Primary Connections: A new approach to primary science and to teacher professional learning

Mark W. Hackling

Edith Cowan University

Mark Hackling is Professor of Science and Technology Education at Edith Cowan University. Mark was co-author (with Goodrum and Rennie) of the report of the national review of the quality and status of science teaching and learning in Australian schools and has provided leadership to a number of national science education projects including the national assessments of Year 6 students' scientific literacy and the development of the Science Education Assessment Resources (SEAR) on-line assessment resource bank. Mark is a Director of the DEST funded Primary Connections professional learning program for primary teachers of science and literacy and is co-author (with Lokan and Hollingsworth) of the soon to be released Australian report on the TIMSS Video study.

Abstract

Primary Connections is a teacher professional learning program supported by curriculum resources that aims to enhance learning outcomes in science and the literacies of science. The program is based on an innovative model that links science with literacy, uses cooperative learning, integrates assessment with teaching and learning, and follows an inquiry process using open investigations. The program was trialled in 56 schools throughout Australia in 2005. Research has demonstrated that the program improves teachers' confidence, self-efficacy and practice, students' learning, and the status of science within schools. The project is an initiative of the Australian Academy of Science, funded by DEST and supported by all states and territories and sectors of schooling.

Introduction

Australia's currently buoyant economy is largely based on exploiting our nation's natural resources of coal, gas, iron ore, gold and other metals. All of these resources are finite and it is timely, at this conference, to focus on boosting science learning as a way of building human capital – the key resource for a knowledge-based economy – so that we can build a future based on ideas and innovation for those times when the natural resources are less abundant. Innovation depends on new thinking, and it is curiosity, creativity and scientific literacy that provide the basis for a knowledge-based economy. Opening minds to the wonders of the natural world, stimulating curiosity and creative thinking, and starting that journey towards scientific literacy requires a strong and effective science program in the primary years of schooling.

High quality teaching of science and literacy in Australian primary schools is a national priority to develop citizens who are scientifically literate and who can contribute to the social, environmental and economic well-being of Australia as well as achieve their own potential (Australian Academy of Science, 2006). Student achievement in science is therefore being monitored through the national assessments of Year 6 students' scientific literacy for which sample testing was undertaken in October 2003 and will be repeated in 2006. Parents also recognise the importance of science rating it as the third most important subject for their primary school children after English and Mathematics (ASTEC, 1997).

Despite science being recognised as a priority area of learning, the teaching of science in primary schools has low status with the second lowest allocation 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 consequently score poorly on self-efficacy scales that measure the extent to which primary teachers feel capable of teaching science effectively (Riggs & Enochs, 1990). The limited science discipline studies and science curriculum studies in many Australian initial teacher education programs (Lawrance & Palmer, 2003) gives student teachers little opportunity to build the pedagogical content knowledge (Gess-Newsome, 1999) required to be confident and effective teachers of science. 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

Phase	Focus
Engage	Engage students and elicit prior knowledge Diagnostic assessment
Explore	Provide hands-on experience of the phenomenon
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 1 The Primary Connections teaching and learning model (Australian Academy of Science, 2005)

of science be given access to quality professional learning opportunities supported by rich curriculum resources to address this problem. It also argued that collaboration between jurisdictions is essential to produce world-class resources and to reduce wasteful duplication of efforts. *The Primary Connections* program was developed in response to these concerns (Australian Academy of Science, 2006).

Recent national assessments of scientific literacy and international assessments of science achievement present a sobering picture of the health of primary science in Australia. Less than 60 per cent of sampled Year 6 Australian students in 2003 attained the national proficiency standard in six of eight jurisdictions (MCEETYA, 2005). The Trends in International Mathematics and Science Study (TIMSS) shows that the science achievement of Australian Year 4 students has remained stable between assessments made in 1994 and 2002 at a level that was above the international mean; however, 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.

Primary Connections

Primary Connections is an initiative of the Australian Academy of Science, funded by the Commonwealth Department of Science Education and Training, (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.

Teaching and learning model

Primary Connections recognises that there are a number of science-specific as well as general literacies required by children to effectively engage with science phenomena, 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 children to develop the literacies needed to learn science and to represent their developing science understandings and processes. The *Primary Connections* 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). 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. The *Primary Connections* teaching and learning model (Figure 1) is therefore scaffolded by an elaborated 5Es inquiry model (Bybee, 1997).

Professional learning model

Primary Connections is a professional learning program comprising a number of complementary elements: professional learning workshops, exemplary curriculum resources, opportunity to practise science teaching supported with resources, reflections

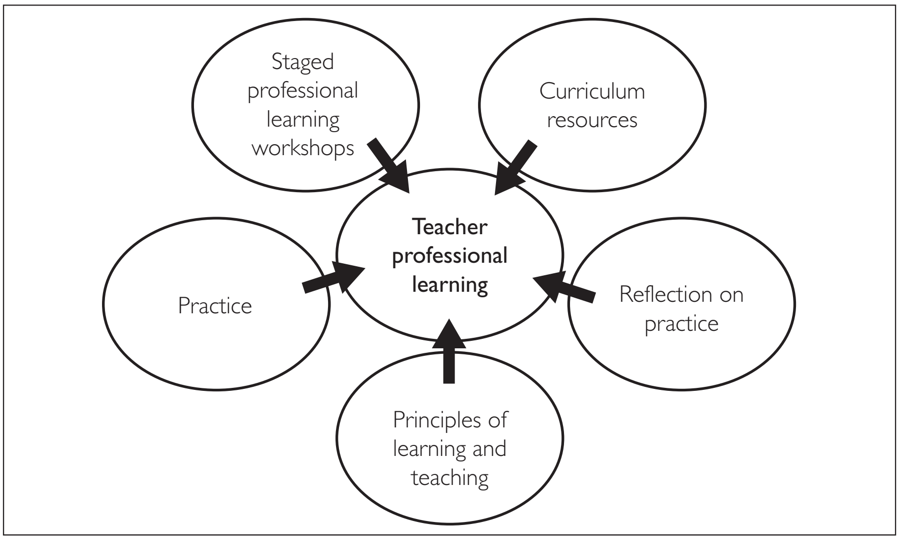

Figure 2 The Primary Connections professional learning model (Hackling & Prain, 2005)

on practice, and is linked to a set of principles of learning and teaching.

This model is based on the Collaboratative Australian Secondary Science Project (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.

In addition to this professional learning program for experienced teachers, a workshop was conducted in July 2005 for university science educators who teach primary science curriculum units in initial teacher education so that new teachers will develop an understanding of the *Primary Connections* approach to science teaching and learning.

Impact of Primary Connections

Primary Connections was trialled in 2005 in 55 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 with three follow-up one-day workshops; the first, half way through Term 1, the second at the end of Term 1 and the third at the end of Term 2. Teachers taught a supplied curriculum unit in Term 1, a unit the teachers developed themselves in Term 2, and a supplied 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; highlights are presented here.

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'

Table 1 Frequency of total self-efficacy scores on each survey (n=89)

Total self-efficacy score	Initial survey (= 2004)	End of summer school	Mid Term 1, 2005	End Term 1, 2005	End Term 2, 2005
1–10	0	0	0	0	0
11–20	2	0	0	0	0
21–30	20	10	4	3	1
31–40	50	49	52	54	49
41–50	17	30	33	32	39
Mean total self efficacy score for all teachers	35*	38	39	40	41*
S.D.	6.8	5.4	4.5	4.6	4.5

Note: Total self-efficacy score = sum of 10 self-efficacy item scores for each teacher, (/50), with the most positive response given the value of 5 and the least positive the value of 1 on a five-point agreement scale, i.e. scores have been reversed for negative items.

Table 2 Minutes of science taught per week by teachers in 2004, Term 1 2005 and in Term 2 2005

Minutes of science taught per week	Per cent of respondents		
	2004 (n=91)	**Term 1 2005 (n=91)**	**Term 2 2005 (n=85)**
60 minutes or more	30.8	72.5	62.4
30 and 60 minutes	40.7	26.4	27.1
Less than 30 minutes	27.5	1.1	10.6

(1990) instrument. Teachers' mean total self-efficacy score (/50) increased significantly ($p < .05$) from 35 to 41, and 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 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 these skills. 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 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, focusing on one topic for a whole term, the 5Es structure, more time on science, increased confidence and the better sequencing and flow between lessons.

When asked at the end of Term 2, 'Has your science teaching improved as a result of participating in the *Primary Connections* program?' 96 out 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. The amount of science taught was greatest in Term 1 of the trial when teachers were working with supplied 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 per cent to 11 per cent.

Time on task has always been recognised as the 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 per cent of teachers rated the amount of students' science learning with Primary Connections as better than previous and 78 per cent 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 2c and at the end of the unit, it had risen to 3c. 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 per cent 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.

Table 3 Changes in levels of achievement between the initial 'Engage' lesson and the final 'Evaluation' lesson for Year 5 students studying the Plants in Action unit at one case study school.

Achievement level	Number of students (n=72) Engage	Evaluate
1a	11	0
2d	16	3
2c	41	5
2a	3	8
3d	1	15
3c	0	22
3a	0	15
4d	0	4
Mean score	2.54*	5.51*
S.D.	0.855	1.473

Note. Levels of achievement were assigned the following scores: 1a = 1; 2d = 2; 2c = 3; 2a = 4; 3d = 5; 3c = 6; 3a = 7; 4d = 8 where d = developing; c = consolidating; a = achieved.
* Mean scores are significantly different (p<.05) using the Wilcoxon signed ranks test.

Impact on schools

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 per cent as a result of the *Primary Connections* trial in their schools. The status of a subject in the school curriculum may also have an influence on the resources and budget allocated to that subject. Previous research (e.g., Keys, 2003) has often indicated that availability of resources and budget are important factors limiting the quality of science teaching in primary schools.

Discussion and conclusions

This paper reports data on the impact of *Primary Connections* on teachers, students and schools based on a trial in 2005 which involved an intensive professional learning program supported with trial curriculum units. The program improved teachers' confidence, self-efficacy and practice, students' learning, and the status of science within schools. The data suggest that the combination of professional learning and being supported in their teaching with curriculum resources enhances teachers' confidence and self-efficacy 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 and thereby increased students' opportunity for learning science, which resulted in strong science achievement gains.

Feedback from the 55 trial schools is used to revise the trial curriculum units so that they are more effective in meeting teachers' needs. The revised and published units are now being implemented in schools throughout Australia. *Primary Connections* professional learning is being provided by trained professional learning facilitators using the professional learning modules. There are variations on the professional learning model across jurisdictions and sectors and the efficacy of these different approaches will be the subject of further research.

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