instead, a combination of sub-set design strategies was used, including Youden designs (a special form of balanced incomplete block design) and fractional factorial designs, and brought together using a completely randomised design executed in real-time via the online survey platform. Some of the aspects of these designs are discussed below.

Each respondent faced three alternatives described by the following features and levels:

Online webinar: Workshops were offered as face-to-face or online webinar workshops. The other attributes of the workshop were then nested, based on whether the offering was face-to-face or online. For example, for webinars, the location of the workshop was described as participating online via a webcam, with workshops of a shorter duration, whereas for face-to-face workshops the location was described in terms of the amount of travel time required to get there in hours, with workshops of a longer duration.

Location: Workshops were described in terms of the travel time required to reach the face-to-face workshop. The time varied between 0 and 7 hours. The times were created using a Poisson distribution, such that the difference between the timings of the face-to-face offerings followed a normal distribution. The distribution of travel-times is shown in Figure 18.

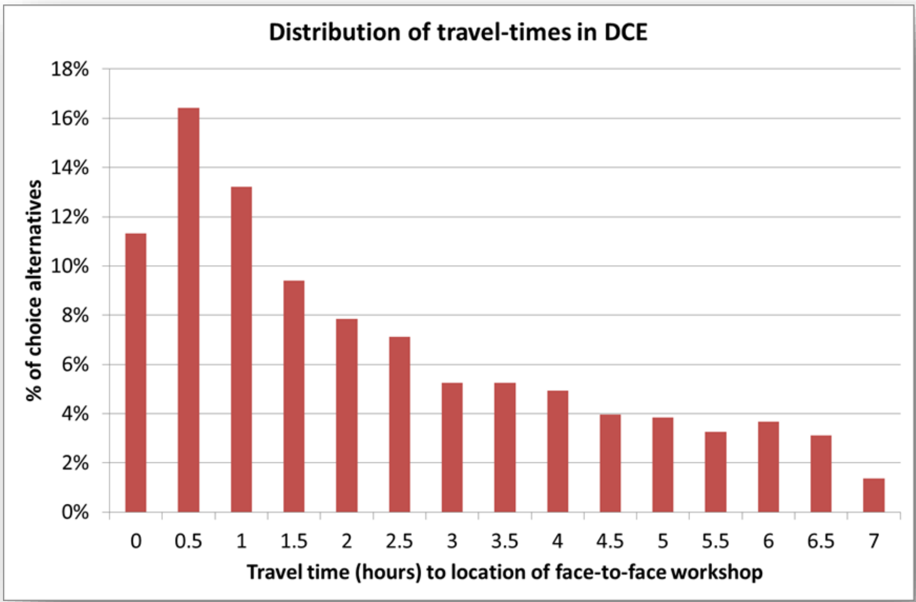


FIGURE 18 DISTRIBUTION OF TRAVEL TIMES

Time of year: Workshops were offered either during school term or during school holidays.

Timing: Options were described in terms of the day of the week the workshop was held (e.g. weekday, Friday or Saturday) along with whether the workshop was held over two separate occasions (e.g. the following week) or consecutively (i.e. the same day or next day). The design also considered the option of whether there would be demand for a 'twilight' option held on a Friday afternoon or evening with another session the next day (i.e. Saturday morning).

Duration:	Face-to-face workshops were described as being 2, 2.5, 3 or 4 hours each (i.e. 4, 5, 6 or 8 hours in total). Online webinars were offered as either 1, 1.5, 2 or 3 hours each (i.e. 2, 3, 4 or 6 hours in total).
Content	A balance incomplete block design was used to describe content on three elements with respect to how to adapt *Primary Connections* units. The eight areas occurred an equal number of times across the design and co-occurred with each other adaptation of content variation an equal number of times. The combinations were varied against an option in which participants could determine the content of the workshop.
Follow-up:	Four types of follow-up were considered against no additional follow-up. The follow-up ranged from initiatives involving phone calls from experts, colleagues as experts in schools, online videos, to expert online discussions.
Fee	Workshop fees were described in dollars. The fee excluded costs that were associated with travel and accommodation. Respondents were asked to report on how they would meet travel and accommodation costs in a later part of the experiment. Costs were drawn from a uniform distribution.

Respondents:

Respondents were invited to complete the survey via an email from *Primary Connections*. Initially, invitations were sent to 1002 in-service teachers who had completed training during 2015 to 2018, 92 of whom had done so in 2018. Another 1602 pre-service teachers who had completed the training were also invited. That is, a total of 2604 teachers were sent an email to participate. Advertisements to complete the survey also appeared on Facebook.

In total, 270 teachers completed the survey in full. Just under a third of participants were pre-service teachers (30%), with a quarter of these being from a school located in a capital city. In-service teachers were located at a diverse range of locations, including schools located in small inland country towns (26%), large inland country cities or towns (17%), coastal cities or towns (16%), or small coastal towns (11%). Only 13% of in-service teachers were from a capital city and 14% were from a remote location, the majority of these inland.

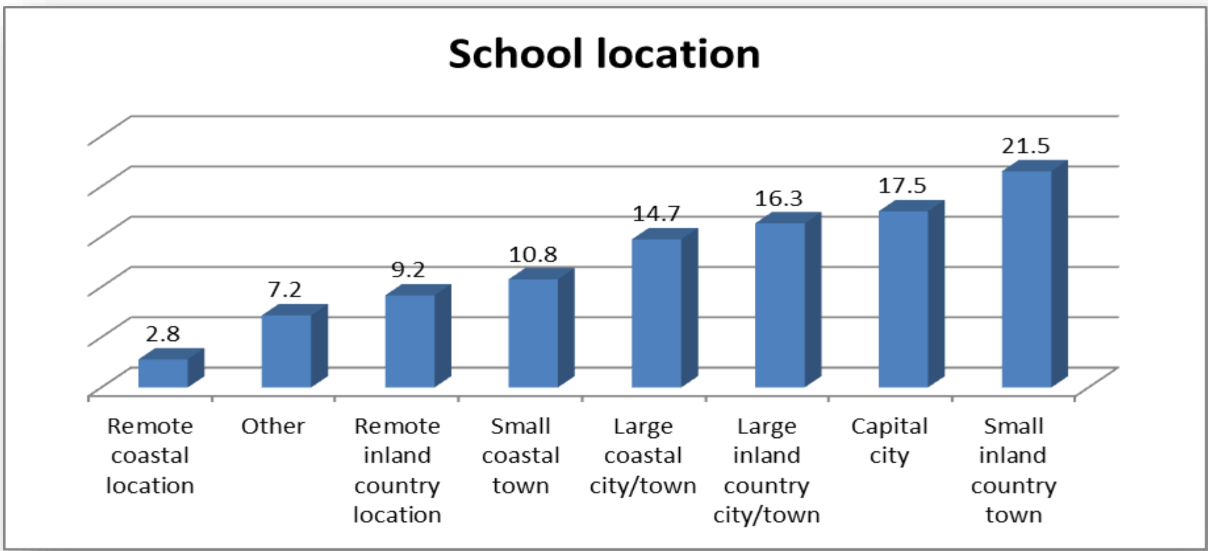


FIGURE 19 SCHOOL LOCATION

The greatest number of respondents came from Queensland (30%), followed by New South Wales (29%), Western Australia (14%), South Australia (6%), Victoria (6%), Australian Capital Territory (5%), Tasmania (4%) and Northern Territory (3%). Most in-service teachers were employed in full-time teaching roles (40%).

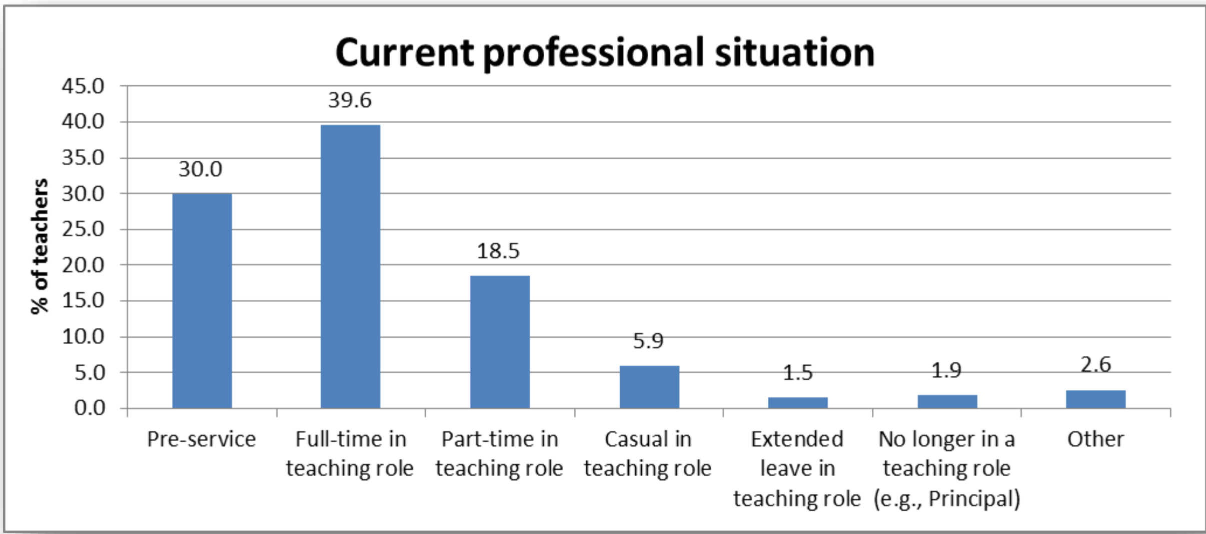


FIGURE 20 CURRENT PROFESSIONAL SITUATION

The median age of respondents was 31-40 years of age, with a range of experiences in primary teaching with respect to how long they had been teaching. All year levels were well represented, with between 46 to 48% of teachers reporting having taught at each of the levels Years 1 to Year 6, and 32% of teachers having taught Kindergarten. Almost half of the sample reported holding a Bachelor's degree as their highest teaching qualification, with 14% holding a postgraduate degree or equivalent in teaching.

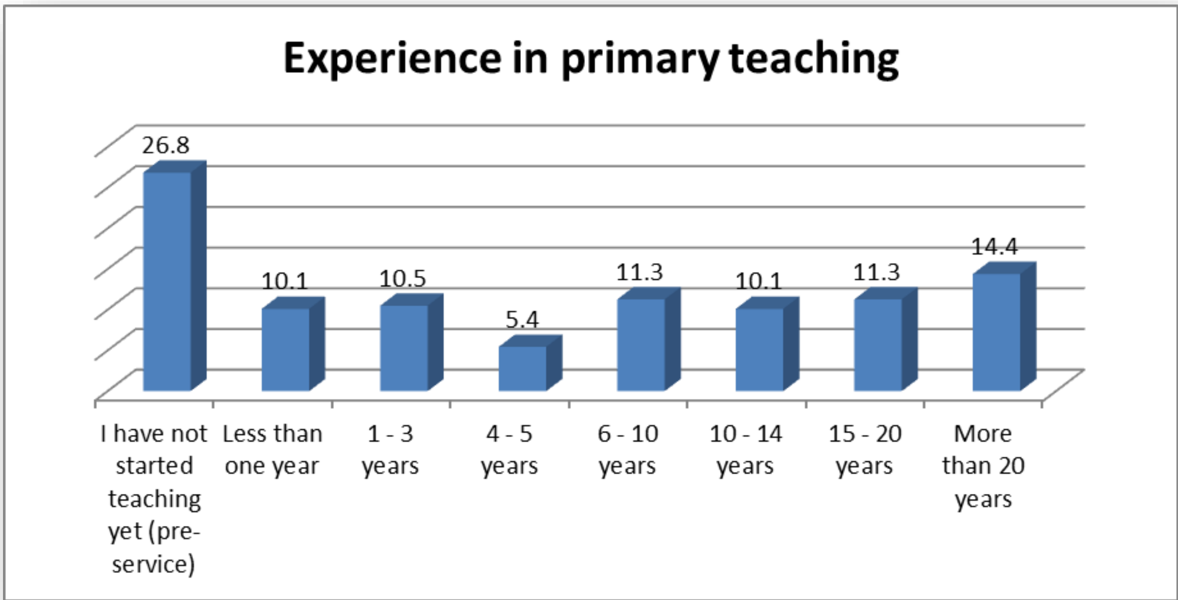


FIGURE 21 EXPERIENCE IN PRIMARY TEACHING

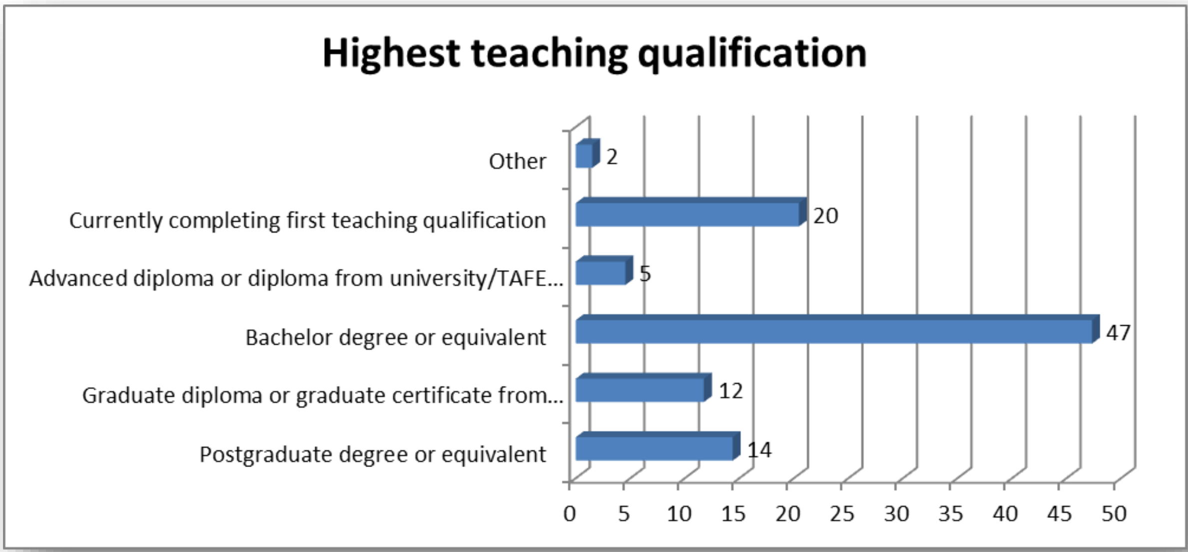


FIGURE 22 HIGHEST TEACHING QUALIFICATION

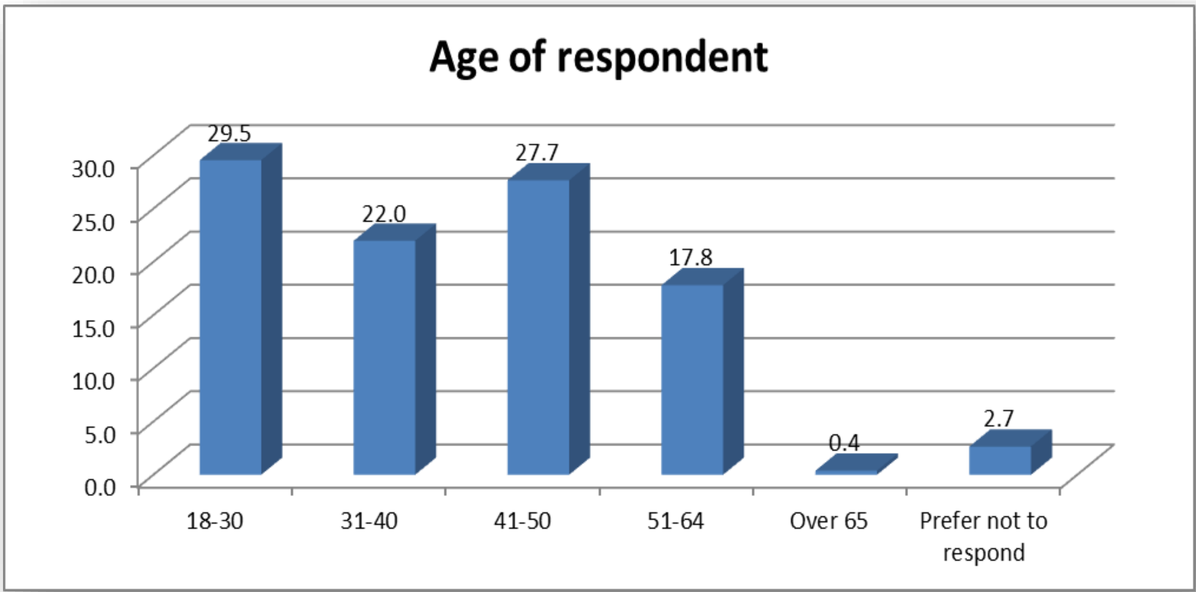


FIGURE 23 AGE OF RESPONDENT

A wide representation of teachers was also surveyed with respect to household composition, work status of their partners, and household income. Most teachers reported being in a relationship, with more than just over half living with children. Whilst 30% reported not having a partner, of those who did, 77% of partners were working full-time, with fewer than 5% being unemployed or not in the workforce. The median household annual income before tax was $88,400, with more than 40% of households having a combined household income of over $104,000.

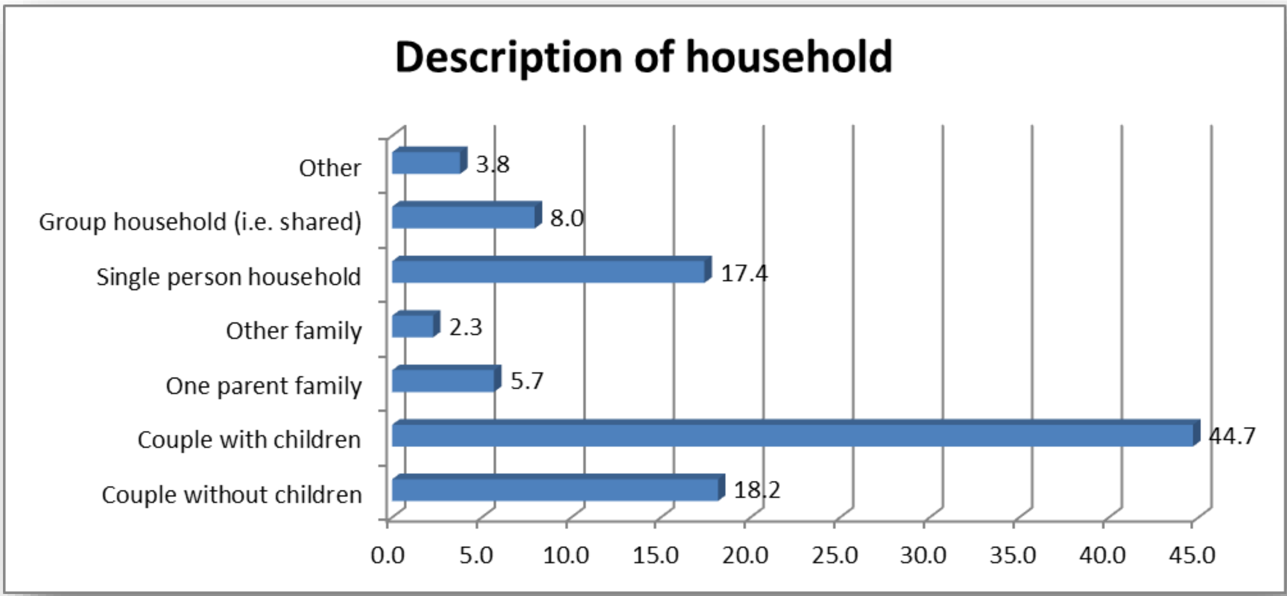


FIGURE 24 DESCRIPTION OF HOUSEHOLD

Preferences for Workshops

Overview of Relative Importance:

A predictive model was estimated based on the choices that teachers made about their preferred *Primary Connections* workshops and whether they would attend. All features were significant in predicting workshop attendance. With respect to relative importance, an approximate indication, which ignores interactions between variables, was estimated based on the contribution of each variable to the model predictions. This indicates that workshop fees are the most important consideration for teachers in their decision about whether or not to attend a workshop. This was followed by the time it takes to travel to the face-to-face workshop and then by when the workshop is held in terms of the eight patterns considered. In relative terms, the type of follow-up a teacher received and whether the workshop occurred during term was less of a consideration. Finally, the remaining variables were fairly similar in terms of explaining variation in teachers' choices; that is, whilst length of workshops and content were important considerations for teachers, and statistically significant, their role was well behind other factors, particularly considerations relating to fees and travel time.

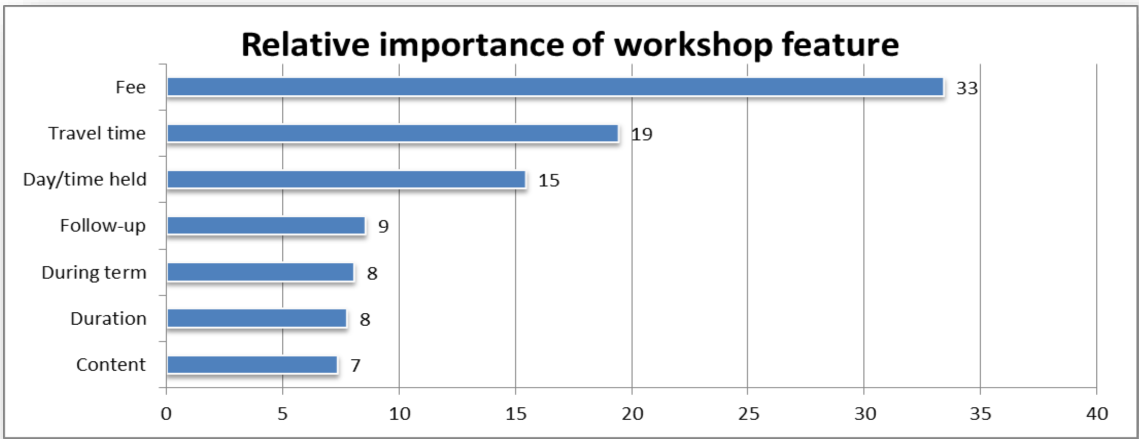


FIGURE 25 RELATIVE IMPORTANCE OF WORKSHOP FEATURE

General Demand and Time of Year:

The model predicts that pre-service teachers are much more likely to attend either workshop, whether held face-to-face or online. In contrast, those in-service teachers working in the city or large towns (representing around 34% of those surveyed) were, on average, least likely to attend any workshop.

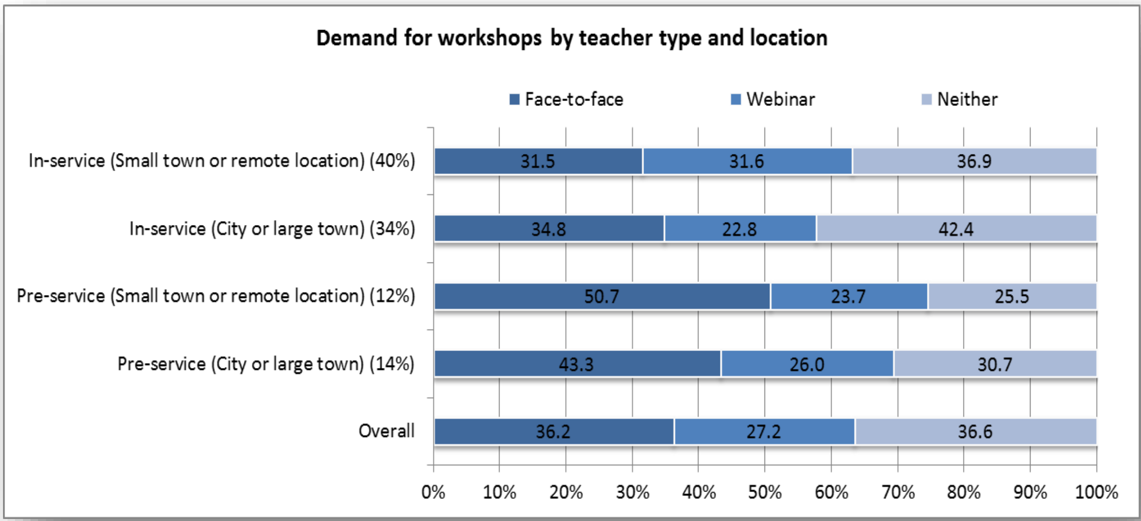


FIGURE 26 DEMAND FOR WORKSHOPS BY TEACHER TYPE AND LOCATION

The vast majority of teachers prefer workshops that are face-to-face rather than held as online webinars (t=-4.7539; p<.0001). However, the preference for face-to-face workshops is dependent on a number of other factors. In-service teachers working in small towns or remote locations appear to be more indifferent about whether workshops are held face-to-face or via webinar, whilst pre-service teachers much prefer face-to-face workshops, particularly when held during school holidays.

For example, face-to-face workshops are more preferable to teachers when they are held during the school term (t=6.8327; p<.0001). In contrast, teachers appear to be indifferent about the time of year to hold workshops, if held via webinar (p=.3428).

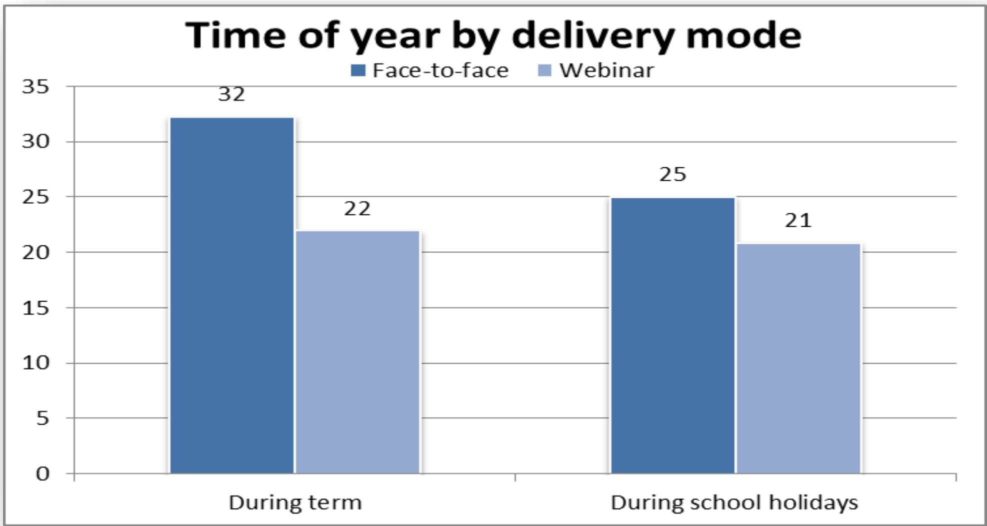


FIGURE 27 TIME OF YEAR DELIVERY MODE

Workshop Timing by Day of Week:

A number of workshop patterns were considered with respect to when to hold workshops (e.g. during the day or of an evening), on what day to hold such workshops (e.g. weekday or weekend) and whether to hold these over consecutive days or weeks. In general, respondents were more indifferent to the timing of workshops when held via webinar. However, these results were correlated with the preference for when to hold face-to-face workshops.

With respect to face-to-face to workshops, there was a clear preference for full-day workshops held during the week (t=7.0411; p>.0001). This was followed by a slight preference for full-day workshops held on a Saturday (p<.05; t=2.4409), relative to workshops held at other times. At the other extreme, there was a strong preference away from workshops held on two evenings from 6pm, regardless of whether these were held in the same week (t=-4.2494; p<.0001) or a week after (t=-.38405; p<.0001). Likewise, at the aggregate level, there was less demand for a twilight option (i.e. held late Friday/Saturday morning) when starting at 6pm, relative to the demand for all other options presented (t=-.2420-5; p<.05). In contrast, a twilight option starting on a Friday afternoon (from 2pm) and continuing on the Saturday morning was more preferable relative to a twilight workshop commencing in the evening, although on the whole, participants were indifferent to this type of offering (t=.8397; p=.4011).

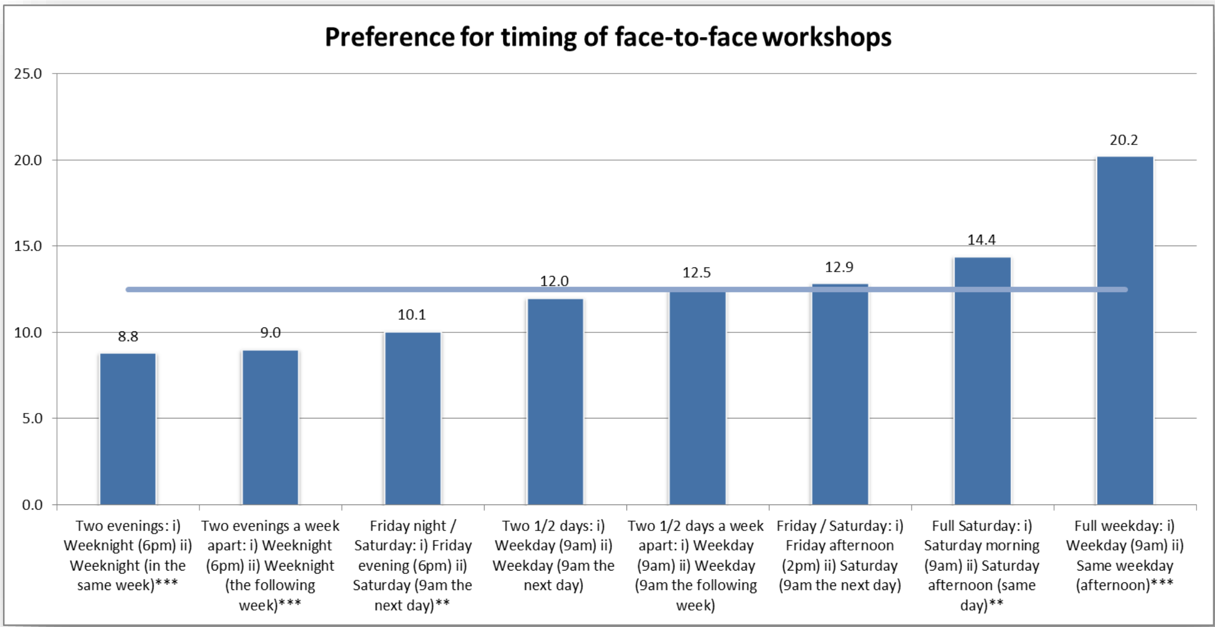


FIGURE 28 PREFERENCE FOR TIMING OF FACE-TO-FACE WORKSHOPS

The preference for workshops based on when they are scheduled does vary across segments of teachers. The strong preference for full-weekday workshops is particularly evident among in-service teachers (t=7.3363; p<.0001). The preference for full Saturday workshops is more pronounced among in-service teachers living in small country towns or remote locations (t=3.0214; p<.001). In-service teachers living in city locations are more opposed to full Saturday workshops, so taken as a whole, in-service teachers are largely indifferent to workshops held on a Saturday (p=.9813). Pre-service teachers, on average, strongly prefer full-day workshops, including those held during the week (t=1.9799; p<.05) and weekends (t=2.6281; p<0.01), but this result is dominated by those pre-service teachers living in larger towns more so than those in smaller towns or remote locations.

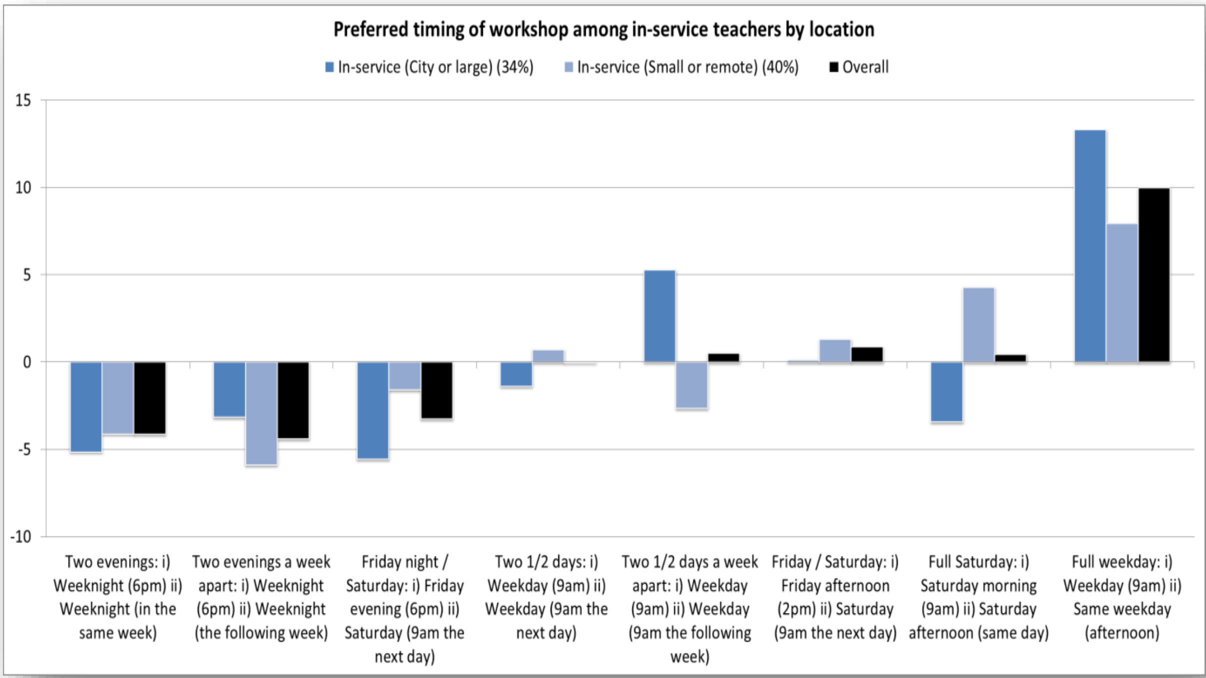
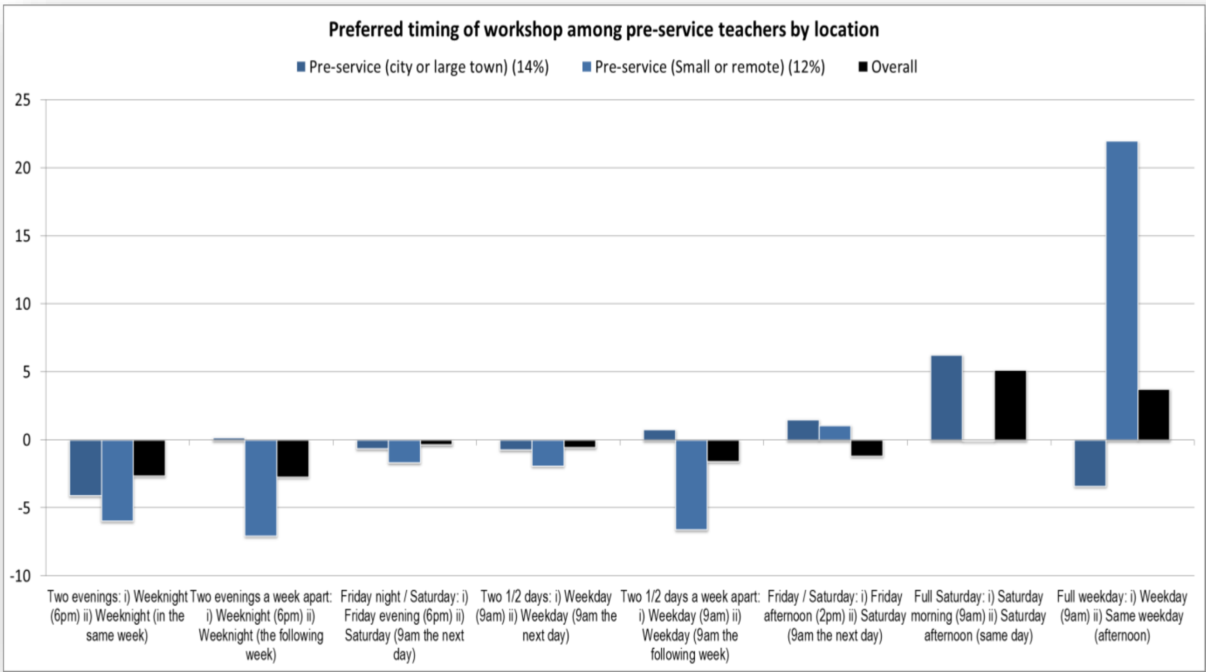


FIGURE 29 PREFERRED TIMING OF WORKSHOP AMONG IN-SERVICE TEACHERS BY LOCATION



A further analysis of workshop timing was performed outside of the DCE. The results reveal a strong preference for workshops to be held during school hours on a Monday or Friday, or to be held on Saturday mornings. The attraction to Saturday morning workshops was particularly pronounced among pre-service teachers rather than in-service teachers. There was no preference for workshops to commence during the evening or on Sundays.

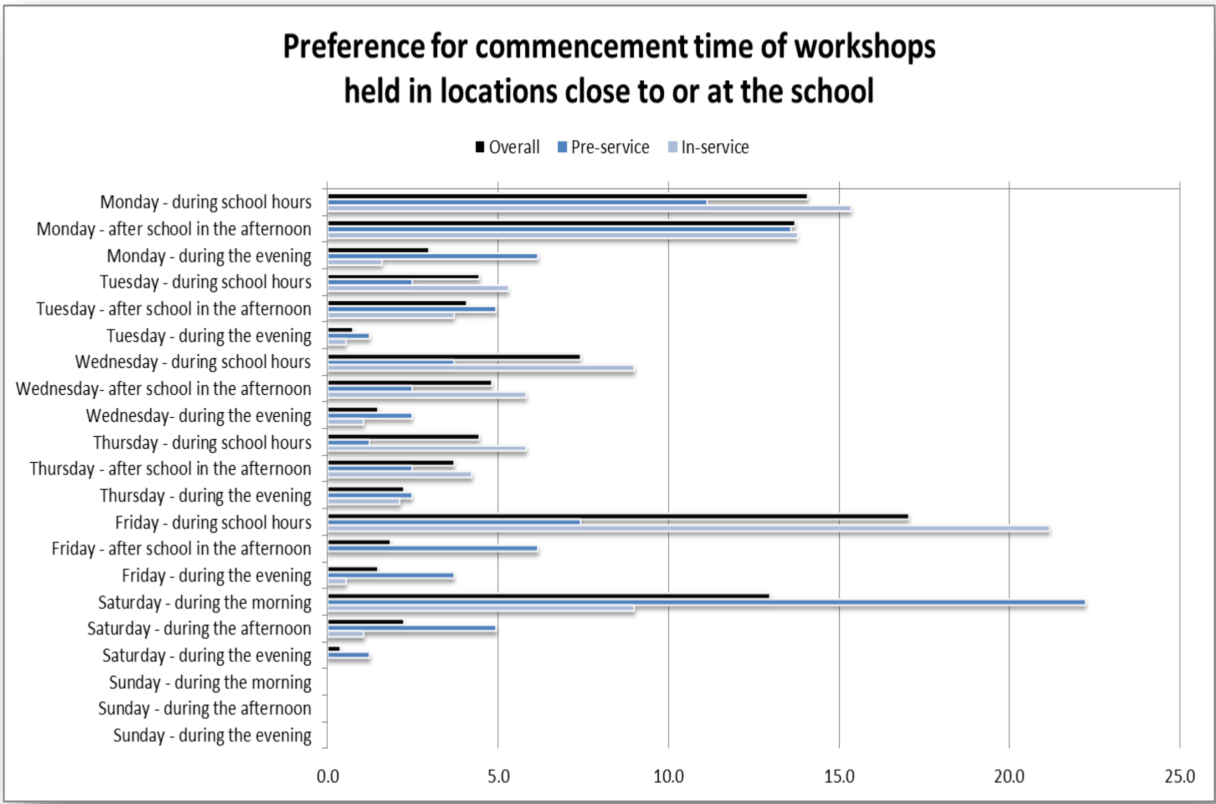


FIGURE 30 PREFERENCE FOR COMMENCEMENT TIME OF WORKSHOPS HELD IN LOCATIONS CLOSE TO OR AT THE SCHOOL

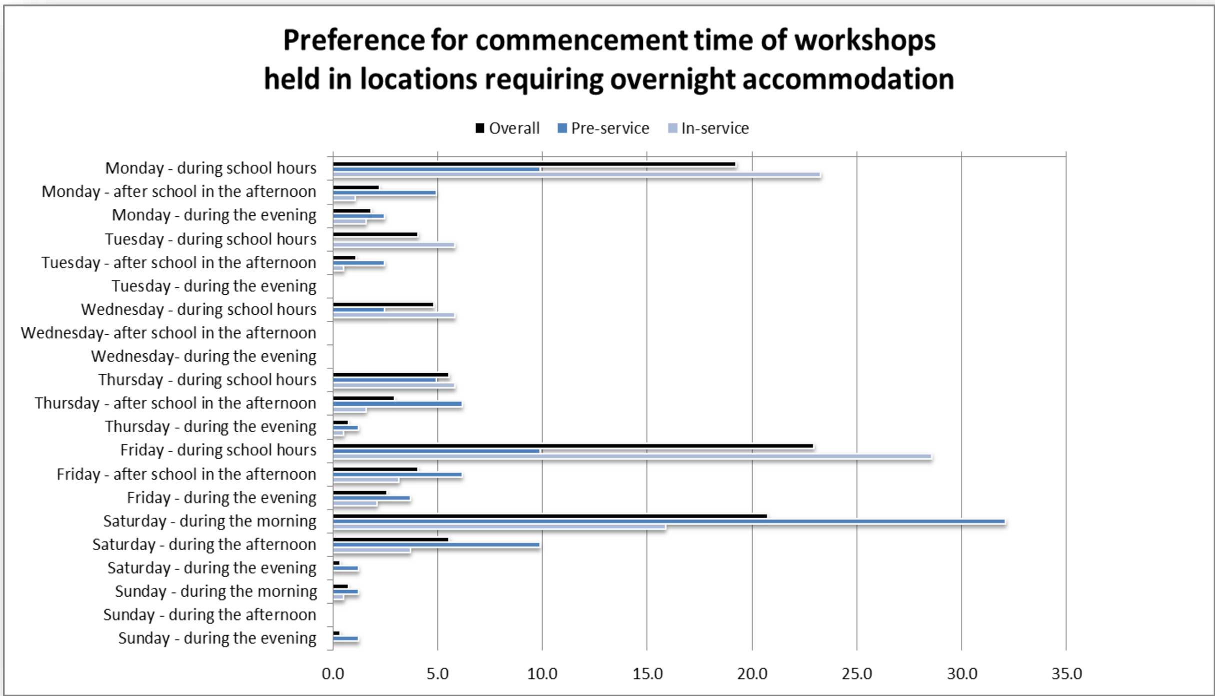


FIGURE 31 PREFERENCE FOR COMMENCEMENT TIME OF WORKSHOPS HELD IN LOCATIONS REQUIRING OVERNIGHT ACCOMMODATION

Location of face-to-face workshops

The demand for workshops was largely dictated by the travel-time to locations. Not surprisingly, the results suggested that workshops requiring less travel time were more attractive, with some indifference to workshops requiring travel of half an hour or one hour, relative to other differences observed. Workshops requiring more than 2 to 2.5 hours were predicted as being unlikely to be attended. There were no systematic patterns associated with the sensitivity to travel-time among teachers with respect to whether they were in-service or pre-service and/or the location of the school at which they currently taught.

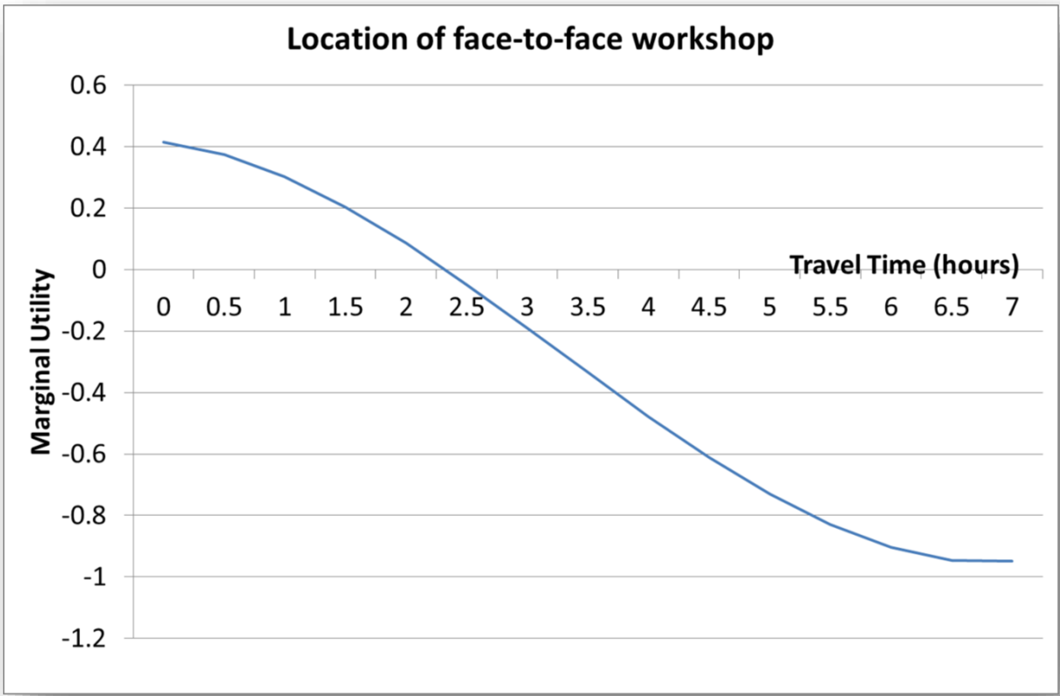


FIGURE 32 LOCATION OF FACE-TO-FACE WORKSHOPS

Some further analysis of location was considered with respect to travelling to face-to-face workshops held in a capital city. Amongst the teachers surveyed, 13% indicated that they lived in a capital city. For those living outside a capital city, 41% lived within two hours of the capital city, whilst it would take 32% of teachers living outside the capital city four or more hours to get there.

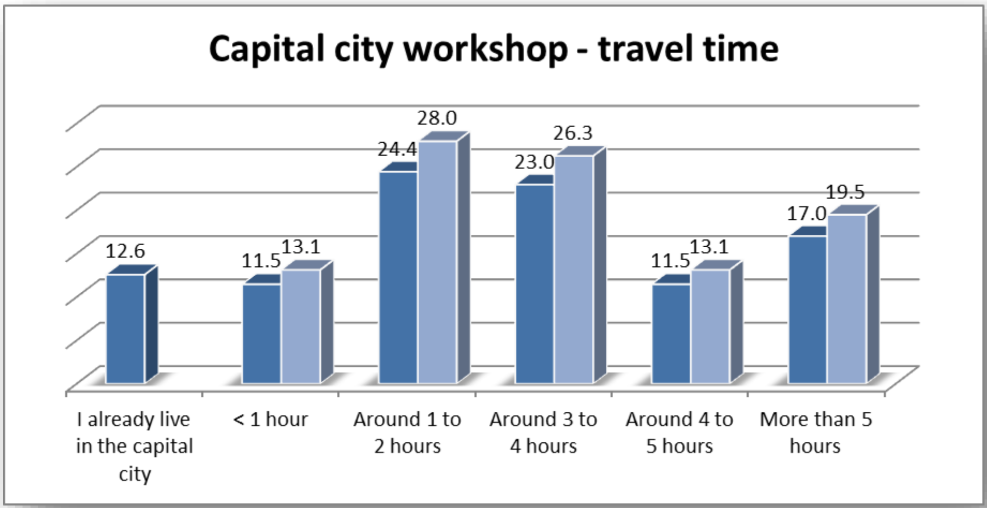


FIGURE 33 CAPITAL CITY WORKSHOP - TRAVEL TIME

Amongst those travelling to the capital city, the majority would travel alone (72%), whilst 10% would travel with their partner and 18% with a friend. Only 4% of participants would travel with their children. For those travelling to a capital city, 30% would stay with their friends or family. Around 64% would stay in a hotel or serviced apartment.

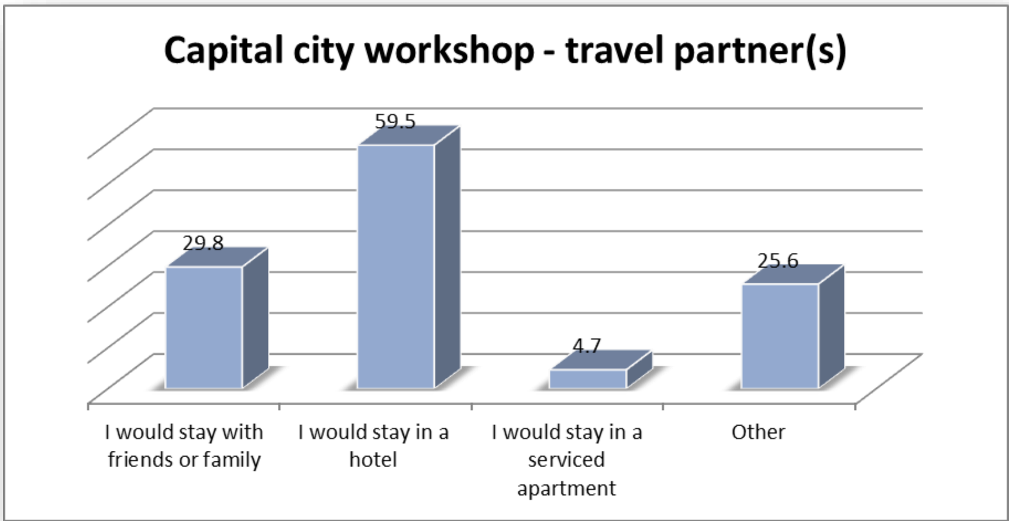


FIGURE 34 CAPITAL CITY WORKSHOP - TRAVEL PARTNER(S)

Cost of workshops in capital cities

The cost of workshops was included in the description of workshops to provide realistic insights into the relative importance of attributes. As previously reported, the decision of teachers to attend workshops was driven by these fees more so than any other attribute.

The costs of workshops were investigated further with respect to remuneration and associated costs that would be borne in travelling to workshops held in capital cities. The model predicts that at a fee of $400, less than 18% of teachers would consider attending a face-to-face workshop, all else being equal. Teachers were asked to nominate how the cost of a $400 workshop would be covered by their schools. In-service teachers were likely to be subsidised in the majority of cases; however, 39% said that the expense would come out of their own pocket. Without employment, the vast majority of pre-service teachers indicated the cost would have to be borne by them.

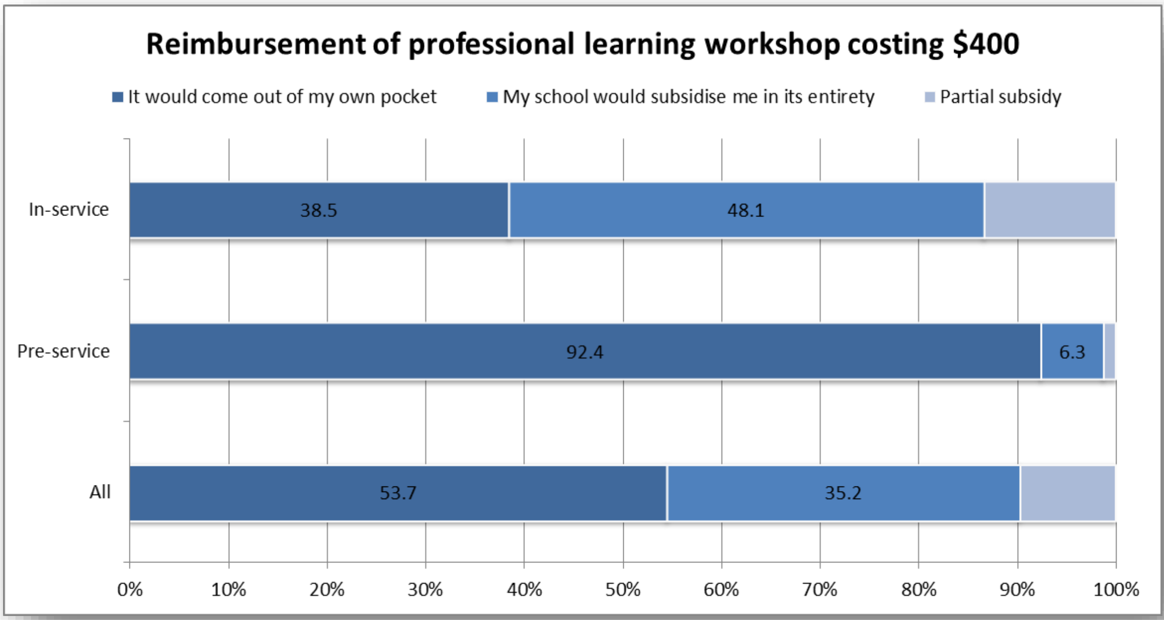


FIGURE 35 REIMBURSEMENT OF PROFESSIONAL LEARNING WORKSHOP COSTING OVER $400

The experiences of teachers generally is that principals were largely supportive of professional learning activities. More than 92% indicated that their principal was supportive of teachers attending professional learning activities, 83% indicated that the principal was happy to release teachers for such activities, and 70% indicated that their principal would be happy to reimburse them if attending a professional learning workshop.

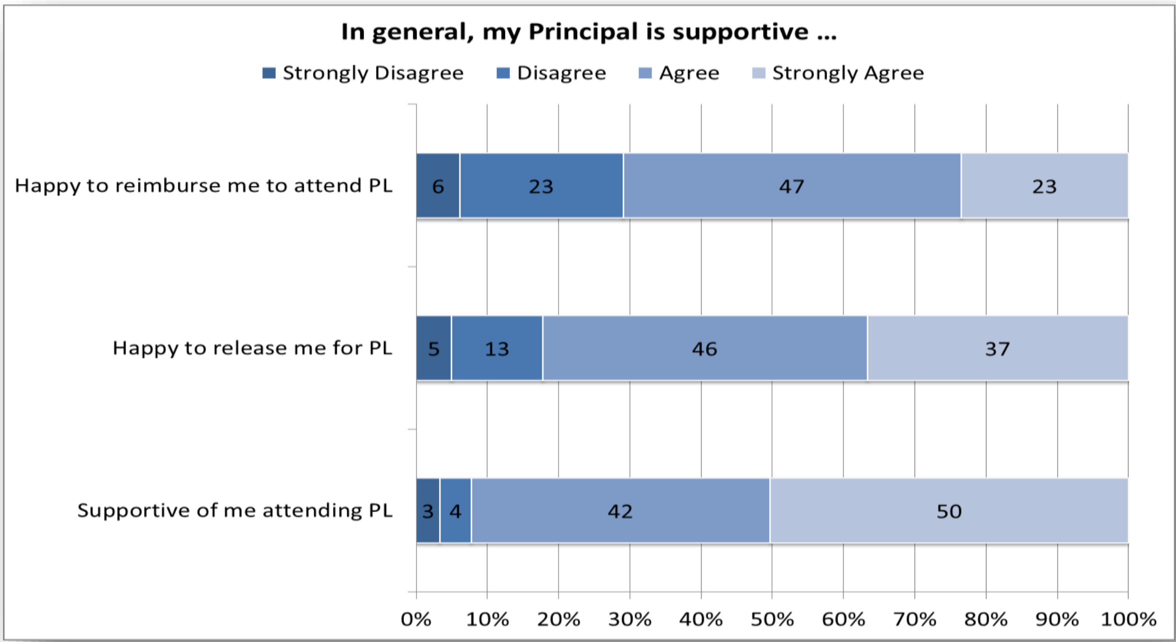


FIGURE 36 PRINCIPAL SUPPORT FOR PROFESSIONAL LEARNING

Content of workshops

Respondents were asked to evaluate workshops with respect to content that may be presented in terms of how to adapt *Primary Connections* to various contexts. With respect to face-to-face workshops, teachers were largely indifferent to the topic, other than a strong dislike for workshops that involved workshop participants choosing the topic of interest. There was greater variation in preference for content in workshops conducted via webinar. In particular, teachers expressed a preference for workshops considering how to adapt *Primary Connections* to integrate with other KLAs (t=2.8764; p<.01), and less about dealing with multi-age classes (t=-2.4973; p<.05).

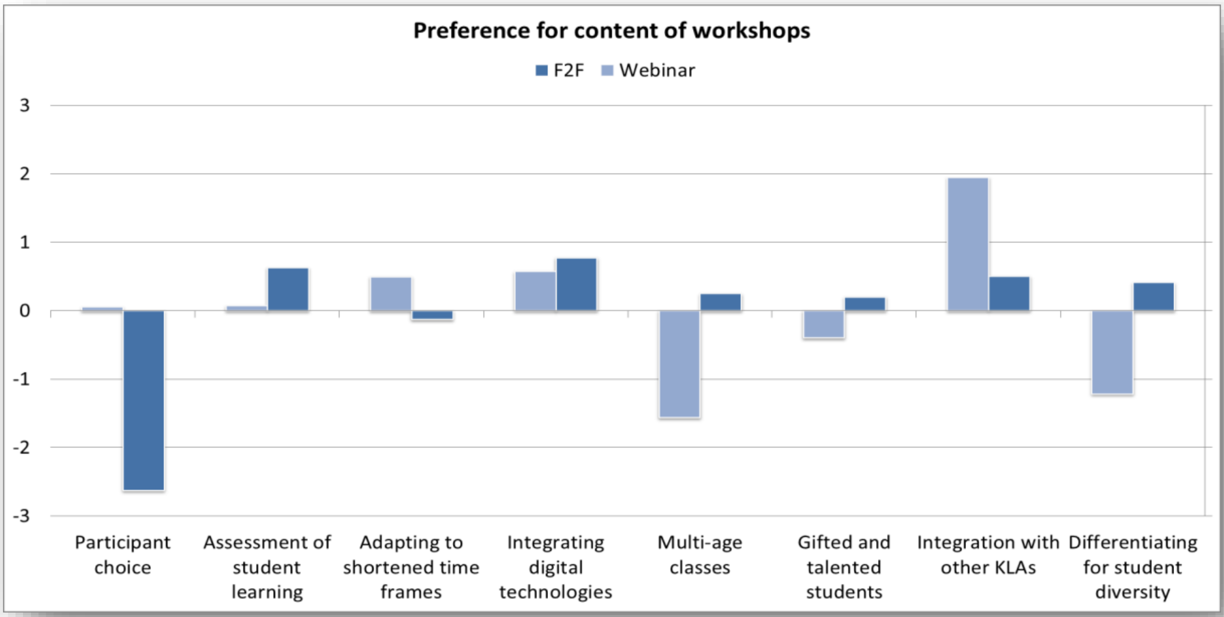


FIGURE 37 PREFERENCE FOR CONTENT OF WORKSHOPS

Follow-up after workshops:

Teachers were asked to evaluate workshops with respect to potential follow-up activities involving *Primary Connections* experts via a number of different modes. Face-to-face workshops were more attractive when presented with follow-up that involved expert-led online discussion forums one month after workshops (t=3.5009; p<.0001). This type of follow-up activity was particularly favoured among pre-service teachers attending face-to-face workshops more so than in-service teachers. In-service teachers were largely indifferent to follow-up activities, other than to oppose having a colleague in their school with *Primary Connections* expertise mentor them (t=-2.7323; p<.01). Workshops held online (i.e., webinars) were more attractive when followed up with provision of access to short annotated online videos relating to the workshop content (t=2.0217; p<.05). Regardless of the mode in which the initial workshop took place, there was strong objection to follow-up that involved a phone-call from a *Primary Connections* expert to discuss implementation (p<.05). This was a follow-up activity that was less preferable than having no additional follow-up at all.

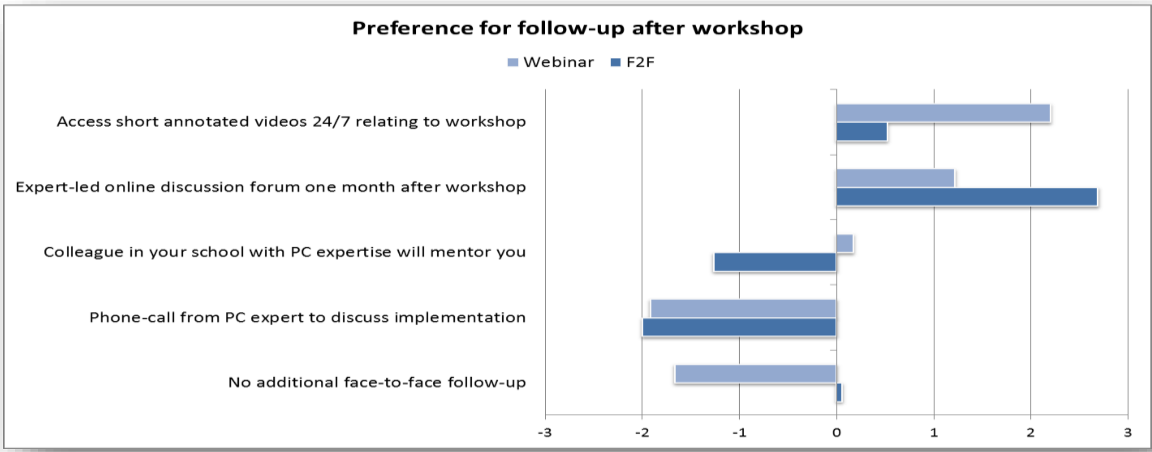


FIGURE 38 PREFERENCE FOR FOLLOW-UP WORKSHOP

Experiences and Likelihood to Recommend

The final set of insights related to the general evaluation of the program. A sizeable 81% of teachers agreed that they would be likely to attend further training in *Primary Connections* in the future. The strength of this agreement is higher among pre-service teachers, with 37% strongly agreeing with the statement regarding likelihood to attend further training relative to 19% of in-service teachers. On the other hand, in-service teachers were more likely to agree that they were more confident in using *Primary Connections* (81%) as compared to pre-service teachers (67%).

TABLE 12 LIKLEHOOD OF ATTENDING FURTHER TRAINING IN PRIMARY CONNECTIONS

	Strongly Disagree	Disagree	Agree	Strongly Agree	Total Agree
I am very likely to attend further training in *Primary Connections* in the future					
Overall	4	14	58	24	82
Pre-service	4	13	46	38	84
In-service	4	14	63	19	81
I am confident in using *Primary Connections*					
Overall	2	21	66	11	77
Pre-service	4	29	53	14	67
In-service	1	18	72	10	81
I would highly recommend professional learning workshops in *Primary Connections* to in-service teachers					
Overall	2	5	49	44	93
Pre-service	5	3	49	43	92
In-service	1	6	49	44	93
I would highly recommend professional learning workshops in *Primary Connections* to pre-service teachers					
Overall	2	5	43	50	93
Pre-service	5	3	35	57	92
In-service	1	6	46	47	93

Finally, both in-service and pre-service teachers agreed that they would strongly recommend professional learning workshops in *Primary Connections*. More than 9 out of 10 teachers would highly recommend professional learning workshops in *Primary Connections* to both pre-service and in-service teachers.

References:

Aubusson, P., Burke, P., Schuck, S., Kearney, M., & Frischknecht, B. (2014). Teachers Choosing Rich Tasks: The Moderating Impact of Technology on Student Learning, Enjoyment, and Preparation. *Educational Researcher*, 43 (5), 219-229.

Ben-Akiva, M. E., & Lerman, S. R. (1985). Discrete choice analysis: theory and application to travel demand (Vol. 9). MIT press.

Burke, P. F. (2013). Seeking Simplicity in Complexity: The Relative Value of Ease of Use (EOU)-Based Product Differentiation. *Journal of Product Innovation Management*, 30 (6), 1227-1241.

Burke, P. F., Aubusson, P. J., Schuck, S. R., Buchanan, J. D., & Prescott, A. E. (2015). How do early career teachers value different types of support? A scale-adjusted latent class choice model. *Teaching and Teacher Education*, 47, 241-253.

Burke, P. F., Schuck, S., Aubusson, P., Buchanan, J., Louviere, J. J., and Prescott, A. (2013). Why do early career teachers choose to remain in the profession? The use of best–worst scaling to quantify key factors, *International Journal of Educational Research*, 62, 259-268.

Burke, P. F., Schuck, S., Aubusson, P., Kearney, M., & Frischknecht, B. (2018). Exploring teacher pedagogy, stages of concern and accessibility as determinants of technology adoption. *Technology, Pedagogy and Education*, 27(2), 149-163.

Carson, R. T., & Groves, T. (2007). Incentive and informational properties of preference questions. *Environmental and Resource Economics*, 37(1), 181-210.

Louviere, J., & Hensher, D. (1982). On the Design and Analysis of Simulated Choice or Allocation Experiments in Travel Choice Modelling. *Transportation Research Record*, 890, 11-17.

Louviere, J. J., & Woodworth, G. (1983). Design and Analysis of Simulated Consumer Choice or Allocation Experiments: An Approach Based on Aggregated Data. *Journal of Marketing Research*, 20, 350-367.

Luce, R. Duncan. (1959). On the possible psychophysical laws. *Psychological Review,* 66 (2), 81.

McFadden, D. (1974). Conditional Logit Analysis of Qualitative Choice Behavior. In Z. P. (Ed.), Frontiers on Econometrics (pp. 105-142). New York: Academic Press.

McFadden, D. (1979). Quantitative Methods for Analysing Travel Behaviour of Individuals: Some Recent Developments. In D. A. Hensher & P. R. Stopher (Eds.), *Behavioural Travel Modelling* (pp. 279-318). London: Groom Helm.

Palmer, T. A., Burke, P. F., & Aubusson, P. (2017). Why school students choose and reject science: a study of the factors that students consider when selecting subjects. *International Journal of Science Education*, 39(6), 645-662.

Thurstone, L.L. (1927). A law of comparative judgment. *Psychological Review*, 34 (4), 273.

Train, K. E. (2003). *Discrete Choice Methods with Simulation*. Cambridge, UK: Cambridge University Press.

APPENDIX 8: COMPARISON OF PRE- AND POST-WORKSHOP QUANTITATIVE SURVEY DATA

To assist in answering Efficiency RQ 2.2, evidence was gathered from in-service and pre-service teachers, who completed a survey to ascertain their perceptions and intentions prior to attending a *Primary Connections* workshop. They completed a second survey to determine the impact of the workshop after their attendance.

Efficiency RQ 2.2 Does training teachers and pre-service teachers in Primary Connections increase the likelihood of teachers and schools comprehensively implementing the program?

Surveys

The AAS sent the pre-workshop survey to workshop participants (both in-service teachers and pre-service teachers) prior to their respective workshops. The post-survey, which included the post-workshop survey and the Best-Worst Scaling survey, was sent to all workshop participants after completion of the workshop.

Survey sample size

There were 114 valid responses from in-service teachers and 169 valid responses from pre-service teachers to the pre-workshop survey. The post-workshop survey received valid responses from 126 in-service teachers and 171 pre-service teachers.

Comparison of the pre- and post-workshop survey responses of in-service and pre-service teachers

This comparison of quantitative data from the pre- and post-surveys was undertaken to determine whether there was any change in responses to common survey items after completion of *Primary Connections* professional learning.

Methodology

Paired samples t-tests were conducted on the pre- and post-workshop survey results of the in-service and pre-service teachers to gauge the impact of the professional learning workshops.

Attitudes to science and science teaching

Following attendance at a *Primary Connections* workshop, the attitudes of both in-service and pre-service teachers towards science and primary science teaching were significantly more positive. A paired samples t-test detected a statistically significant increase ($p<0.01$) in the levels of interest, enjoyment, confidence, and comfort in teaching science among in-service teachers after they had attended a *Primary Connections* workshop (Table 13).

TABLE 13 ATTITUDES TO SCIENCE TEACHING AMONG IN-SERVICE TEACHERS

Statements regarding science and science teaching	In-service teachers' pre-survey (n=114) Mean	S.D.	In-service teachers' post-survey (n=126) Mean	S.D.	
I am not that interested in science (R)	8.17	2.21	9.22	1.47	**
I enjoy teaching science	7.71	2.06	8.65	1.73	**
I am not that confident in teaching science (R)	6.83	2.41	8.09	2.28	**
I'm quite comfortable teaching science	6.69	2.26	7.98	1.84	**
I had negative experiences at high school with respect to science (R)	7.04	2.65	7.14	2.91	

Items were measured on a 10-point scale with 1=Strongly disagree to 10=Strongly agree.
(R) = items are reverse coded.
** Significant difference between pre- and post-surveys at the p <0.01 confidence level

Similarly, there was a statistically significant increase in interest, enjoyment, confidence and comfort in science and science teaching among pre-service teachers following the workshop (Table 14).

TABLE 14 ATTITUDES TO SCIENCE AND SCIENCE TEACHING IN PRE-SERVICE TEACHERS

Statements regarding science and science teaching	Pre-service teachers' pre-survey (n=169) Mean	S.D.	Pre-service teachers' post-survey (n=171) Mean	S.D.	
I am not that interested in science (R)	8.25	2.08	8.85	1.68	**
I enjoy teaching science	7.10	2.30	7.98	1.73	**
I am not that confident in teaching science (R)	6.38	2.17	7.69	2.12	**
I'm quite comfortable teaching science	5.73	2.04	7.35	1.69	**
I had negative experiences at high school with respect to science (R)	6.59	2.68	5.91	3.04	

Items were measured on a 10-point scale with 1=Strongly disagree to 10=Strongly agree.
(R) = items are reverse coded.
** Significant difference between pre- and post-surveys at the p <0.01 confidence level

Impact of Primary Connections Workshops

The impact of having completed a *Primary Connections* workshop increased in-service teachers' confidence in a number of different areas. There was a statistically significant increase, according to a paired samples t-test, in confidence in their understanding of the aims, major principles and pedagogy of *Primary Connections,* and of the 5Es teaching and learning model. They also significantly increased their confidence in understanding the relationship between science and literacy and their ability to use *Primary Connections* to enhance student learning in these areas. Table 15 shows pre- and post-workshop means and standard deviations relating to in-service teacher confidence on a 5-point scale *(1=Not confident, 2=Limited confidence, 3=OK, 4=Confident, 5=Very confident).*

TABLE 15. IMPACT OF *PRIMARY CONNECTIONS* WORKSHOPS ON CONFIDENCE OF IN-SERVICE TEACHERS

Confidence in ability to:	In-service teachers' pre-workshop survey Mean	S.D.	In-service teachers' post-workshop survey Mean	S.D.	
Understand the aims of the *Primary Connections* Program	3.70	0.90	4.13	0.69	**
Understand the major principles and the pedagogy of *Primary Connections*	3.58	0.90	4.06	0.70	**
Understand the 5Es teaching and learning model	3.60	0.94	4.14	0.75	**
Understand the relationship between science and literacy	3.88	0.77	4.21	0.73	**
Use *Primary Connections* tools to enhance student learning in science and literacy	3.86	0.73	4.04	0.74	*
Apply the research that *Primary Connections* is based on	3.74	0.74	3.73	0.77	
Use the range of *Primary Connections* curriculum units and other resources	3.88	0.70	4.13	0.77	

Items were measured on a 5-point scale with 1=Not confident to 5=Very confident.
*/** Significant difference between pre- and post-surveys at the p <0.05/0.01 confidence level

Pre-service teachers' confidence in relation to their understanding of the aims and pedagogical principles of *Primary Connections* and the relationship between science and literacy also showed a statistically significant increase after they had attended a workshop, as shown in Table 16.

TABLE 16 IMPACT OF PRIMARY CONNECTIONS WORKSHOPS ON CONFIDENCE OF PRE-SERVICE TEACHERS

Confidence in ability to:	Pre-service teachers' pre-workshop survey Mean	S.D.	Pre-service teachers' post-workshop survey Mean	S.D.	
Understand the aims of the *Primary Connections* Program	3.71	0.95	4.12	0.68	**
Understand the major principles and the pedagogy of *Primary Connections*	3.74	1.03	4.15	0.66	**
Understand the 5Es teaching and learning model	3.91	0.92	4.22	0.69	**
Understand the relationship between science and literacy	3.89	0.79	4.14	0.76	**
Use *Primary Connections* tools to enhance student learning in science and literacy	4.07	0.73	4.06	0.74	
Apply the research that *Primary Connections* is based on	3.95	0.68	3.85	0.76	
Use the range of *Primary Connections* curriculum units and other resources	4.07	0.73	4.15	0.70	

Items were measured on a 5-point scale with 1=Not confident to 5=Very confident.
** Significant difference between pre- and post-surveys at the p <0.01 confidence level

School and Teacher Capabilities in Science teaching

In-service teachers were asked about school capabilities with respect to primary science teaching both before and after attending a *Primary Connections* workshop. Table 17 shows pre- and post-workshop means and standard deviations on a 4-point scale *(1=Strongly disagree, 2=Disagree, 3=Agree, 4=Strongly agree)*. The mean values generally were not high, with '*Teachers at my school have the opportunity to receive ongoing professional learning in primary science'* showing the lowest mean value (2.54) in the pre-workshop survey. *'Time is a major factor inhibiting primary science program delivery at my school'* showed the highest mean value (2.91) in the pre-survey. There were no significant differences between the pre- and post-workshop responses, as may be expected, since these items related to the school situation, not to individual participants.

TABLE 17 IN-SERVICE TEACHERS' PERCEPTIONS OF SCHOOL CAPABILITIES IN PRIMARY SCIENCE TEACHING

	In-service teachers' pre-workshop survey		In-service teachers' post-workshop survey	
Perceptions of school capabilities in science	Mean	S.D.	Mean	S.D.
Teachers at my school have a positive attitude to the teaching of primary science.	2.89	0.54	2.95	0.64
My school is well resourced for the teaching of primary science.	2.60	0.66	2.76	0.77
Teachers at my school have the opportunity to receive ongoing professional learning in primary science.	2.54	0.72	2.83	0.74
My school places a strong emphasis on primary Science.	2.59	0.59	2.71	0.71
Teachers at my school have the confidence and skills to teach primary science competently.	2.71	0.49	2.68	0.66
Teachers at my school have a good background knowledge in primary science.	2.61	0.51	2.60	0.63
Time is a major factor inhibiting primary science program delivery at my school.	2.91	0.72	2.92	0.73
Teachers at my school have a sound knowledge of strategies known to be effective for the teaching of science.	2.61	0.51	2.66	0.55
Teachers at my school have a good understanding of the primary science syllabus.	2.68	0.52	2.69	0.61

Items were measured on a 4-point scale with 1=Strongly disagree to 4=Strongly disagree.

Conclusion

The results clearly show that attending a *Primary Connections* workshop has a significant impact on primary science teaching. Both in-service and pre-service teachers indicated that their understanding of primary science pedagogy and their confidence and interest in teaching science had significantly increased following completion of a *Primary Connections* workshop. This strongly suggests that training teachers and pre-service teachers in *Primary Connections* increases the likelihood of teachers and schools implementing the program.

APPENDIX 9: ANALYSIS OF SURVEY OPEN RESPONSES

Open-ended questions were included in the *Primary Connections* evaluation post-workshop surveys of in-service and pre-service teachers to allow the respondents to elaborate on their closed responses. Their answers were analysed to identify emergent themes. This analysis provides evidence in relation to:

Efficiency RQ 2.2 Does training teachers and pre-service teachers in Primary Connections increase the likelihood of teachers and schools comprehensively implementing the program?

Effectiveness RQ 3.3 What else can the Primary Connections program offer to assist teachers and pre-service teachers to implement the Australian science curriculum?

The survey questions:

For in-service teachers

Q4. Please tell us why you chose to attend a Primary Connections workshop.

Question 35. What else do you think the Primary Connections program can offer to assist teachers and pre-service teachers to implement the Australian Curriculum: Science?

For pre-service teachers

Question 27: What else do you think the Primary Connections program can offer to assist teachers and pre-service teachers to implement the Australian Curriculum: Science?

FINDINGS

In-service teachers

There were 126 responses to the in-service teacher survey, which included two open response questions.

Q4. Please tell us why you chose to attend a Primary Connections workshop.

There were 125 responses to Question 4.

The most prevalent reason given by teachers for attending the *Primary Connections* workshop was to develop their science teaching skills. (33 responses)

There were 18 responses from teachers who indicated that they were specialist science teachers and wanted to attend the workshop for this reason.

There were 13 teachers who declared their passion or special interest in science and were attending the workshop for that reason.

Eleven teachers said that they were attending the workshop because the school already had or was using the *Primary Connections* resources.

There were 10 teacher attending as and introduction to *Primary Connections*.

There were 8 teachers who gave wanting to learn more about inquiry learning as a reason for attending.

There were 4 teachers attending in order to help their colleagues.

There were also 4 who were attending because the workshop was free.

There were 3 who were attending because they were beginning teachers.

TABLE 18 SUMMARY OF TABLE OF FREQUENCY OF IN-SERVICE TEACHERS' RESPONSES TO QUESTION 4

Response theme	Number of responses
Develop skills	33
Specialist science teacher	18
Interest in science	13
School has *Primary Connections* materials	11
Introduction to Primary Connections	10
Learn about inquiry	8
Assist colleagues	4
Free workshop	4
Beginning teacher	3
Linking to other KLA/s	2

FIGURE 39 WORD CLOUD SHOWING WORD FREQUENCY IN IN-SERVICE TEACHERS' RESPONSES TO "PLEASE TELL US WHY YOU CHOSE TO ATTEND A PRIMARY CONNECTIONS WORKSHOP"

Question 35. What else do you think the Primary Connections program can offer to assist teachers and pre-service teachers to implement the Australian Curriculum: Science?

There were 89 responses by in-service teachers to Question 35.

The most frequent response from teachers related to suggesting an additional component to the *Primary Connections* program. These suggestions were mainly related to assessment and more hands-on activities. (17 responses)

The second most frequent response was one of satisfaction with what *Primary Connections* provides or praise for the program. (14 responses)

There were 13 responses indicating that teachers would like *Primary Connections* to provide some kind of online support. This could be some kind of social network for teachers to exchange ideas, follow-up for teachers who have attended workshops to keep them up to date or providing support materials and news about development in *Primary Connections* on the website.

Thirteen teachers mentioned that they would be interested in having access to more digital technologies within the *Primary Connections* units.

The need for support in adapting *Primary Connections* to multi-age classes was mentioned by 11 teachers.

The cost of *Primary Connections* materials was mentioned by 8 teachers, who wanted more affordable resources for schools.

Seven teachers made suggestions about the content of *Primary Connections* workshops, including requests for support in adapting units to Distance Education, linking more with STEM and more literacy ideas.

There were 6 responses requesting additional workshops, particularly in regional and remote areas.

Support for differentiating learning within the *Primary Connections* units was mentioned by 5 teachers.

Teachers would like to see best practice pedagogy and suggested online videos of *Primary Connections* activities being conducted by teachers in their classrooms would be useful. (5 responses)

Suggestions for condensing *Primary Connections* units to cater for the limited time often available in schools would be appreciated according to 4 responses.

TABLE 19 SUMMARY TABLE OF FREQUENCY OF IN SERVICE TEACHERS' RESPONSES TO "WHAT ELSE DO YOU THINK THE PRIMARY CONNECTIONS PROGRAM CAN OFFER TO ASSIST TEACHERS AND PRE-SERVICE TEACHERS TO IMPLEMENT THE AUSTRALIAN CURRICULUM: SCIENCE?"

Response theme	Number of responses
Primary Connections component suggestion	17
Praise, nothing to add	14
Online support	13
Activities using digital technologies	11
Multi-age class support	9
Affordable resources	8
Workshop content	7
Additional workshops	6
Differentiated learning	5
Show best practice pedagogy	5
Condensed unit plan	4
Link to state education requirements	3
Need to build confidence	2
Primary Connections visits to schools	2
Access to appropriate science content knowledge	1

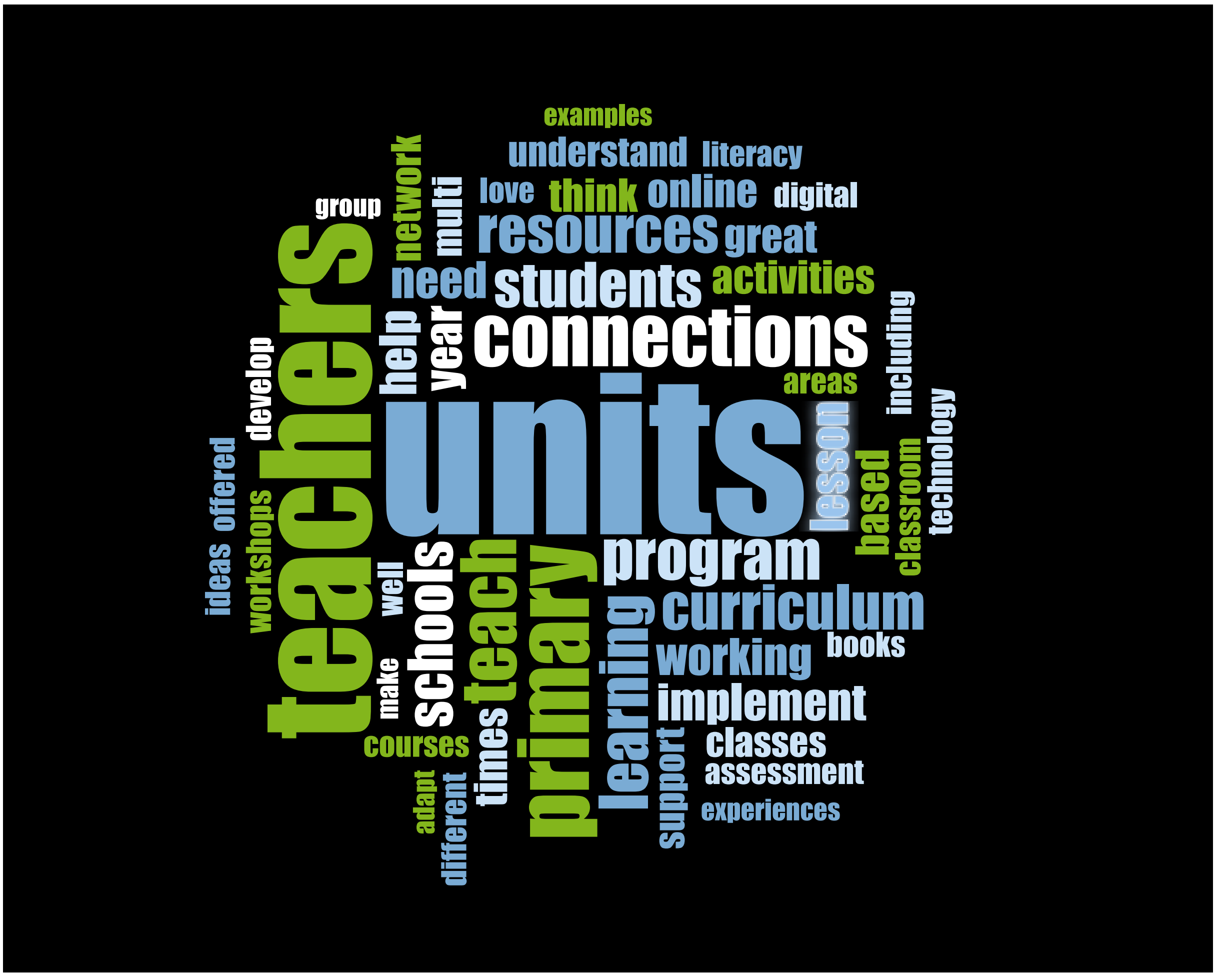


FIGURE 40 WORD CLOUD SHOWING THE WORD FREQUENCY IN THE IN-SERVICE TEACHERS' RESPONSES TO "WHAT ELSE DO YOU THINK THE PRIMARY CONNECTIONS PROGRAM CAN OFFER TO ASSIST TEACHERS AND PRE-SERVICE TEACHERS TO IMPLEMENT THE AUSTRALIAN CURRICULUM: SCIENCE?"

Pre-Service teachers

There were 171 responses to the pre-service teacher survey, and of these, 93 answered the open response question.

Question 27: What else do you think the Primary Connections program can offer to assist teachers and pre-service teachers to implement the Australian Curriculum: Science?

The most frequent response to this question was that pre-service teachers would like to see best practice pedagogy, mostly suggesting that this could be achieved by having online videos of teachers in classrooms using the *Primary Connections* resources with their classes. (16 responses)

The next most frequent response was of praise for *Primary Connections* or that they could not suggest anything else that might assist. (14 responses)

Pre-service teachers also mentioned equally that they would like to have additional workshops (11 responses) and that they would like some sort of online support available to them. (11 responses)

They felt that they needed to boost their confidence to teach science and would like *Primary Connections* to be able to provide a means of doing that. (6 responses)

Equally, pre-service teachers would like *Primary Connections* to provide more support for them to be able to differentiate learning. (6 responses)

They made suggestions for material they would like to see included in workshops (6 responses), e.g. more practical activities and experience of more units.

Some pre-service teachers said that they had difficulty accessing *Primary Connections* resources and

They would like to have them all available online. (5 responses)

Help with adapting *Primary Connections* for multi-age classes was also mentioned. (5 responses)

The pre-service teachers also expressed a need to increase their science content knowledge as background to some units and would like appropriate links or materials to provide that. (4 responses)

Other responses occurring 3 times each were: help with condensing units when time is short, links to state syllabus requirements; raising awareness of the program in schools so that they may have the opportunity to use it during their professional experience; and more digital science activities.

TABLE 20 SUMMARY OF FREQUENCY OF PRE-SERVICE TEACHERS' RESPONSES

Response theme	Number of responses
Show best practice pedagogy	16
Praise, nothing to add	14
Additional workshops	11
Online support	11
Need to build confidence	6
Differentiated learning	6
Workshop content, more practical, more units	6
All *Primary Connections* material available online	5
Multi-age class support	5
Access to appropriate science content knowledge	4
Compare to other inquiry models	3
Condensed unit plan	3
NSW syllabus links	3
Awareness raising in schools	3
Technology enabled science learning	3
Opportunity to train as specialist science teacher	2

FIGURE 41 WORD CLOUD SHOWING THE WORD FREQUENCY IN THE PRE-SERVICE TEACHERS' RESPONSES

CONCLUSION

The most prevalent reason given for teachers to attend a *Primary Connections* workshop was to increase their knowledge and skills and many of the attendees expressed a special interest in the area of science. Quite a number of teachers indicated that they were either specialist science teachers or were teaching science as relief from face-to-face teachers. For this reason, or because they had a special interest in science, they were keen to further their skills and knowledge.

The most frequent response from teachers, when asked what *Primary Connections* can offer to assist them to implement the *Australian Curriculum: Science,* was to suggest additional *Primary Connections* components, like assessment activities and more hands-on activities. Most teachers were happy with *Primary Connections* as is, which is indicated either by a nil response to this question or a response in praise of the program. Other suggestions were for some type of online support or follow-up from the workshops and to have access to more activities using digital technologies.

When asked how else *Primary Connections* could support them to implement the *Australian Curriculum: Science,* pre-service teachers most frequently indicated that they would like to see best practice pedagogy, mostly suggesting online videos of teachers in classrooms using the *Primary Connections* resources with their classes. They also seemed satisfied with what *Primary Connections* currently offered, and requested additional workshops and online support.