

Executive summary

Importance of the project

Science plays a crucial role in developing new ideas that can be applied to innovative technologies which can be commercialised and drive the economy. Science education not only plays a role in developing future scientists but also in developing scientifically literate citizens who can contribute to the social and economic well-being of Australia, as well as achieve their own potential. National assessments of Year 6 students' scientific literacy indicate that as few as 54 per cent of the sample in some jurisdictions reached the proficiency standard (MCEETYA, 2005). The national review of the status and quality of science teaching in Australian schools raised concerns about the quality and amount of science taught in our primary schools (Goodrum, Hackling and Rennie, 2001) and there have been long-standing concerns about the confidence and competence of primary teachers for teaching science (eg, Yates and Goodrum, 1990).

Research evidence from the trial of *Primary Connections* demonstrates that this program has had a large and positive impact on teachers' practice, students' learning and the status of science in schools and has the potential to have a significant impact on improving the teaching and learning of primary science throughout Australia.

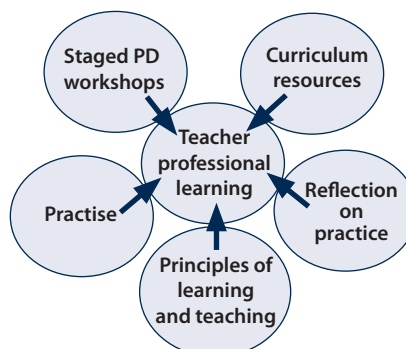
Purpose

The purpose of *Primary Connections* is to improve learning outcomes in science and literacy through a sophisticated professional learning program supported with rich curriculum resources that will improve teachers' knowledge of science and science teaching and thereby improve teachers' confidence and competence for teaching science and the literacies needed for learning science.

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

Figure 1: The *Primary Connections* professional learning model



Teaching and learning model

A teaching and learning model was created by elaborating the 5Es model (Bybee, 1997) to guide the development of the curriculum resources. The model is based on an inquiry and investigative approach in which students work from questions to undertake investigations and construct explanations. It is therefore consistent with contemporary constructivist learning theory which suggests that learners actively construct knowledge and make personal meaning from their experiences. Students are given opportunities to represent their developing understandings using a wide range of texts such as student journals, posters, tables and captioned diagrams as well as information communication technologies (ICTs) such as powerpoints and digital cameras. Assessment is integrated with teaching and learning. The model is illustrated in Figure 2.

Figure 2: The *Primary Connections* teaching and learning model

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

Key research findings

Effectiveness of the *Primary Connections* teaching and learning model

Anecdotal evidence, questionnaire data and case studies indicate that teachers wholeheartedly support the teaching–learning model and that the model was appropriate and effective because:

- The curriculum units structured and guided teaching and learning, supported the progressive development of understandings, and effectively integrated science and literacy so that learning in both science and literacy were improved.
- The model also facilitated significant changes to teachers’ practice so that there was an increase in hands-on activity work, use of diagnostic assessments, and cooperative group work.
- Students developed a wide range of forms of representation of their knowledge (eg, text, drawings, diagrams, tables and graphs) and the increased use of digital cameras extended the ways of capturing and representing data using ICTs.

Impact on teachers, students and schools

The research data indicate that *Primary Connections* has had a profound and positive impact on teachers, students and schools.

Teachers

Initially, many of the trial teachers had low confidence and beliefs about their ability to teach science effectively (self-efficacy). Half of the 106 trial teachers had not completed any science studies beyond Year 12 and half had not attended any science professional learning programs in the previous year. Studies of science and science education and experience of teaching science build pedagogical content knowledge — the complex knowledge of science, curriculum, students, teaching strategies and learning needed to effectively teach science. Teachers with limited pedagogical content knowledge have low confidence and self-efficacy beliefs about their ability to teach science effectively, and tend to avoid teaching science.

Primary Connections significantly increased teachers' confidence with science and literacy teaching strategies and significantly increased teachers' self-efficacy. The number of teachers with low self-efficacy was dramatically reduced.

Primary Connections increased the amount of time devoted to science teaching, and science moved from being an afternoons-only subject to one taught across mornings and afternoons as science and literacy teaching were integrated.

Teachers integrated science and literacy by developing the literacies of science in literacy lessons and by using science to provide contexts and purpose for literacy learning. Almost 90 per cent of teachers considered the integrated approach had improved science learning and 73 per cent considered that the integrated approach had improved literacy learning.

By the end of term 2, teachers' concerns had changed from focusing on activities and strategies to focusing on achieving learning outcomes. Teachers attributed improvements in their science teaching to increased confidence and improved pedagogical content knowledge.

Classroom observations made of case study teachers indicated that as they gained experience teaching with the support of *Primary Connections* units, the teachers' confidence increased and their teaching through inquiry improved.

Students

The research focused on students' engagement with and enjoyment of science and their learning outcomes.

The student survey data show that a large majority of students enjoyed science and believed that they had learned more science using *Primary Connections* than previously.

Almost 90 per cent of teachers indicated that their students had responded positively or very positively to the *Primary Connections* activities and learning approach. More than 75 per cent indicated their students had learned more science and the quality of science learning was higher with *Primary Connections* than with their previous science program.

These student and teacher perceptions of high learning outcomes were corroborated by student science achievement data which indicated that mean achievement scores for a sample of Year 5 students increased significantly over one unit (more than doubled). Almost 80 per cent of the sample of Year 5 students were working at or above level 3 on the national scientific literacy progress map, which is the national proficiency standard for Year 6 students.

Schools

Teachers also reported many positive impacts of the program at the school level. More than 90 per cent of teachers indicated that *Primary Connections* had a significant impact on their schools increasing students' and teachers' interest in science, the profile of science within the school and local community, and increasing the amount of science being taught in their schools.

Primary Connections supported a large increase in science teaching time and the status of science in the school curriculum.

The increase in science teaching time can be attributed to teachers' increased confidence and self-efficacy, and having a quality curriculum resource to support their teaching.

It should be noted, however, that even with the support of the *Primary Connections* program, a significant number of teachers reported that their schools had inadequate school budgets for science (26 per cent), insufficient equipment and consumables (20 per cent), they had no science coordinator (37 per cent) and did not report science achievement as a separate subject on school reports to parents (30 per cent).

Insights into effective teacher professional learning gained from the trial whole-school roll-out of the professional learning model in the case study schools

Case study 2 provides an account of a very successful whole-school implementation of *Primary Connections* and identifies a number of factors that contributed to the success of the initiative at the school.

Strong support and leadership from the school executive, effective coordination of the program by the deputy principal, and peer support from two trial teachers who had attended the summer school professional learning workshop, engendered involvement and commitment to the project from the whole school staff.

Teachers at this school considered that the one-day professional learning workshop that introduced teachers to the program was effective in helping teachers to teach the science and literacy program; however, follow-up support was needed to assist teachers with emerging issues as they taught the program.

Planning of the professional learning resources for Stage 3 of the project will take account of the feedback from this pilot of a whole-school implementation. Resources are being prepared for a one-day workshop with a smorgasbord of follow-up 1.5 hour workshops that will provide further support in key areas such as implementing and assessing open investigations, developing literacies needed for learning science, and assessment.

Further enhancing the curriculum and professional learning resources for implementation in Stage 3

Almost 90 per cent of the teachers considered the curriculum units to be effective or very effective. Detailed teacher feedback will guide the revision of these units before widespread distribution. The most common suggestions were that the lessons should be shorter, the units should be shorter and the expected literacy demands be moderated for the Early Stage 1 and Stage 1 units.

Almost 90 per cent of teachers indicated that the professional learning program was as good as, or better than, any they had attended. The whole-school one-day professional learning workshop was piloted at the four case study schools and was well-received by teachers. Teachers commented that video clips of teachers working with *Primary Connections* would have enhanced the professional learning experience. Video clips are being prepared for inclusion in the professional learning resources.

Compatibility with jurisdictions' curriculum frameworks and professional learning support structures

Many teachers commented about the flexibility of the curriculum resources and that they found it relatively easy to adapt them to local contexts and needs. Continual monitoring of changes to jurisdictions' curriculum frameworks and the development of a National Statement of Learning for science will guide the development of new units.

Discussions with representatives from the various jurisdictions on the reference group has indicated that the project's design and resources will support a wide range of models of implementation that will be needed as the professional learning support structures vary in different jurisdictions.

Almost 90 per cent of teachers considered the units compatible with their jurisdictions' curriculum frameworks and schools' science programs, and 95 per cent of teachers wanted the Australian Academy of Science to produce additional units.

The quality and flexibility of the program has resulted in the trial being successfully completed in all of Australia's educational jurisdictions and sectors, and in metropolitan, regional and rural schools.

Recommendations

The research conducted as part of the evaluation of the Stage 2 trial of *Primary Connections* indicates that the program has been very successful in terms of its impact on teachers, students and schools. The flexibility of the program has enabled the program to be implemented effectively in different types of schools and sectors throughout Australia. Research evidence demonstrates that *Primary Connections* has the potential to improve the quality of science and literacy teaching and enhance the scientific literacy of young Australians.

The following recommendations are made to guide planning for future developments of the program and more widespread implementation of *Primary Connections*.

Recommendation 1

The research evidence provides a compelling case for the continuation and extension of the project to Stage 3. It is therefore recommended that the Australian Government's Department of Education, Science and Training and state and territory Departments of Education and Training provide further support to the *Primary Connections* initiative so that Stage 3 of the project can be commenced from term 4, 2005. A smooth transition between stages is imperative to maintain momentum and enthusiasm.

Recommendation 2

That Stage 3 of the *Primary Connections* project train professional learning facilitators from each state and territory and develop further curriculum units to support whole-school implementations of *Primary Connections*. Further research should be conducted to evaluate new units being trialled, the effectiveness of the professional learning facilitators and the impact of the whole-school implementations on students, teachers and schools.

Recommendation 3

The reference group agreed that a number of principles should guide the implementation of the *Primary Connections* program in Stage 3 to ensure the quality and sustainability of the ongoing implementation of the program. It is recommended that the following principles guide the implementation of *Primary Connections* in Stage 3:

- whole-school implementation (where possible);
- implementation be based on a combination of professional learning and curriculum resources;
- professional learning workshops to be facilitated by *Primary Connections* trained facilitators;

- professional learning workshops to be presented by facilitator plus a trial teacher where facilitators are not trial teachers;
- team-based school coordination to ensure succession planning;
- ongoing support and coordination for the team of facilitators within each jurisdiction.

Recommendation 4

Feedback from the trial teachers clearly indicates a preference for hardcopy and CD-ROM formats for the curriculum resources. It is therefore recommended that the curriculum resources are made available to schools in hardcopy and CD-ROM formats, and that the professional learning resources are made available in DVD/CD-ROM formats. The *Primary Connections* website should be further developed and funded to enable ongoing upgrading and effective communication with and between all participants, and to ensure currency of resources.

Recommendation 5

Major reform of teaching and learning can only be achieved through ongoing professional learning of inservice teachers; however, new teachers to the profession can have a large impact if properly prepared for implementing initiatives such as *Primary Connections*. It is therefore recommended that an initial teacher education resource pack be developed as part of Stage 3 to provide universities with a set of coherent resources to induct pre-service teachers into the *Primary Connections* teaching and learning model and to develop familiarity with the resources. A one-day professional learning workshop for university science teacher educators would enhance the uptake and impact of the resource pack.

Recommendation 6

It is recommended that Stage 3 further develop connections with Indigenous contexts and knowledge for learning science and the literacies needed for learning science within *Primary Connections* curriculum units to engage Indigenous students and improve their educational outcomes in science and literacy.

Recommendation 7

It is recommended that Stage 3 strengthen links with other national science education initiatives such as SEAR, Learning Objects (The Learning Federation) and the National Statements of Learning, and that further professional learning programs, supported by quality curriculum resources, be prepared to ensure continuity of engagement with science learning across the whole school experience.

Background to the *Primary Connections* project

Primary Connections is an innovative national initiative of the Australian Academy of Science which links the teaching of science with the teaching of the literacies needed for learning science in primary schools. It comprises a sophisticated professional learning program supported with rich curriculum resources and is designed to increase teachers' confidence and competence in the teaching of science and the literacies of science.

Primary Connections is based on an inquiry and investigative approach in which students work from questions through investigations to constructing explanations and is therefore consistent with contemporary constructivist learning theory. Students are given opportunities to represent and re-represent their developing understandings using a wide range of texts and information communication technologies (ICTs). Assessment is integrated with teaching and learning. Students' representations of their developing understandings provide opportunities for teachers to monitor students' learning progress and use this information to facilitate further learning.

The program is being implemented in stages. Stage 1 was funded by the Australian Academy of Science and involved developing a conceptual model for the program and gaining support from jurisdictions. The project model has been developed in partnership with a reference group which was established in December 2003. All states and territories and major groups involved in the teaching of science and literacy in Australia are represented. This group strongly supported the need for such a project.

Stage 2 was funded by the Australian Government Department of Education, Science and Training, who provided \$1.8 million under the Australian Government's Quality Teacher Programme (AGQTP). Stage 2 developed and trialled curriculum resources and a professional learning program with 106 teachers from 56 schools drawn from all Australian education jurisdictions and sectors. Funding is currently being sought for Stage 3, to write further curriculum resources and train professional learning facilitators from all states and territories to support the roll-out of the program in schools throughout Australia.

Curriculum resources

To ensure that the curriculum resources would support each of the educational jurisdictions to implement their curriculum frameworks, a curriculum mapping exercise was conducted to identify common content and contexts for learning. From this mapping, a chart was developed mapping the scope of learning across the four common conceptual outcome strands (Earth and Beyond, Energy and Change, Life and Living, and Natural and Processed Materials) and the sequence of learning through the years of schooling. This scope and sequence chart was used to guide the development of the curriculum units.

Mapping also included essential learnings, which describe generic learning outcomes from several jurisdictions' frameworks, and technology from the New South Wales science and technology syllabus. The chart also mapped units against four broad stages of learning and a unifying theme was developed for each stage of learning. Stages were linked to years of schooling and to levels in the national scientific progress map.

A key feature of the *Primary Connections* project is that it has made links to all relevant national science education initiatives. Items from the Science Education Assessment Resources (SEAR) Project and links to the website (www.curriculum.edu.au/sear/) have been included in the curriculum resources. Trial teachers received professional learning on the use of The Learning Federation (TLF) Learning Objects, and opportunities to use Learning Objects were included in *Weather in my world*, an Early Stage 1 unit. The National Scientific Literacy Progress map underpinning SEAR and the national Year 6 scientific literacy assessments (MCEETYA, 2005) has been used to inform *Primary Connections*, and discussions are underway on the alignment of *Primary Connections* with the National Learning Statement for Science.

Eight curriculum units were developed and trialled in the 56 trial schools. These units are mapped against stages of learning and conceptual strands in Figure 3.

Figure 3: The eight units developed and trialled in Stage 2 of the project

Stage	Conceptual context			
	Earth and Beyond	Energy and Change	Life and Living	Natural and Processed Materials
Early Stage 1	<i>Weather in My World</i>	<i>On the Move</i>		
1		<i>Push-pull Power</i>		<i>Material Matters</i>
2	<i>Spinning in Space</i>		<i>Plants in Action</i>	
3			<i>Marvellous Micro-organisms</i>	<i>Build it Better</i>

A unit designed to make connections to Australian Indigenous contexts, *Ochre and Crystals*, was also developed and trialled in two schools in term 2. Further trialling and refinement of this unit and other approaches to make connections with Indigenous culture and knowledge will be required. Further development of professional learning and curriculum resources that will engage Indigenous students in science and improve their learning outcomes in science and literacy are recommended for future stages of this project.

A unit planner and template were also developed and trialled. They were used by teachers to develop their own units based on the *Primary Connections* teaching and learning model. A website and CD-ROMs provided teachers with background science information, assessment resources, sound files and images for use in their teaching.

An additional three units are planned for development late in 2005 so that they are ready for trial in term 2 of 2006.

Participants in the Stage 2 trial

106 teachers were recruited in pairs from 56 schools from all states and territories. The sample included 45 government schools, seven Catholic schools and four independent schools, and two of these schools had high enrolments of Indigenous students. Schools were drawn from metropolitan, regional and rural locations.

Project implementation

The trial teachers were provided with a five-day summer school professional learning workshop in January 2005, which engaged them in deep professional learning about science and literacy teaching practices, familiarised them with the *Primary Connections* teaching and learning model and curriculum resources, and prepared them for teaching the first *Primary Connections* unit in term 1 of 2005. In addition to these 106 teachers implementing the program in their classes at their schools, four of the trial schools undertook a whole-school implementation with all teachers at their schools. These four case-study schools piloted the model of implementation planned for Stage 3 of the project. A one-day professional learning workshop was presented at each of these schools prior to the commencement of term 1 teaching.

Follow-up one-day professional learning workshops were provided for the 106 trial teachers at mid-term 1, end-term 1 and end-term 2 to provide opportunities for reflection, resolving emerging concerns and to extend professional learning to the more complex pedagogical issues of unit writing and assessment.

Teachers taught units prepared by the Australian Academy of Science in terms 1 and 3 and taught a unit they prepared themselves using the planner and template in term 2.

Research and evaluation model

The research program gathered formative data that is being used to revise and improve the curriculum and professional learning component of the program following the Stage 2 trial. It also collected the summative data needed to evaluate the impact of the Stage 2 program on students, teachers and schools. Case studies in four selected schools that piloted a whole-school implementation have provided information that will guide the development of the whole-school model planned for the full roll-out of the program in Stage 3.

The research and evaluation was framed around the following research questions:

1. How workable and effective is the teaching and learning model which has been used in developing the curriculum units and template?
2. What impact has the program had on students, teachers, schools and jurisdictions?
3. What insights into effective teacher professional learning are gained from the trial whole-school roll-out of the professional learning model in the case study schools?

4. How can the curriculum and professional learning resources be enhanced before implementation in Stage 3?
5. Is *Primary Connections* compatible with jurisdictions' curriculum frameworks or professional learning support structures?

Data were gathered by teacher questionnaires, student surveys, teacher focus group discussions, student focus group discussions, classroom observations and analysis of student work samples. Teachers also provided detailed feedback on each unit they taught in the form of annotations on copies of the units.