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Primary Connections: Reforming science teaching in Australian primary schools

by Mark Hackling, Shelley Peers and Vaughan Prain

Concerns about the status and quality of science teaching in Australian primary schools led the Australian Academy of Science to develop *Primary Connections* over 2004–8 with funding from DEST and the support of states and territories. *Primary Connections* is a teacher professional learning program supported with curriculum resources that aims to enhance learning outcomes in science and the literacies of science by supporting both inservice and preservice primary teachers to teach science effectively. *Primary Connections* is a systematic, widespread and innovative reform that complements programs within states and territories. The program is based on an innovative teaching and learning approach that links science with literacy, uses cooperative learning, embeds assessment with teaching and learning, and follows an inquiry process including student-planned investigations. Research has demonstrated that the program improves teachers' confidence, self-efficacy and practice, students' learning, and the status of science within schools.

Introduction

Australia needs a scientifically literate community if it is to develop a knowledge-based economy, address environmental concerns about water conservation and global warming, and health issues such as obesity and diabetes. High quality teaching of science in Australian primary schools is a national priority in order to develop citizens who are scientifically literate and who can contribute to the social, environmental and economic well-being of Australia (Peers, 2006). Student achievement in science is therefore being monitored through national assessments of scientific literacy and international assessments of science achievement. Stimulating curiosity and creative thinking and commencing the learning journey towards scientific literacy requires a strong and effective science program in the primary years of schooling.

Recent national assessments of scientific literacy and international assessments of science achievement raise concerns about the health of primary science in Australia. Less than 60% of sampled Year 6 Australian students attained or exceeded the proficiency standard in the 2003 national assessments of scientific literacy (MCEETYA, 2005). The Trends in International Mathematics and Science Study (TIMSS) indicates that while the science achievement of Australian Year 4 students has remained stable between 1994 and 2002 at a level that was above the international mean, countries such as Singapore, Hong Kong and Latvia have made significant improvements between 1994 and 2002 (Thomson & Fleming, 2004). Seven countries scored significantly higher than Australia on the 2002 assessments (Singapore, Taiwan, Japan, Hong Kong, England, USA and Latvia), and most of these are our trading competitors in terms of knowledge-based exports.

Despite science being recognised as a priority area of learning for governments and parents (ASTEC, 1997) many schools are poorly equipped for teaching science, have an inadequate budget for science and do not have a science coordinator (Hackling & Prain, 2005). Science as a learning area receives the

second lowest amount of time in the primary school curriculum averaging 2.7% of teaching time (Angus *et al.*, 2004). Many primary teachers lack confidence and competence for teaching science (Appleton, 1995; Palmer, 2001; Yates & Goodrum, 1990) and score poorly on self-efficacy scales that measure their beliefs about being able to teach science effectively (Riggs & Enochs, 1990). The limited science discipline studies and science curriculum studies in many Australian initial teacher education courses (Lawrance & Palmer, 2003) gives student teachers little opportunity to develop the pedagogical content knowledge (Gess-Newsome, 1999) required to be confident and effective teachers of science.

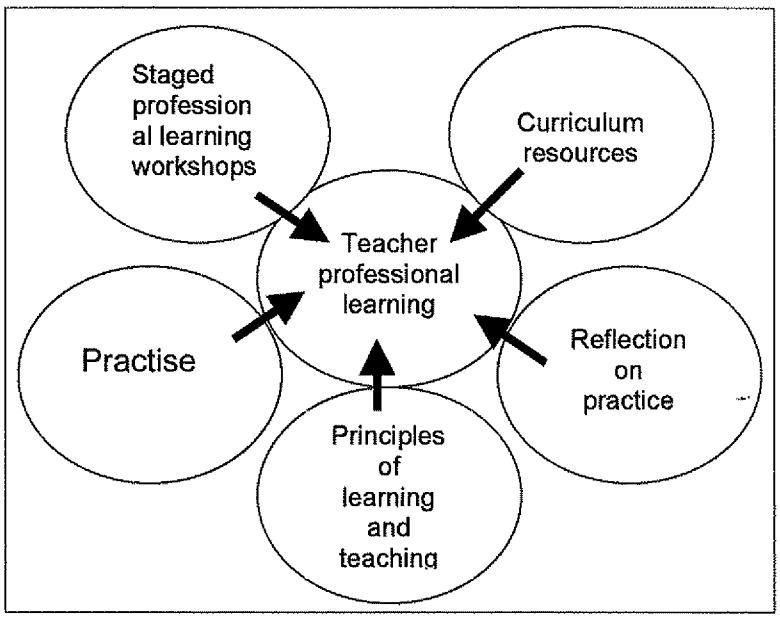


Figure 1. *The Primary Connections professional learning model (Hackling & Prain, 2005)*

The 2001 national review of the status and quality of science teaching and learning (Goodrum, Hackling & Rennie, 2001) indicated that the teaching of science in primary classrooms is patchy and recommended that primary teachers be given access to quality professional learning experiences supported by rich curriculum resources. It also argued that a collaborative national approach is essential to develop world class resources. The *Primary Connections* program was developed in response to these concerns (Peers, 2006).

Primary Connections

Primary Connections is an initiative of the Australian Academy of Science, funded by DEST and supported by all state and territory education departments, Catholic and independent schools sectors, and by science and literacy teacher professional associations. *Primary Connections* is a teacher professional learning program supported with curriculum resources that aims to enhance learning outcomes in science and the literacies of science.

Professional learning

Primary Connections is the first Australian initiative to address the professional learning needs of both inservice and preservice teachers of science.

Professional learning for inservice teachers. *Primary Connections* provides a professional learning program for inservice teachers comprising a number of complementary elements: professional learning workshops, exemplary curriculum resources, opportunity to practise science teaching supported with resources, reflections on practice, and is linked to a set of principles of learning and teaching. These elements are represented in the *Primary Connections* professional learning model in Figure 1.

This model is based on the CASSP professional learning model that proved successful in effecting teacher change in an earlier Australian project (Goodrum, Hackling & Trotter, 2003; Sheffield, 2004) elaborated with a set of pedagogical principles derived from the *Science in Schools* project (Tytler, 2002). *Primary Connections* has developed a suite of comprehensively resourced professional learning modules and has trained a cadre of professional learning facilitators who can deliver *Primary Connections* professional learning workshops in schools throughout Australia. Professional learning facilitators participated in a three-day workshop to familiarise them with the *Primary Connections* teaching and learning approach, curriculum resources and professional learning workshop resources. They also worked in state/territory teams to plan approaches for implementing *Primary Connections* in their jurisdictions.

Professional learning for preservice teachers. A two-day workshop was conducted in February 2007 for 64 science educators from 36 universities who teach primary science curriculum units in initial teacher education courses so that new teachers will develop an understanding of the *Primary Connections* approach to science teaching and learning. Elements of *Primary Connections* are now being incorporated in teacher education programs in universities throughout Australia.

The *Primary Connections* approach to teaching and learning

The *Primary Connections* approach, exemplified by the curriculum units, is based on the 5Es teaching and learning model with assessment embedded into the teaching and learning process. The approach is highly innovative in that it makes links between science and literacy, follows an inquiry and investigative approach, and integrates cooperative learning strategies.

The *Primary Connections* 5Es teaching and learning model. The *Primary Connections* 5Es teaching and learning model (Figure 2) is an elaborated version of Bybee's (1997) 5Es model that is both inquiry based and constructivist

Phase	Focus
Engage	Engage students and elicit prior knowledge *Diagnostic assessment*
Explore	Provide hands-on experience of the phenomenon *Formative assessment*
Explain	Develop science explanations for experiences and representations of developing understandings *Formative assessment*
Elaborate	Extend understandings to a new context or make connections to additional concepts though student planned investigations *Summative assessment of investigating outcomes*
Evaluate	Re-represent understandings, reflect on learning journey and collect evidence about achievement of outcomes *Summative assessment of conceptual outcomes*

Figure 2. *The Primary Connections 5Es teaching and learning model (Australian Academy of Science, 2005)*

in that ideas are developed from experiences of science phenomena, prior knowledge, rich discussions, teacher feedback and explanation, and opportunities to represent and re-represent developing understandings.

Embedded assessment. The *Primary Connections* 5Es teaching and learning model embeds diagnostic, formative and summative assessment into the teaching and learning process because research shows that students' prior knowledge and teachers' monitoring of students' learning and the provision of formative feedback are powerful factors influencing achievement (Black & Wiliam, 1998; Hattie, 2003). Embedding the diagnostic and formative assessment supports teaching that addresses students' alternative conceptions and moves them towards more scientifically valid explanations.

Linking science and literacy. *Primary Connections* recognises that there are synergies that can be achieved in the teaching and learning of science and literacy. Science-specific as well as everyday literacies are required by students to effectively engage with science, construct science understandings and develop science processes, and to represent and communicate ideas and information about science (Gee, 2004; Lemke, 1998; Norris & Phillips, 2003; Unsworth, 2001). *Primary Connections* provides opportunities for students to develop the literacies needed to learn science and to represent their science understandings and processes. Science provides a purpose and context for meaningful literacy activities in which students interpret and construct science texts.

Inquiry and investigative approach. To develop an understanding of the nature of science (Lederman & Lederman, 2004), an understanding of scientific evidence (Gott & Duggan, 1996) and to become scientifically literate, students need to be engaged in an inquiry oriented and an investigative approach to learning science. *Primary Connections* units include both teacher-guided and student-planned investigations so that students can practise and develop the processes and skills required for working scientifically.

Cooperative learning. *Primary Connections* recognises social constructivist principles by providing opportunities for cooperative group work in which discussion and negotiation facilitate co-construction of meaning. Team roles and skills based on those developed in the *Primary Investigations* program (Australian Academy of Science, 1994) are used to support cooperative group work in *Primary Connections*. Research has demonstrated that cooperative learning facilitates gains in achievement, higher order thinking, generation of new ideas, and in social and communication skills (Johnson & Johnson, 1994).

Curriculum resources

To support teachers in the practical implementation of the innovative teaching and learning approach, *Primary Connections* is developing a suite of curriculum units. Each unit contains comprehensive, easy-to-read teacher background information and step-by-step lesson guides based on the *Primary Connections* 5Es teaching and learning model with assessment embedded at each stage. Appendices explaining some of the science literacies used, and containing 'How to' sheets for techniques such as conducting a fair test and organising cooperative teams are provided, as well as equipment lists. The website supports teachers with assessment rubrics they can download and modify, and provides information on further resources such as factual and narrative texts and relevant websites.

Development of the curriculum units. The development of the curriculum resources is based on mapping of state and territory curriculum frameworks, the national scientific literacy progress map (MCEETYA, 2005) and the national statements of learning for science (MCEETYA, 2006). Draft curriculum units are trialled in over 50 trial schools throughout Australia and feedback from the trial is used to revise the units before they are published and made available for purchase by schools. As units become reprinted as revised editions, further amendments are made as opportunities for enhancements are identified.

These quality assurance processes enabled *Primary Connections* to win the *2006 Australian Publishers Award for Excellence in Educational Publishing* in the primary teaching and learning category.

Scope and sequence of curriculum units. *Primary Connections* units are written in developmental stages (see Figure 3) linked to years of schooling and outcome levels of the national scientific literacy progress map (MCEETYA, 2005), and are mapped to the four conceptual strands of the national statements of learning for science (MCEETYA, 2006). For example, the *Plants in Action* unit which focuses on the life cycle of flowering plants is a Stage 2 unit, having learning outcomes at Levels 2 and 3, and is suitable for students in their fourth and fifth years of schooling.

Primary Connections stage	Years of schooling	Outcome levels*
Early Stage 1	1	<1–1
Stage 1	2–3	1–2
Stage 2	4–5	2–3
Stage 3	6–7	3–4

* From the *National Scientific Literacy Progress Map* (MCEETYA, 2005)

Figure 3. *Relationships between stages, years of schooling and scientific literacy progress map levels*

Impact of *Primary Connections*

Primary Connections was trialled in 2005 in 56 schools involving 106 teachers and more than 3000 students. Teachers completed an initial five days of professional learning at a summer school in January 2005 and three follow-up one-day workshops. Teachers taught a trial *Primary Connections* unit in Term 1, a unit the teachers developed themselves based on the *Primary Connections* model in Term 2, and a trial *Primary*

Connections unit in Term 3. Data were collected by teacher questionnaire, student questionnaire, case studies and by analysis of student work samples. A full research report (Hackling & Prain, 2005) documents all details of the data collection, analysis and research findings. Impacts of the program on teachers, students and schools are reported here in summary form.

Impact on teachers. Teachers' confidence with nine science and literacy teaching strategies was assessed on a five point scale. Mean confidence scores increased significantly ($p < .05$) from 3.34/5 at the beginning of the program to 4.04/5 at the end of Term 2. Teachers' self-efficacy beliefs were assessed using a 10 item scale based on Riggs and Enochs' (1990) instrument. Teachers' mean total self-efficacy score (/50) increased significantly ($p < .05$) from 35 to 41, that is, teachers had more positive beliefs about their effectiveness as teachers of science. Of educational significance, the number of teachers with low to moderate self-efficacy scores (≤30) was reduced from 22 to one by the end of Term 2. Teachers with low self-efficacy are likely to avoid teaching science.

Teachers also reported the frequency with which they used a range of teaching and learning strategies. The strongest increase in strategy use was recorded for developing literacy skills needed for learning science, which suggests that teachers recognised the importance of these skills and had the resources and confidence to teach them. There was also a strong increase in the frequency of use of diagnostic assessment as a consequence of it being scaffolded into *Engage* lessons, and an increased frequency of doing hands-on activities. At the end of Term 1, teachers indicated their science teaching had improved through increased hands-on practical work, inquiry and investigations, focussing on one topic for a whole term, the 5Es structure, more time on science, increased confidence and the better sequencing and flow between lessons.

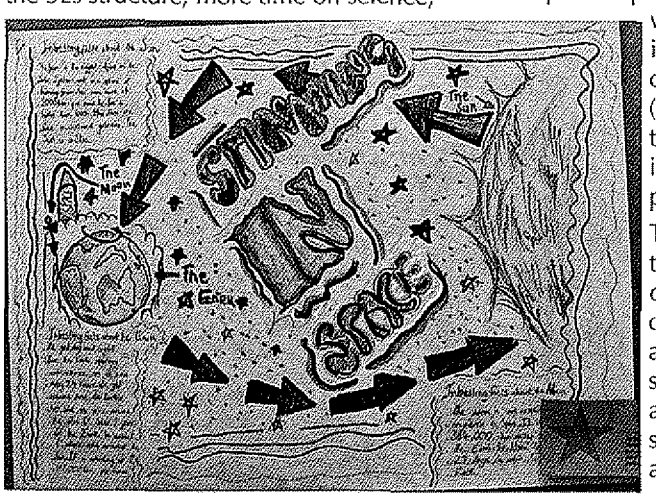
The following interview quotes from trial teachers exemplify the impact of *Primary Connections* on their confidence and pedagogical content knowledge:

... for a start, I'm teaching science, which is remarkable. Even more amazing is that I'm aware of how important science and good science teaching are to a child's education. What is the bonus for me is that I'm enjoying teaching science. (Teacher 46)

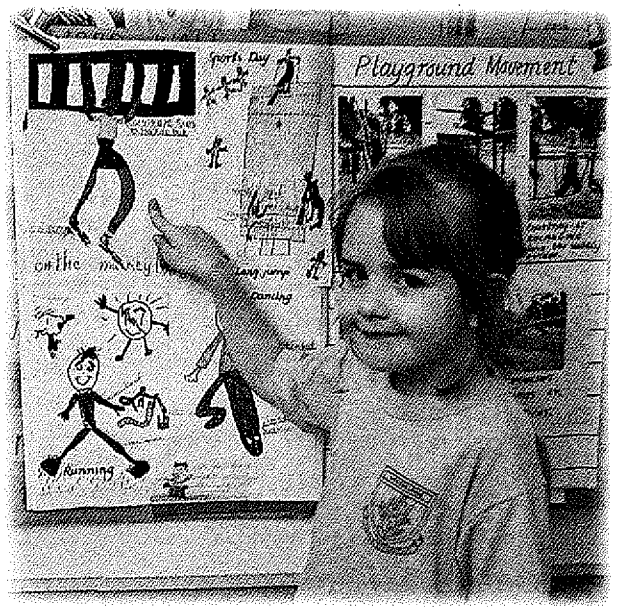
I now have more lead-in sessions to a topic/concept, rather than just one-off lessons. The teaching in sequence approach over a period of time is a more meaningful experience for everyone. (Teacher 27)

I need a book to list how this program has helped my science teaching. More organised, more contact with outcomes/ indicators, confident with experiments, can see a purpose, big picture is much clearer, can talk (about science) more confidently, children have picked up on enthusiasm etc. (Teacher 15)

When asked at the end of Term 2, 'Has your science teaching improved as a result of participating in the *Primary Connections* program?', 96 of 97 teachers responded 'Yes'. When asked to explain how their science teaching had improved the teachers identified aspects of their knowledge, confidence and practice that had improved as a result of participating in the program. Almost a third of teachers indicated they were now more confident, corroborating other evidence about confidence and increased self-efficacy. A fifth indicated they had a better understanding of the concepts and processes of science, which is indicative of improved pedagogical content knowledge (PCK). Improving teachers' PCK was an important aim of the program.



The amount of science taught increased dramatically as a result of the trial and there was also a shift from teaching science mainly in the afternoon to teaching science in both mornings and afternoons. The



amount of science taught was greatest in Term 1 of the trial when teachers were working with trial *Primary Connections* units, however, even when working from teacher developed units in Term 2 the percentage of teachers teaching less than 30 minutes per week was reduced from 27% to 11% and the percentage teaching an hour or more per week had increased from 31% to 62%. Time on task has been recognised as a fundamental variable influencing learning as it determines learning opportunity. Clearly this program has given students in the trial schools far more opportunity to learn science.

Impact on students. Eighty-seven per cent of teachers reported that students had responded positively or very positively to the *Primary Connections* activities and learning approach. Seventy-six percent of teachers rated the amount of students' science learning with *Primary Connections* as better than previous and 78% indicated that the quality of students' science learning was better than previous.

To provide a measure of learning achievement, the science journals of three classes of students who completed the *Plants in Action* unit at one of the case study schools were analysed. The students represented two intact classes of Year 5 students and the Year 5 students from a combined Year 4/5 class. The work samples generated in the *Engage* and *Evaluate* lessons were rated against levels in the National Scientific Literacy Progress Map (MCEETYA, 2005). To provide a more fine-grained analysis, levels of achievement were further subdivided into the sublevels—developing, consolidating and achieved. Explicit criteria for levels and sublevels were defined and dual coding by consensus of two experienced coders

ensured a high level of coding reliability.

At the beginning of the unit the modal level of achievement was Level 2 Consolidating and at the end of the unit it had risen to Level 3 Consolidating. Levels were converted to scores to facilitate calculation of means and statistical comparison of *Engage* and *Evaluate* mean scores. The mean score had more than doubled over the course of the unit and at the end of the unit 78% of these Year 5 students were working at or beyond Level 3 in their conceptual understandings of plant life cycles. Level 3 is the national proficiency standard for Year 6 students' scientific literacy.

Impact on schools. Trial teachers' perceptions of the status of science in their schools were elicited in the teacher questionnaires. Teachers were asked to rank science in importance relative to nine other learning areas. The percentage of teachers indicating science was in the top three subjects doubled from 24% to 50% as a result of the *Primary Connections* trial in their schools. When principals of trial schools were asked 'What impact has *Primary Connections* had on your school?', the most common responses were: it has raised the profile of science in my school; the whole school is involved in teaching science; science teaching has improved; and, more science is being taught in my school.

Discussion and conclusions

Primary Connections is a national initiative that aims to reform the teaching of science in Australian primary schools and enhance learning outcomes in science and the literacies of science. The project supports inservice teachers with professional learning workshops and curriculum resources illustrating the *Primary Connections* approach to teaching and learning. By January 2008 approximately 300 professional learning facilitators will have been trained to facilitate workshops in schools throughout Australia. University science educators from all Australian universities that offer teacher education courses have attended a workshop on the *Primary Connections* approach to science and literacy teaching and learning. Elements of the *Primary Connections* approach are being incorporated into science curriculum units in initial teacher education courses to ensure that new graduates are familiar with the program and its approach to science teaching and learning.

Research data from the trial of *Primary Connections* in 2005 indicates that the program has had a positive impact on teachers, students and schools. The program improved teachers' confidence, self-efficacy and practice, students' learning, and the status of science within schools. The combination of professional learning and being supported in their teaching with curriculum resources enhances teachers' confidence, self-efficacy and practice through building science pedagogical content knowledge. As a consequence of increased confidence and self-efficacy and using the curriculum resources, the teachers increased the amount of time they taught science. Teachers improved practice and teaching time increased students' opportunity for learning science which resulted in strong science achievement gains.

Acknowledgement

This project and associated research is funded by the Australian Government Department of Education, Science and Training as a quality teacher initiative under the Australian Government Quality Teacher Programme.

Further information

Further information about *Primary Connections* and the research report on the 2005 trial of the program is available at www.science.org.au/primaryconnections

References

Angus, M., Olney, H., Ainley, J., Caldwell, B., Burke, G., Selleck, R., & Spinks, J. (2004). *The sufficiency of resources for Australian primary schools.* Canberra: DEST.

Appleton, K. (1995). Student teachers' confidence to teach science. Is more science knowledge necessary to improve self-confidence? *International Journal of Science Education, 17,* 357–369.

Australian Academy of Science. (1994). *Primary Investigations.* Canberra: Australian Academy of Science.

Australian Academy of Science. (2005). *Primary Connections: Plants in action.* Canberra: Australian Academy of Science.

Australian Science, Technology and Engineering Council (ASTEC). (1997). *Foundations for Australia's future: Science and technology in primary schools.* Canberra: Australian Government Publishing Service.

Black, P., & Wiliam, D. (1998). Inside the black box: Raising standards through classroom assessment. *Phi Delta Kappan, 80*(2), 139–148.

Bybee, R. W. (1997). Achieving scientific literacy: From purposes to practical action. Portsmouth, NH: Heinemann.

Gee, J. P. (2004). Language in the science classroom: Academic social languages as the heart of school-based literacy. In E. W. Saul (Ed.), *Crossing borders in literacy and science instruction: Perspectives in theory and practice* (pp. 13–32). Newark, DE: International Reading Association/ National Science Teachers Association.

Gess-Newsome, J. (1999). Pedagogical content knowledge: An introduction and orientation. In J. Gess-Newsome & N.G. Lederman [Eds.], *Examining pedagogical knowledge: The construct and its implication for science education.* Dordrecht: Kluwer Academic Publishers.

Goodrum, D., Hackling, M., & Rennie, L. (2001). *The status and quality of teaching and learning of science in Australian schools: A research report.* Canberra: Department of Education, Training and Youth Affairs.

Goodrum, D., Hackling, M. & Trotter, H. (2003). *Collaborative Australian Secondary Science Program: Pilot study.* Perth: Edith Cowan University.

Gott, R., & Duggan, S. (1996). Practical work: Its role in the understanding of evidence in science. *International Journal of Science Education, 18*(7).

Hackling, M. W. & Prain, V. (2005). *Primary Connections: Stage 2 Trial: Research Report.* Canberra: Australian Academy of Science.

Hattie, J. (2003). *Teachers make a difference: What is the research evidence?* Paper presented at the Australian Council for Educational Research Conference on Building Teacher Quality.

Johnson, R. T. & Johnson, D. W. (1994). An overview of cooperative learning. In J. Thousand, A. Villa & A. Nevin (Eds). *Creativity and collaborative learning.* Baltimore: Brookes Press.

Lawrance, G. A. & Palmer, D. H. (2003). *Clever teacher, clever sciences:* Preparing teachers for the challenge of teaching science, mathematics and technology in 21st Century Australia. Canberra: DEST.

Lederman, N. G., & Lederman, J. S. (2004). Nature of science and scientific inquiry. In G. Venville & V. Dawson (Eds.), *The art of science teaching in Australian schools.* Melbourne: Allen and Unwin.

Lemke, J.(1998) Multiplying meaning: Visual and verbal semiotics in scientific text. In J, Martin & R. Veel (Eds.)*Reading science: Critical and functional perspectives on discourses of science.* London; Routledge.

Ministerial Council on Education, Employment, Training and Youth Affairs (MCEETYA). (2005). *National Year 6 science assessment report: 2003.* Melbourne: Curriculum Corporation.

Ministerial Council on Education, Employment, Training and Youth Affairs (MCEETYA). (2006). *Statements of learning for science.* Melbourne: Curriculum Corporation.

Norris, S. P., & Phillips, L. M. (2003). How literacy in its fundamental sense is central to scientific literacy. *Science Education, 87,* 224–240.

Palmer, D. H. (2001). Factors contributing to attitude exchange amongst preservice elementary teachers. *Science Education, 86,* 122–138.

Peers, C. (S.) E., (2006). *Making a Difference: Primary Connections Stage 3 Project Brief.* Canberra: Australian Academy of Science. Retrieved on 1 June 2006 from www.science.org.au/primaryconnections

Riggs, I. & Enochs, L. (1990). Towards the development of an elementary teacher's science teaching efficacy belief instrument. *Science Education, 74,* 625–637.

Sheffield, R. (2004). *Facilitating teacher professional learning: Analysing the impact of an Australian professional learning model in secondary science.* Unpublished PhD thesis, Edith Cowan University, Perth, Western Australia.

Thomson, S. & Fleming, N. (2004). *Examining the evidence: Science achievement in Australian schools in TIMSS 2002.* Camberwell, Victoria: Australian Council for Educational Research.

Tytler, R. (2002). School Innovation in Science (SiS): Focussing on teaching. *Investigating, 18*(3), 8–11.

Unsworth, L. (2001)*Teaching multiliteracies across the curriculum: Changing contexts of text and image in classroom practice.* Buckingham, UK: Open University Press.

Yates, S. & Goodrum, D. (1990). How confident are primary school teachers in teaching science? *Research in Science Education, 20,* 300–305.

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