The Winston Churchill Memorial Trust of Australia

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2008 Churchill Fellow

The Nancy Fairfax Churchill Fellowship to study inquiry-based primary science education in the United States of America, Europe and the United Kingdom

Contents

		page
Introduction	…….	3
Acknowledgements	…….	3
Executive Summary	…….	4
Program	…….	5
Findings	…….	6
Discussion	…….	9
Conclusions	…….	12
Recommendations	…….	14
Appendix 1: Organisations represented on the National Science Resources Centre Advisory Board, USA.	…….	15

Introduction

The importance of the teaching of science in primary schools can not be overstated. Several recent reports indicate that unless students are 'switched on' to science before secondary school, it is unlikely they will continue to enjoy and learn science. There are approximately 125,000 primary school teachers in Australia. They want to improve their teaching of science but lack the support that they require to do so.

Primary Connections is a project of the Australian Academy of Science which aims to address teacher concerns and to improve their confidence and competence in teaching science. Primary science education is currently not a priority and until it takes a more equal place alongside literacy and numeracy in the psyche of those responsible for primary education, it will continue to be dismissed and languish in the shadows of the primary curriculum. This is despite its perceived importance by parents, teachers, politicians and the community.

The Nancy Fairfax Churchill Fellowship has allowed a study of inquiry-based primary science education in the United States, Europe and the United Kingdom to inform the field in Australia, in particular, to benefit the development of Primary Connections. I am indebted to the many people I visited and I am grateful for their time to share their expertise.

Acknowledgements:
I wish to acknowledge and thank the people who made this Fellowship possible:

- The Vincent Fairfax Family Foundation for sponsoring the Nancy Fairfax Churchill Fellowship which has allowed me to undertake this study to identify ideas to influence the teaching and learning of science in primary schools in Australia.

- The Winston Churchill Memorial Trust for providing the fellowship opportunities which foster the expertise of Australians and which subsequently enrich the Australian community.

- The people that I visited for so generously giving of their time in their busy schedules and for sharing their expertise.

- The Australian Academy of Science for their support to undertake this study and the entrée into Academies of Science in the countries that I visited.

The Australian Government Department of Education (formerly the Department of Education, Science and Training) have funded the development and implementation of the Primary Connections project since 2005, following the development of a proof of concept for the project in 2003 – 2004 by the Australian Academy of Science. For further information see: www.science.org.au/primaryconections

Executive Summary

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Position:	Project Director, Primary Connections Project, Australian Academy of Science
Telephone:	02) 6201 9424
Project Description:	To study inquiry-based primary science education in the United States, Europe and the United Kingdom.

The following conclusions and recommendations arising from this report have the potential to be addressed through my role as Director of the Primary Connections project.

Conclusions

1. There is a positive case for continued investment by the Australian Government in the Primary Connections project, an initiative of the Australian Academy of Science.
2. There is a need to 'think big and long term' to develop programs of support for teachers in primary science education. Approaches should be achievable, scaleable and sustainable.
3. There needs to be an expectation that science is taught and reported on in all grades of primary school by all current classroom teachers, and that teachers and schools are accountable for implementing quality primary science education.
4. The responsibility for improving the teaching of science in primary schools is a shared one.
5. There is confusion about what characterises inquiry-based approaches to primary science education and how these improve teaching and learning.
6. Evidence is needed of the impact of inquiry-based approaches on the teaching and learning of primary science.
7. The profile of the Australian Academy of Science needs to be leveraged for maximum influence on the scientific literacy of the nation.
8. Primary Connections is a potential vehicle for the Australian Academy of Science to take an advocacy role in science education nationally and internationally.

Recommendations

1. That the Australian government continue funding the Australian Academy of Science's Primary Connections project.
2. That the support for teachers to teach science in primary schools be substantially increased over the long term, and a culture of continuous improvement be promoted for teacher professional learning in primary science.
3. That state and territory education departments establish systems of accountability and support for the teaching of science in primary schools.
4. That corporate, industry and community groups consider supporting the teaching of science in primary schools.
5. That clear statements of the characteristics of inquiry-based approaches to primary science education are developed and communicated to teachers and used to evaluate the impact of approaches.
6. That ongoing research is continued as part of the Primary Connections project.
7. That the Australian Academy of Science position itself as a national hub for the promotion of primary science education.
8. That Primary Connections is promoted both in Australia and internationally.

Program

Date of visit		Location	Institution/organisation visited
From	**To**		
18/5/09	19/5/09	Colorado Springs, USA	BSCS (Biological Sciences Curriculum Study) 5415 Mark Dabling Boulevarde COLORADO SPRINGS
21/5/09	22/5/09	Washington, USA	National Science Resources Centre (NSRC) National Academy of Sciences 2100 C Street NW/22nd 23rd Street WASHINGTON NSRC National Coalition Meeting and NSRC Advisory Board Meeting
26/5/09	27/5/09	London, UK	Nuffield Foundation 28 Bedford Square , LONDON International Society for Design and Development in Education Conference
29/5/09		Berlin, GERMANY	Liebniz Hall, Markgrafenstrasse BERLIN European Commission Conference on inquiry-based primary science programs Co-convened by the 'Pollen' project of the French Academy of Sciences and the Berlin Academy of Science
2/6/09	4/6/09	Paris, FRANCE	'Pollen' Offices French Academy of Sciences 1 Rue Maurice Amoux, MONTROUGE 'La Main a la Pate' project
8/6/09	11/6/09	York, UK	University of York Heslington, YORK Department of Educational Studies, and National Science Learning Centre
15/6/09	16/6/09	Cheshire, UK	Millgate Education - Stuart Naylor and Brenda Keogh Active assessment; Concept cartoons; Puppets and literacy in primary science
18/6/09		West Sussex, UK	North East Professional Centre Science Conference Furnace Drive, Furnace Green, WEST SUSSEX Anne Goldsworthy Keynote presenter on "Working scientifically; literacy and primary science"
19/6/09		LONDON, UK	Royal Society 6-9 Carlton House Terrace, LONDON

Findings

The Nancy Fairfax Churchill Fellowship has allowed a study of inquiry-based primary science education in the United States, Europe and the United Kingdom to inform the field in Australia, in particular, to benefit the development of the Primary Connections project of the Australian Academy of Science.

This report does not focus on the specific learnings or comment on specific sites that were visited. Rather it is a synthesis of the overarching issues in the field that were explored and an analysis of how what was learned can be used to continue to improve the teaching and learning of science in primary schools in Australia and beyond.

Main learnings from the United States of America

In the United States the culture of philanthropic support for education is underpinned by a societal expectation that those with influence have a duty to be involved in and informed about education. The organizations represented on the Board meeting of the National Science Resource Centre at the National Academies of Sciences in Washington (see Appendix 1) provides an example of the stakeholders who actively participate in educational initiatives in the United States. They include representatives from government and corporate sectors, commercial interests, philanthropic foundations and international bodies. This is a major difference to Australia where societal expectation is that the government will provide the necessary educational services.

The larger populations and more elaborate transport networks in the United States mean that economies of scale can be utilized to develop and distribute educational resources and to conduct professional learning. However, the disparate structure of the education authorities with multiple, autonomous districts hampers efforts for implementation of sustainable programs. Both of the USA sites I visited have long standing histories in primary science education (50 years and 24 years). They emphasized that it takes sustained time, effort and ongoing support to develop effective approaches, build staff knowledge and competencies, and develop the necessary relationships with key bodies and stakeholders for uptake of inquiry-based science education approaches.

Main learnings from Europe

Initiatives in Europe appear very collaborative and groups are mutually supportive of each others' efforts in the area and they willingly share their work. Australia is somewhat isolated from such opportunities to share and learn from what others are doing.

However, the extensive range of approaches seemed somewhat piecemeal and lacking a comprehensive approach to building effective pedagogy. There was a strong influence of scientists in the initiatives, and there was an assumption that teachers were professionally competent in selecting appropriate teaching strategies and unit planning frameworks for science, which research suggests is not usually the reality. Research into the effectiveness of programs appears minimal up to the present time, but likely to be expanded in coming years.

At the Berlin conference I attended, a speaker from the tertiary sector highlighted her perception that a key problem in Europe was that the tertiary sector preparation of pre-service teachers didn't model suitable teaching practices and that improvement in this area was a priority to enhance the preparation of teachers. Anecdotally, this could well be the case in many countries.

Several European initiatives provide an on-line service where professional scientists answer teachers' questions about science. This requires a large investment of time to co-ordinate the responses. An education officer groups the questions into similar categories and then arranges for a scientist with appropriate expertise to develop a response which is then posted on the website. With our relatively lower population levels in Australia, this approach would probably not be sustainable.

Many reports have identified that improvement of teacher quality is the most important factor in improving student learning. France is progressing legislation to make a Masters qualification a necessary pre-requisite for primary teacher registration. A Masters is the base qualification for a primary teacher in Finland, and because Finland has consistently been at the top of the international test results of the Trends in International Mathematics and Science Study (TIMSS) and in the OECD Program for International Student Assessment (PISA), some countries are now considering adopting similar qualifications. Caution needs to be exercised because the level of qualification requirements for Masters level differs in different countries.

Main learnings from the United Kingdom

The national curriculum in the United Kingdom, first introduced in 1992, is currently undergoing one of several revisions since its inception. The review proposes to reduce the prescription in the curriculum and to increase teacher flexibility in order to meet the needs of different schools and pupils. Expectations in primary science in the first version of the national curriculum are now considered to have been excessive, restrictive and largely unattainable by teachers. This is perceived to have stifled teacher initiative. It has also stifled the primary school culture of inter-disciplinary approaches to curriculum as teachers struggled to meet the requirements and cover the curriculum. The publication of school 'league tables' in the media impacted on teacher confidence and resulted in teachers teaching to the test and a substantial de-professionalization of teaching. However, the implementation of national curriculum brought with it the expectation that primary teachers would implement the science curriculum and be held accountable for it through the inspection system. Courses for Masters in Teaching and Learning are also being developed. There is also an expectation in the education culture in the United Kingdom that teachers will undergo continuous professional learning throughout their career.

The Association for Science Education in the UK, which is one of the largest professional associations of teachers in the world with membership of some 15,000 teachers, many of them primary, conducts conferences, workshops and publishes handbooks and resources to support teachers.

There is a philosophy of sponsorship of most science support initiatives in the United Kingdom by large philanthropic bodies such as the Wellcome Trust, the Gatsby Foundation, and the Nuffield Foundation as well as sponsorship by industries such as the chemical industry. The funds provided are substantial, at times long term, and directed at both resource development and professional learning.

Because philanthropic foundations have funded major science education initiatives, some decisions that have been made by governing boards have been made in isolation from the science education community and awareness of complementary programs. This has resulted in disenfranchisement of district professional learning providers who are competing for the same client base. In some cases local districts feel divorced from major initiatives whereas previously they were a central part of providing quality teacher support.

A National Science Learning Centre and a network of nine regional centres have been established since 2001with substantial funding from the Wellcome Trust. To date, minimal research has been conducted on their effectiveness, but a researcher has recently been appointed to commence longitudinal studies. While the Centres offer support to all teachers regardless of grade level, it was anticipated that secondary science teachers would be the major clients. However, these teachers have not responded as anticipated and the majority of participants are primary teachers. Hence, there is now a decision to restrict the numbers of primary teachers who can access the professional learning courses at the National hub which seems contrary to the purpose.

The professional learning courses conducted by the national hub have been developed so they have credit recognition towards a Masters qualification. This has resulted in the courses being very university oriented. There is some concern about whether courses will be sufficiently flexible to meet the needs of teachers, schools and districts. However, a positive outcome of these professional learning courses is that it is anticipated they will raise the profile and status of primary science teaching and build leadership in primary science which may also have an impact on other areas of the primary curriculum.

While the volume of workshops attended by primary teachers, in particular science coordinators, is larger than in Australia, there is large variability in the impact back at schools. Some school science co-ordinators are very active, with strong principal support and well developed school science plans. But in some instances an individual co-ordinator may attend a conference and there is no mechanism for or interest in the information being disseminated at the school level.

From my discussions, it appeared that the extent to which training programs made an actual difference depended on whether there were systems of support and accountability in place to ensure follow-through and implementation of these learnings in schools.

Discussion:
The quality and quantity of the teaching and learning of science in primary schools around the world continues to be of concern. Currently primary science teaching is contentious in terms of its quality and quantity, and in terms of the financial expenditure on professional learning, resources and curriculum materials for teachers. There are also low expectations that science will be appropriately taught, assessed and reported on, despite the existence of policies for its inclusion in the primary curriculum. The exception is in the United Kingdom where the inspectorate system drives accountability against the national curriculum. However, the quality of school-based programs there seems to have been compromised by the way the national curriculum was originally drafted. It contained so many objectives and expectations, all of which had to be taught and reported on, that teachers and schools found it too difficult to implement.

In many respects, the same issues and trends were encountered in the countries that were visited as occur in Australia. There are however, significant areas of difference. These are:

- differences in education policy and in education department administration practices
- differences in the size of populations and thus in the scale of operational responses to educational needs
- differences in the kinds of groups or partnerships formed to develop support for teachers to implement quality teaching and learning in primary science
- differences in the role of governments in supporting education initiatives.

On the later, there was a major difference between government engagement with primary science education in Australia compared to the countries visited. One of the commonest queries was about how the Primary Connections Project had attracted, sustained and received multiple funding agreements with the Australian Government. There was jealousy of the Academy's ability to leverage government support that could enhance a national profile. They were also amazed that there was relatively no competition from commercial quick-fix approaches that aren't effective in improving student learning. There was a recognition that systemic change requires the support of bureaucracies and that for major initiatives to be effective, a collaborative approach to program development, promotion and implementation was needed.

As in Australia, inquiry-based approaches were considered the preferred model of primary science education in all sites visited. However, there are a variety of activities and programs occurring under this banner and there is a lack of clarity about what these approaches entail. Inquiry science is not simply doing activities or adopting hands-on approaches. Both overseas and from the research for the Primary Connections project, assisting teachers to understand the differences between approaches has been difficult and it has been shown to take considerable time and effort for teachers to move from novice, to competent to expert. There is a need to establish clarity of the characteristics of inquiry approaches, clear arguments for why such approaches ought to be adopted, and appropriate measures to provide evidence of impact using these approaches.

Historically, efforts at reform in primary science teaching in all countries have frequently been driven by passionate, well-intentioned but ill-informed advocates who have repeated ineffective approaches similar to previous initiatives. This has been exacerbated by changing governments, stop-start programs, and staffing changes - new staff being unaware of previous initiatives or the research in the field.

This study revealed that there was a consistent belief in all countries visited that primary science was considered important, and that it can be taught with appropriate teacher support. However, there was a lack of clarity about who was thought to be accountable, for what, and to whom.

These issues also plague the Australian scene. With the impending implementation of a national curriculum in the sciences from 2011, there will be renewed opportunities to re-visit these issues and raise the profile of primary science. However, as seen in the United Kingdom, national curriculum of itself doesn't improve practice. The support for implementation will be critical in translating curriculum intent into visions for classroom practice.

In Australia, as the newly established Australian Curriculum, Assessment and Reporting Authority (ACARA) finalises the first Australian national curriculum in the sciences, the growing expectations of state and territory education departments and indeed of the community about the teaching of science in primary schools will soon highlight a number of key questions that have arisen in the countries visited and which will need to be resolved. These questions are:

- What is it that is valued about primary science education?
- What characterizes inquiry-based primary science teaching and learning?
- Where is science to be positioned in the primary teaching curriculum, and what is to be its priority in terms of curriculum time allocation compared to literacy and numeracy?

Overseas, there was a strong culture of the expectation of continuous professional development (CPD) for teachers, particularly in the United Kingdom, which as yet is not reflected in Australia. If Australia is to maintain and improve its ranking on international tests of scientific literacy, then primary science education requires an enhanced status in the primary curriculum. There is a need to have heightened expectations that it will be taught for reasonable time periods in the curriculum and to high and continuously improving standards.

The Academies of Science in the USA and Europe have major initiatives in primary science education, as in Australia. However, there needs to be caution in assuming that the involvement of scientists ensures quality programs. Famous scientists can provide a high profile to raise awareness of the importance of primary science. However, professional scientists tend to see science education and, more specifically, primary science education differently to educators. Science education and science are different fields and practitioners in each have their own expertise. School science isn't professional science. Scientists don't create and sing songs and build mobiles of what they have

learned, and they don't represent their findings and arguments using role plays and dramatic enactments. Yet these might be appropriate and effective strategies to support student learning in a school setting. An appreciation of how the two fields are different is needed, so that the expertise of scientists and educators can be harnessed in appropriate ways to foster improved teaching and learning.

Initiatives for major reform efforts need to be achievable, sustainable and scalable. While approaches may have complex underpinning frameworks, they need to be presented in such a way that teachers feel they can say: 'I can do it, and do it well'. Teachers need to be able to have success professionally and see benefits for their students. Proposed approaches need to be able to be embraced by the great majority of teachers and be able to be sustained despite changes in staffing. They also need to be inexpensive to implement, able to be rolled out on a large scale, apply to multiple sites and contexts, deal with the common topics, and require minimal resource management. They also need to be able to promote local professional initiative and flexibility, informed by best practice.

It was emphasized that quality curriculum unit writing processes take a long time to establish. It was also thought that developing or changing teacher practice was a long-term process. Hence, initiatives need to be financed by advocates who understand the processes, are non-partisan, stay in for the long haul, and are positive about what teachers are capable of with appropriate support.

An unresolved question that was challenging overseas initiatives which is also a contentious topic in Australia is: "Do primary teachers need to know the science content? The most consistent response emerging was that the science content knowledge has no meaning for primary teachers unless it is within a context, and that it is more effective for teachers to experience how students will learn science rather than science itself as this has the potential to inform their teaching practice. Primary Connections curriculum units each include a CD of science background information (copyright owned by the State of Victoria, Department of Education and Early Childhood Development). This was seen as a valuable inclusion by science specialists in particular.

Implications for the Primary Connections project

There were many comments that in a short timeframe of five years, the Primary Connections project has achieved remarkable results and gained a critical mass of support. It is a comprehensive approach which includes practical professional learning which models the underpinning philosophies, curriculum resources which exemplify the approach in the classroom, and it is informed by research and monitored by an ongoing evaluation process at all stages. The collaboration at many levels such as the engagement with government and the building of a supportive Reference Group has contributed to a national profile.

The evaluative research to date for Primary Connections has been an important part of the credibility of the project. Ongoing research is needed to measure impact and provide evidence of the effectiveness of models of implementation of inquiry approaches.

The main learnings for the project are to develop and nurture key relationships and continue to be responsive to the needs of the target audiences, increase advocacy, explore international applicability to share its successes, and plan for future sustainability.

While the Academy of Science is not in a position to mandate implementation of change to teaching practice, its credibility and reputation for supporting teachers to teach science puts it in a privileged position to influence reform. That profile needs to be leveraged for maximum influence on the scientific literacy of the nation.

Conclusions

1. *There is a positive case for continued investment by the Australian Government in the Primary Connections project, an initiative of the Australian Academy of Science.*

   Primary Connections has trained more teachers and developed more units with its funding of six million dollars than any other program in the countries visited. What has been achieved with this relatively small investment provides evidence of what can be done with raised expectations, continuity of funding, and a coherent national approach with builds broad support.

   The research evidence is showing that teacher capacity can be enhanced using Primary Connections and it has a positive impact on student learning.

   In a country such as Australia with a relatively small population, the limited resources available need to be well-utilised on credible projects and not wasted on multiple short term, disparate initiatives.

2. *There is a need to 'think big and long term' to develop programs of support for teachers in primary science education. Approaches should be achievable, scaleable and sustainable.*

   Teachers can successfully teach science, but they need support to do so. Effective initiatives require long term planning to develop quality approaches and to allow time for teachers to change practice.

   There are 125,000 primary classroom teachers in Australia. Enabling them is the only viable solution to improve the quality and quantity of science learning for the majority of Australian primary students.

3. *There needs to be an expectation that science is taught and reported on in all grades of primary school by all current classroom teachers, and that teachers and schools are accountable for implementing quality primary science education.*

   Primary science education requires an enhanced status in the primary curriculum. However, it is not enough to simply expect primary school teachers to teach science

and to leave it at that. There needs to be a clear set of systemic accountabilities accompanied by appropriate supports to ensure that science is taught and taught well, and if it is not, then to remedy that. Such accountabilities and supports apply in the areas of literacy and numeracy. Without these, the sincere ambition to improve the teaching of primary science may amount to very little.

4. *The responsibility for improving the teaching of science in primary schools is a shared one.*

   There is the potential for corporate, industry and community groups to provide support to develop quality science education programs, both financial support and through providing expertise (eg science knowledge; assisting in the classroom; resource acquisition, management and maintenance). However, such support needs to be guided by collaboratively determined goals to ensure alignment to the requirements of the national curriculum (in development), and the needs of teachers.

5. *There is confusion about what characterises inquiry-based approaches to primary science education and how these improve teaching and learning.*

   This has resulted in a range of activities with little evidence of their effectiveness. A description of the characteristics of inquiry-based approaches will assist teachers to develop a vision of classroom practice. These descriptors need also to be used in research as a basis to evaluate the impact of such approaches.

6. *Evidence is needed of the impact of inquiry-based approaches on the teaching and learning of primary science*.

   This is needed so that teachers have a rationale for expending the effort needed to change their practice, and so that funding bodies have evidence to justify their investment in the ongoing development of such approaches.

   Effective ways to measure the impact of inquiry-based approaches need to be identified and what is learned from this research needs to be communicated to teachers with practical strategies for their classroom practice.

7. *The profile of the Australian Academy of Science needs to be leveraged for maximum influence on the scientific literacy of the nation.*

   The Australian Academy of Science has a history of quality support for teachers. This includes the development and promotion of professional learning and curriculum resources, as well as a web presence. This should be capitalized on to enhance the teaching of primary science.

8. *Primary Connections is a potential vehicle for the Australian Academy of Science to take an advocacy role in science education nationally and internationally.*

Primary Connections is a comprehensive approach (not just a set of workshops and units), it is based on research both in its development and in evaluating implementation, it is building a national profile, and there is evidence of significant impact on teaching and learning. It appears that it has a real contribution to make to improve the teaching of science in the primary school. Therefore its potential needs testing in the widest possible arena to develop the scientific literacy of citizens, to prepare the next generation of scientists, and to enhance the public understanding of science. These are objectives of the education programs of the Australian Academy of Science.

Recommendations

1. That the Australian government continue funding the Australian Academy of Science's Primary Connections project.

2. That the support for teachers to teach science in primary schools be substantially increased over the long term, and a culture of continuous improvement be promoted for teacher professional learning in primary science.

3. That state and territory education departments establish systems of accountability and support for the teaching of science in primary schools.

4. That corporate, industry and community groups consider supporting the teaching of science in primary schools.

5. That clear statements of the characteristics of inquiry-based approaches to primary science education are developed and communicated to teachers and used to evaluate the impact of approaches.

6. That ongoing research is continued as part of the Primary Connections project.

7. That the Australian Academy of Science position itself as a national hub for the promotion of primary science education.

8. That Primary Connections is promoted both in Australia and internationally.

Appendix 1
Organisations represented on the National Science Resources Centre Advisory Board, USA.

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