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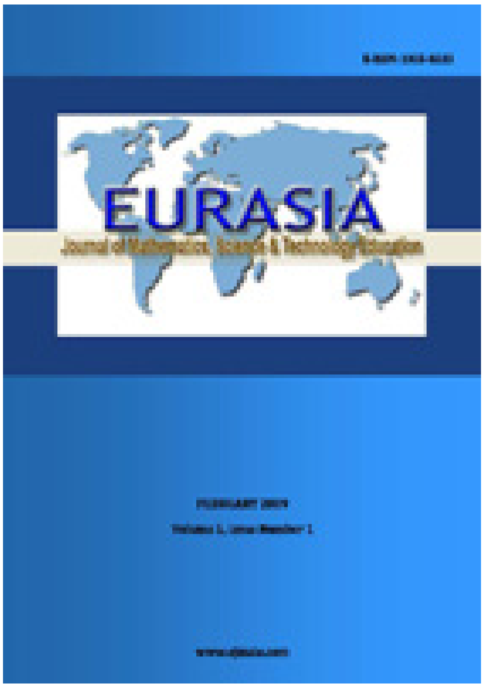

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Gillian Kidman
Queensland University of Technology, AUSTRALIA

Received 13 March 2011; accepted 29 November 2011
Published on 27 February 2012

APA style referencing for this article: Kidman, G. (2012). Australia at the crossroads: A review of school science practical work . *Eurasia Journal of Mathematics, Science & Technology Education*, 8(1), 35-47.

Linking to this article: DOI: 10.12973/eurasia.2012.815a

URL: http://dx.doi.org/10.12973/eurasia.2012.815a

ISSN: 1305-8223 (electronic) 1305-8215 (paper)

The article starts with the next page.

Eurasia Journal of Mathematics, Science & Technology Education, 2012, **8**(1), 35-47

Australia at the crossroads: A review of school science practical work

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In Australia we are at a crossroads in science education. We have come from a long history of adopting international curricula, through to blending international and Australian developed materials, to the present which is a thoroughly unique Australian curriculum in science. This paper documents Australia's journey over the past 200 years, as we prepare for the implementation of our first truly Australian National Curriculum. One of the unique aspects of this curriculum is the emphasis on practical work and inquiry-based learning. This paper identifies seven forms of practical work currently used in Australian schools and the purposes aligned with each form by 138 pre-service and experienced in-service teachers. The paper explores the question 'What does the impending national curriculum, with its emphasis on practical inquiry mean to the teachers now - are they ready?' The study suggests that practical work in Australian schools is multifaceted, and the teacher-aligned purposes are dependent not only upon the age of the student, but also on the type of practical work being undertaken. It was found that most teachers are not ready to teach using inquiry-based pedagogy and cite lack of content knowledge, behaviour management, lack of physical resources and availability of classroom space as key issues which will hinder their implementation of the inquiry component of Australia's pending curriculum in science.

Keywords: Australian curriculum, science, science inquiry skills, practical work, inquiry-based pedagogy

HISTORICAL HIGHLIGHTS OF THE CHANGING ROLE OF PRACTICAL WORK IN AUSTRALIAN SCIENCE EDUCATION

Lazarowitz and Tamir (1994) cite Edgeworth & Edgeworth's 1811 publication which argued that practical work allowed students to exercise their minds by conducting simple experiments relating to areas of student interest. The purpose of the practical work was to confirm theory and it was not considered important if the experiment did not work – the answers were in the text book. It seems that nearly 200 years ago, practical work was becoming an important aspect (even if only to confirm theory) of the British school science curriculum. But that is the story of the infancy of a practical science education in Great Britain, not Australia. In 1811, Australia was still a penal colony, and Governor Macquarie had just arrived (from Great Britain) to re-establish discipline and social order after a period of unrest. In 1812, Governor Macquarie wrote that schools were intended to improve the 'morals of the lower orders and develop religious principles in the young' and make them 'dutiful and obedient'. His report urged that lower class children be separated 'as much as possible from the adverse moral influence of their parents'. These are clear indications that schooling was for the management of the 'lower class' (Barcan, 1965, p36). There is scant documentation of the development of science education in Australia until following the Second World War. One can assume we continued to follow the British system (as we did with most things) with an emphasis on physics and chemistry, followed by biology then geology. It was not until 1945 that the general science movement including practical work, reached Australia. One by one, the Australian States and Territories introduced general science courses, but there was great variation in both the content and emphasis between the science courses.

Correspondence to: Dr. Gillian Kidman, School of Mathematics, Science and Technology Education, Queensland University of Technology, Kelvin Grove, Queensland, 4059, AUSTRALIA
E-mail: *g.kidman@qut.edu.au*

ISSN: 1305-8223

State of the literature

- Practical work has been in Australian science curriculum documents for many decades. However it has a history of being poorly implemented.
- There is a discrepancy between what the curriculum documents advocate, and what is actually implemented in the classroom.
- To improve student engagement as well as teacher knowledge and pedagogical skills, Australia as invested large amounts of funding on science initiatives, the latest of which is the development and recent implementation of a national curriculum.

Contribution of this paper to the literature

- This study describes the variety of practical work, the teacher perceptions of the purpose of practical work, as well as teacher readiness for teaching the *Australian Curriculum:* Science which has a key emphasis on inquiry.
- Different forms of practical work are evident across Australia. In primary schools, teachers are interested in developing hands on skills and social interactions. In the secondary school the emphasis is on content knowledge and fact verification. Pre-service teachers emphasise interest and the enjoyment factor, and fact verification through student discovery. In-service teachers emphasise a purpose of understanding the theoretical parts of science.
- Most teachers feel inadequately prepared to teach the inquiry component of the Australian Curriculum: Science. It is felt that behaviour management, content knowledge, a lack of pedagogical skills to develop open inquiry lessons, and the lack of space and resources would all hinder the implementation of the *Australian Curriculum: Science.*

In 1955, the first issue of the *Australian Science Teachers Journal* (A.S.T.J.) was published, and included a report which highlighted a principal requirement of chemistry classes to be individual practical work: 'descriptions of reactions and demonstrations must be avoided; the pupils must have the excitement of carrying out the experiments themselves. In passing they will learn a few techniques and maybe unlearn some bad ones' (Simes, 1955, p9). The early issues of A.S.T.J. indicate there was growing concern that science was being taught as a set of facts, isolated from the laboratory. This view was shared in the UK and USA, and resulted in the development of inquiry-based discovery learning projects (e.g. Biological Sciences Curriculum Study [BSCS]; Physical Science Study Curriculum [PSSC]; Nuffield Science). By adopting these discovery learning projects, Australia intended to increase student participation in experimental work. The proposition was 'students acquire a better understanding of science through their active involvement in experimental investigations' (Wilkinson & Ward, 1997, p49). Unfortunately Australian classrooms were not designed for practical classes, and we didn't have ready access to the necessary equipment.

In 1970, research started to guide science education in Australia, and it was decided we needed to move to a process approach of practical work. According to Fensham (1990), it was thought that there should be an emphasis on the methods of science, so the teaching of process was necessary. This was a turning point in Australian science education. Instead of continuing to use international programs developed for the UK or USA classrooms, with UK or USA examples, Australia developed a national science curriculum project of its own - the *Australian Science Education Project* (ASEP). Piagetian principles provided a strong basis for the ASEP philosophy, and gave support for an activity-based science curriculum with a strong emphasis on practical work. Students were required to identify problems, observe, measure, classify, order, infer, predict and form hypotheses, search for meaningful patterns, design and perform experiments, interpret and analyse data, and to verify the validity of conclusions reached. In other words, the inductive processes of scientific inquiry were emphasised. Although ASEP writing concluded in 1974, it produced an abundance of teaching materials written for both the teacher and student which are still in use in some Australian schools today. Some schools still use the original booklets, whilst others use reprints.

Disappointment with science curriculum projects of the 1960s and 1970s led to science being viewed as a human social construct, and the debate began around the notion of a national curriculum in Australia. The reliance on inductivism presented a distorted view of science methodology as it lacked a prior conceptual framework. The importance of a student's prior knowledge, as well as their skill development, needed to become the focus of future curriculum documents. This was brought about by Fensham (1981) where he linked 'head science' and 'hand science' in a bid to achieve scientific literacy. Fensham proposed an instruction sequence (see Figure 1) for skill development.

The change in the philosophy of science education is evident in the document *A statement on science for Australian schools* (Curriculum Corporation, 1994) which recognised the importance of prior knowledge and existing beliefs in a learner's conceptual development. This statement provided a framework for the future development of Australian science curricula. Laboratory

Figure 1. Instructional sequence for Fensham's 'heads, hearts and hands' model (Fensham, 1981, p57).

work was described as being of high importance because it enables students to work between theoretical ideas and direct experience. The statement declares that students should be able to 'recognise and value scientific knowledge as reliable knowledge, based on observations, reproducible experiments and logic' and 'evaluate experiments and arguments and the validity of results' (ibid, p84). The inclusion of a *Working Scientifically* strand (Strand 1) linked the valuing of ideas and seeking of explanations; the respect of evidence and logical reasoning; open-mindedness; being critical and sceptical about evidence and arguments; being honest and open to new ideas; being creative and to accepting that knowledge changes. Working scientifically was considered to be something done in our regular daily lives.

Following the release of *A statement on science for Australian schools*, each state and territory in Australia was required to develop a curriculum which would present students with a broad range of science concepts organised in contexts that were of interest and relevant to the daily lives of the students. Whilst each Australian state and territory was permitted to develop their own response to the national curriculum statement, there is what Goodrum, Hackling and Rennie (2001) called a 'common heritage' in that the rationales all emphasised the importance and relevance of science for all students as part of their everyday life. The rationales 'adhere closely to the idea of scientific literacy and ... it seems fair to say that the rationale for teaching science includes a commitment to scientific literacy' (Goodrum *et al.*, 2001, p31). Concluding comments in the seminal report *The Status and Quality of Teaching and Learning of Science in Australian Schools* by Goodrum and colleagues (2001) in relation to the Australian science curriculum documents in use at the time were that they provided 'an appropriate modern and progressive vision of the intended science curriculum' (p152). However, Goodrum *et al.* continued to claim that although the curriculum documents were consistent with the scientific literacy goal, there was a sizable gap between the intended science curriculum of the documents, and the actual implemented curriculum in the classroom. This was especially apparent in the secondary science curriculum (for students aged 13 to 18 years) which was 'traditional, disciplined based and dominated by content' (ibid, p152). This posed a problem, as such a curriculum did not prepare the student for their future life through the development of their scientific literacy. Although the curriculum reviewed by Goodrum *et al.* was traditional and content laden, there was a component of practical work, but this tended to be the traditional closed book laboratory exercises. The Goodrum *et al.* report highlighted that Australian science education had a major problem: The curriculum documents all advocated a general goal of an education for scientific literacy, but in reality the lessons offered to the students did not reflect this goal (italics added for clarification):

> *For many secondary students the science they are taught is neither relevant nor interesting. Traditional chalk-and-talk teaching, copying notes and cookbook practical lessons offer little challenge or excitement to students. Disenchantment with science is reflected in the decline in science subjects taken by students in upper secondary school [17 and 18 years old]. In primary schools [students aged 5 to 12 years], the problem is not what is taught, but whether it is taught at all. Where science is taught on a regular basis, it is generally taught in a student-centred, activity based manner that results in a high level of student satisfaction. When students move to the secondary school many experience disappointment, and it is here that students' interests wane markedly (ibid, p166).*

In the intervening years since the Goodrum *et al.* (2001) report was released, considerable funds and efforts have been expended in an effort to address the problem of the intended and the enacted science curriculum in Australia. Numerous reports have been commissioned (for example DEST, 2006; Dow, 2003 a,b,c; ETC, 2006; Goodrum & Rennie, 2007; MCEETYA, 2006; Tytler, 2007) and numerous programs developed nationwide. Many of the actions developed in the programs are consistent with recommendations made in these reports. As a result, a range of initiatives in all Australian States and Territories exist, all attempting to enhance the quality of science education in Australian Schools. In the following section, three of these initiatives are reviewed. These examples relate to practical work in the classroom and are specifically relevant to two of the nine themes proposed by Goodrum *et al.* (2001, pVii) which describe the 'ideal' science education that would promote the development of scientific literacy:

> *Theme (2) 'Teaching and learning of science is centred on inquiry. Students investigate, construct and test ideas and explanations about the natural world', and*
>
> *Theme (7) 'Excellent facilities, equipment and resources support teaching and learning'.*

These examples are also particularly relevant to the now well-established purpose of science education in Australia – to provide opportunities for students to know science as a body of knowledge, as a way to know the world and as a human endeavour, and to develop students' scientific literacy (MCEETYA, 2006).

Initiatives featuring practical work in Australian classrooms Primary Connections (PC)

'*Primary Connections: Linking science with literacy*' (PC) began in 2004 as an innovative approach to teaching and learning which aims to enhance primary school teachers' confidence and competence for teaching science in a practical way. It is widely used across all States and Territories. PC employs Bybee's 5Es teaching and learning model and is based on the theory that students learn best when they are allowed to work out explanations for themselves over time through a variety of learning experiences structured by the teacher. The aim of the PC project is to:

> …*improve the quality and quantity of science teaching and learning in Australian primary schools through enhancing teachers' confidence and competence. This is achieved by developing teachers' pedagogical content knowledge in science and literacy through an innovative programme of professional learning supported with rich curriculum resources (Peers, 2006, p2).*

Significant innovations in the PC approach are that it is inquiry oriented and hands-on, so students have an authentic experience of science; science and literacy teaching and learning are integrated and there is explicit teaching of the literacies of science; and assessment is used to both support and evaluate learning.[i]

Science by Doing

Science by Doing is the most recent Australian national initiative that aims to actively engage junior secondary school students in learning science through an inquiry-based approach. The project is managed by the Australian Academy of Science in partnership with the Commonwealth Scientific Industrial Research Organisation (CSIRO), the Australian Science Teachers Association and the education systems of the states and territories. *Science by Doing* aspires to improve learning by supporting school-based learning communities that acknowledge and build upon teacher expertise. *Science by Doing* will provide opportunities by which students can find answers to questions about science phenomena. To accomplish this goal, the *Science by Doing* project aims to develop three important components:

- *Professional learning resources* - that use digital technology in innovative and effective ways
- *Curriculum resources* - that are inquiry-based and also use digital technology in innovative ways
- *Professional learning approach* - that includes establishing professional learning communities with an emphasis on leadership

In the present stage of *Science by Doing*[ii] the following six professional learning modules are currently being developed:

- *Inquiry-based teaching*
- *Effective questioning*
- *Assessment*
- *Facilitating change*
- *Managing an inquiry-based classroom*
- *Science by Doing learning model*

Australian School Innovation in Science, Technology and Mathematics (ASISTM) school projects

In an attempt to boost the teaching, learning and interest in science, technology and mathematics in both primary and secondary schools, 355 ASISTM school projects were funded by the Australian Government between 2005 to 2007. Over one-fifth of Australia's schools, 1000 partner organisations including 36 of Australia's universities, and over 2000 teacher associates (Curriculum Corporation, N.D.) under the banner of the *Boosting Innovation, Science, Technology and Mathematics Teaching* (BISTMT) Programme. The BISTMT Programme worked to raise the scientific, mathematical and technological literacy and the innovative capacity of Australian school students, to create learning environments from which more world-class Australian scientists and innovators would emerge, and to provide impetus for the development of a new generation of excellent teachers of science, technology and mathematics (DEST, 2005). ASISTM school projects particularly aimed to foster a sustained culture of innovation in schools through science, technology and mathematics teaching and learning. According to DEST, ASISTM[iii] school projects promoted improvement:

- ✓ *'in the classroom - teacher practice and student learning in relation to science, technology and mathematics;*
- ✓ *in the wider school - new practices in planning, resourcing, communicating and collaborating; and*
- ✓ *at a whole community level - with boundaries between schools and other organisations becoming more permeable, and shared goals, expectations and directions being adopted' (p6).*

Common to these three initiatives, and the many others being experienced by Australian students, is the notion that Australian students need to experience a science education which will empower them to live in societies which are constantly changing due to scientific and technological advances. We need our students to participate in scientific inquiry, be able to appreciate the role science has in society, and we need to educate our future scientists. It is now widely recognised that only the minority of students will seek a scientific career, so educating for the sake of scientific knowledge is a thing of the past. Whilst we want our students to gain scientific content knowledge, we now acknowledge that a shared emphasis is required on the practical nature of science, the socio-cultural aspect of science as well as science content knowledge. This three pronged emphasis to science education is the basis of the structure of the national science curriculum currently being developed in Australia.

The Australian Curriculum: Science

In November 2007, Kevin Rudd was elected Prime Minister of Australia. A central election promise of the Rudd campaign was an 'education revolution'. Shortly after coming to office, Rudd announced the development of a national curriculum for Australian schools would begin by 2009. After several decades of debate this was welcome news. As far back as the 1970s, Australian governments and the education community were debating the concept of a uniform curriculum for Australian schools in all States and Territories. Although previous discussions and attempts at developing a national curriculum had failed, in favour of the current plan is the level of collaboration among states, territories and the Australian government. Currently, Australia has 34 separate organisations contributing to the development of curricula and this has created significant disparities in educational attainment between the six states and two territories. Student achievement in science (as well as maths, literacy and numeracy) benchmarks varies widely between each state and territory. For example: New South Wales is the only state to better the average of Year 8 students (approximately 13 years of age; the second year of high school) reaching the advanced international benchmark in maths and science (Australian Labor Party, 2008).

The Australian Curriculum Assessment and Reporting Authority (ACARA) is responsible for developing the Australian curriculum and is guided by the 2008 Melbourne Declaration on Educational Goals for Young Australians. The Melbourne Declaration commits 'to supporting all young Australians to become successful learners, confident and creative individuals, and active and informed citizens', and to promoting equity and excellence in education. The Australian curriculum will 'equip all young Australians with the essential skills, knowledge and capabilities to thrive and compete in a globalised world and information rich workplaces of the current century.' The national curriculum will be accessible to all young Australians, regardless of their social or economic background or the school they attend (ACARA, 2009). The aim of the Australian Curriculum: Science is,

> *...to provide students with a solid foundation in science knowledge, understanding, skills and values on which further learning and adult life can be built. In particular, the science curriculum should foster an interest in science and a curiosity and willingness to speculate about and explore the world. Students ... should be able to identify and investigate scientific questions, draw evidence-based conclusions and make informed decisions about their own health and wellbeing. (NCB, 2009, p5).*

Structure of the Australian Curriculum: Science

The *Australian Curriculum: Science* is organised around three interrelated strands: science understanding (facts, laws, principles and models etc); science as a human endeavour (moral, ethical, social implications, career paths etc); and science inquiry skills (SIS) of equal importance. The SIS involves posing questions, planning, conducting and critiquing investigations, collecting analysing and interpreting evidence and communicating findings. This strand is concerned with evaluating claims, investigating and making valid conclusions (NCB, 2009, p6). The three strands are drawn together by *Unifying ideas* and presented in year groupings. Unifying ideas are developmental in nature with subsequent unifying ideas building on those for the previous year grouping. This allows for students 'to accumulate knowledge over time for deeper understanding' (NCB, 2009, p6). Table 1 presents the curriculum focus and SIS for the year groupings of the *Australian Curriculum: Science* for 5 to 15 year olds – the compulsory years of schooling.

The first draft of the curriculum K-10 was released for public opinion in March 2010.[iv] The documents indicate the intent of the curriculum is to have the three strands all with equal emphasis therefore a pedagogical emphasis aligning with inquiry. This is expected to be a challenge for the majority of primary school teachers, as well as for some secondary teachers who teach science but are not trained to do so (Harris, Jensz & Baldwin, 2005). There is also a specified number of minutes per week allocated to science in each year level, which will also challenge many primary school teachers who currently teach very little science.

Australia is therefore at a crossroads. We have always been influenced by international curricula, but for the past 40 years we have been producing our own taking cognisance of both local and international research. Australia is on the verge of teaching its first truly national curriculum in English, Mathematics, Science and History, with other disciplines to follow. The curriculum writers have explored curriculum and research from around the world and used this to guide the development of Australia's own unique national curriculum. The equal emphasis of the three strands in the *Australian Curriculum*: *Science* is a new approach and it will be interesting to follow the implementation of the curriculum, from both the teacher and the student

Table 1. Australian Curriculum: Science - curriculum focus and inquiry skills

Year Grouping	Curriculum Focus	Science Inquiry Skills
Years K-2 (typically from 5 to 8 years of age)	Awareness of self and the local world	• Explore, be curious and wonder • Ask questions and begin to investigate • Describe what has happened • Use evidence to support ideas
Years 3-6 (typically from 8 to 12 years of age)	Recognising questions that can be investigated scientifically and investigating them	• Identifying questions and predictions for testing • Plan and conduct simple investigations • Observe, describe and measure • Collect, record and present data as tables, diagrams or descriptions • Analyse data, describe and explain relationships • Discuss and compare results with predictions • Draw conclusions and communicate ideas and understandings.
Years 7-10 - High School (typically from 12 to 15 years of age)	Explaining phenomena involving science and its applications	• Formulate scientific questions or hypotheses for testing • Design and conduct science investigations involving measurement and repeated trials • Gather and organise data from a variety of sources • Analyse and test models and theories based on the evidence available • Explain and summarise patterns in data using science concepts

Table 2. The purpose of using the demonstration in science classrooms.

Type of practical work used in schools	**Reasons for use of school practical work**	**Primary (n=90)**		**Secondary (n=48)**	
		Pre-service % (n= 70)	In-service % (n=20)	Pre-service % (n=28)	In-service % (n=20)
Demonstration	To make science more interesting & enjoyable through actual experience	70	10	61	15
	To enable student to discover or verify facts & ideas for themselves	79	20	86	30
	To promote thinking in a scientific way	90	80	89	90
	To help students understand theoretical parts of science	33	60	50	95

perspective. Only time will tell if the gap between the intended and the enacted science curriculum in Australia, as identified by Goodrum *et al.* in 2001, persists.

The research focus

Two questions have become apparent as a result of the historical overview of practical work in Australian schools. Firstly, 'What practical work do Australian teachers use and why?' and 'What does the impending national curriculum, with its emphasis on practical inquiry mean to the teachers now - are they ready?' In order to answer these questions, a small study was conducted in mid 2009. The study was based on research by Wilkinson and Ward (1997) who compared student and teacher perceptions of the purpose of practical work in schools. Wilkinson and Ward had teachers and their classes complete a survey by rank ordering 10 items relating to aims of practical work. The present paper focuses on the pre-service-teacher and in-service teacher perspectives relating to the purpose of practical work in the curriculum. However, as several authors have pointed out, 'practical work' is such a broad term that encompasses hands-on activities of a wide variety and with widely differing aims and objectives (Lunetta & Tamir, 1979; Millar, Le Maréchal & Tiberghien, 1999). It is difficult then, to probe the inclusion and purpose of practical work (in general) in the science curriculum. Rather, we need to consider the inclusion and purpose of specific types or examples of practical work, or specific practical tasks. This paper therefore attempts to document the variety and purpose of 'practical tasks' currently in use in a sample of Australian primary and secondary schools, and it attempts to explore teacher readiness for a curriculum with a key emphasis on inquiry.

METHODOLOGY

The study sample was largely opportunistic. The author had access to 98 pre-service teachers enrolled at a large university in a capital city in Australia. 70 were destined to be generalist primary school teachers. The remaining 28 were destined to be specialist secondary school teachers of Biology, Chemistry, and Physics. All pre-service teachers had attended a school for a four week period undertaking field experience. Upon their return to university, the pre-service teachers were asked to participate in a tutorial discussion group relating to practical science lessons they had observed or participated in whilst in their school. Five tutorial discussion groups each were conducted (3 groups of approximately 23 generalist primary pre-service teachers and 2 smaller groups of the specialist secondary pre-service teachers). Each discussion lasted between 60 and 75 minutes, and was audio recorded for later transcription. A pre-service teacher in each discussion group was asked to act as a scribe on the whiteboard in an attempt to capture, ideas and lists that emerged during the discussion. Each discussion topic was guided by a set of questions adapted from the Wilkinson and Ward (1997) study (see Appendix for the three discussion topics).

The author also sought responses to the Appendix questions from practicing primary and secondary science teachers. A total of 39 experienced in-service teachers participated. The author personally visited 4 primary schools and 4 secondary schools in a large capital city in Australia. Discussion groups of 3 teachers per school were conducted during a school lunch break and audio recorded for later transcription. The time for each discussion ranged from 20 to 35 minutes. The author acted as scribe in an attempt to record any ideas and lists from the discussions. In order to reduce the biases established from all participants in discussion groups considering schools located in the same capital city, the author also sought feedback, via telephone, from teachers in randomly selected primary and secondary schools in each capital city in Australia. An additional 15 teachers (7 primary and 8 secondary) participated and were initially contacted by telephone at their school, from details obtained from the internet. The author recorded (for later transcription) her end of the telephone discussion, with the participant's permission, and repeated key ideas back to the teacher for confirmation. The time for each discussion ranged from 8 minutes to 24 minutes.

RESULTS AND DISCUSSION

The participants identified seven different forms of practical work that were currently used in Australian schools. Some forms were more widely used than others. The participants either used these forms of practical work, or knew a teacher in their school who did. In the remainder of this section, each form of practical work is briefly defined, according to the teachers, and is accompanied by the teachers' perceived purpose of the form of practical work. Although a teacher may not currently use a particular form of practical work, it was found that all teachers had a view on what the purpose of each form of practical work involved.

Demonstration – The teacher or other individual does the experiment. The students observe and use the results in a discussion. Students can be asked to predict and reflect upon results. In Table 2, it is apparent that the teachers used four of Wilkinson and Ward's (1997) ten statements in defining the purpose of a demonstration. There appears to be a number of trends in the responses:

- ✓ *The pre-service teacher (both primary and secondary) tends to feel that the purpose of the demonstration is to make science more interesting and enjoyable as the student discovers or verifies facts, more so than the experienced teacher.*
- ✓ *There is a widespread perception that the purpose of the demonstration is to promote scientific thinking.*
- ✓ *Experienced teachers have the perception that the demonstration helps in the understanding of theory, more so than the pre-service teacher.*

Directed Activity – The teacher provides specific instructions and set questions. The students follow the instructions, answer the set questions and the content is learned through the practical activity. An example of this are the ASEP materials developed in the 1970s, but still in use today. Eight of the ten Wilkinson and Ward (1997) statements alluding to the purpose of directed activity were used by the participants in defining the purposes of directed activity (see table 4). Of interest is the following:

- ✓ *The pre-service teacher, either in primary or secondary training, see the purposes of directed activity to be interest and enjoyment related, for discovering and verifying facts, to promote scientific thinking, and for cooperative work, more so than the experienced teacher.*
- ✓ *The experienced secondary teacher, more so than other teachers, perceives directed activity for making and interpreting observations.*
- ✓ *Only about one third of the experienced secondary teachers considered the purpose of helping students understand theoretical parts of science to be relevant to directed activity. This is interesting as the ASEP project of the 1970's was directed activity, aimed to develop understanding through working with process.*

Table 3. The purpose of using the laboratory experiment / closed inquiry in science classrooms.

Type of practical work used in schools	Reasons for use of school practical work	**Primary (n=90)**		**Secondary (n=48)**	
		Pre-service % (n= 70)	In-service % (n=20)	Pre-service % (n=28)	In-service % (n=20)
Laboratory Experiment / Closed Inquiry	To make science more interesting & enjoyable through actual experience	96	90	68	75
	To enable students to discover or verify facts & ideas for themselves	71	80	86	80
	To gain practice at making accurate observations & interpreting them	61	45	86	85
	To promote thinking in a scientific way	100	100	100	100
	To help students understand theoretical parts of science	100	95	69	65
	To develop skills in working cooperatively with others	100	100	80	65
	To give training in solving problems & conducting investigations	96	100	50	45
	To gain experience in using scientific equipment	81	90	66	30
	To give practice in following a set of instructions	100	95	86	35
	To prepare student for examinations	0	0	21	15

Table 4. The purpose of using the directed activity in science classrooms.

Type of practical work used in schools	Reasons for use of school practical work	**Primary (n=90)**		**Secondary (n=48)**	
		Pre-service % (n= 70)	In-service % (n=20)	Pre-service % (n=28)	In-service % (n=20)
Directed Activity	To make science more interesting & enjoyable through actual experience	80	60	82	55
	To enable student to discover or verify facts & ideas for themselves	96	80	93	50
	To gain practice at making accurate observations & interpreting them	66	80	86	90
	To promote thinking in a scientific way	81	75	54	70
	To help students understand theoretical parts of science	71	95	68	30
	To develop skills in working cooperatively with others	93	45	57	50
	To give training in solving problems & conducting investigations	49	80	96	85
	To gain experience in using scientific equipment	61	95	93	90

Undirected Activity – The teacher allows the student free time to explore a topic of interest. The student may choose to fiddle with equipment, use trial and error and use simple problem solving. This behaviour is often a familiarisation with the equipment. The teacher is unable to progress a lesson until the student has familiarised themselves. For example, Tom, a pre-service physics teacher realised on his school placement that:

Students needed to 'play' with crash carts and dummies prior to starting my lesson on forces and inertia. My supervising teacher said if I didn't let them have some fun and play, they would do it anyway, and I would have to repeat the intro to my lesson (Tom, pre-service physics teacher).

An inspection of Table 5 indicates only three purposes for the undirected activity. Irrespective of the purpose, it appears the experienced teacher sees its relevance more than that of a pre-service teacher. This may be that the lack of experience in conducting practical work with a class of students has not highlighted the importance of this type of activity. Primary teachers see the purpose of the undirected activity to promote scientific thinking more than a secondary teacher does.

Skill Development – The teacher provides opportunities for the student to repeatedly access basic scientific equipment. The student uses the equipment as a standalone task, devoid of context, thus developing manipulative skills. Common examples would be lighting a Bunsen burner, and glassware usage. Process and inquiry skills, for example collecting and recording and interpreting data are skills best developed in connection with content. From Table 6, the purposes

Table 5. The purpose of using the undirected activity in science classrooms

Type of practical work used in schools	Reasons for use of school practical work	**Primary (n=90)**		**Secondary (n=48)**	
		Pre-service % (n= 70)	In-service % (n=20)	Pre-service % (n=28)	In-service % (n=20)
Undirected Activity	To gain practice at making accurate observations & interpreting them	49	75	57	85
	To promote thinking in a scientific way	14	65	21	45
	To gain experience in using scientific equipment	33	75	50	75

Table 6. The purpose of using skill development in science classrooms

Type of practical work used in schools	Reasons for use of school practical work	**Primary (n=90)**		**Secondary (n=48)**	
		Pre-service % (n= 70)	In-service % (n=20)	Pre-service % (n=28)	In-service % (n=20)
Skill Development	To make science more interesting & enjoyable through actual experience	90	45	50	45
	To gain practice at making accurate observations & interpreting them	61	75	50	50
	To develop skills in working cooperatively with others	14	65	0	10
	To give training in solving problems & conducting investigations	0	0	21	15
	To gain experience in using scientific equipment	81	75	25	85
	To give practice in following a set of instructions	0	20	0	10
	To prepare student for examinations	0	0	11	25

Table 7. The purpose of using guided inquiry in science classrooms

Type of practical work used in schools	Reasons for use of school practical work	**Primary (n=90)**		**Secondary (n=48)**	
		Pre-service % (n= 70)	In-service % (n=20)	Pre-service % (n=28)	In-service % (n=20)
Guided Inquiry	To make science more interesting & enjoyable through actual experience	96	90	69	85
	To enable students to discover or verify facts & ideas for themselves	93	85	86	95
	To gain practice at making accurate observations & interpreting them	49	65	50	50
	To promote thinking in a scientific way	96	85	86	95
	To help students understand theoretical parts of science	81	80	93	95
	To develop skills in working cooperatively with others	81	75	10	10
	To give training in solving problems & conducting investigations	33	20	69	85
	To gain experience in using scientific equipment	33	10	86	90

for defining the development of skills vary depending upon the ages of the students:

1. *Primary teachers perceive the purpose of skill development to be for making and interpreting observations, and for working cooperatively, more so than secondary teachers.*
2. *A small number of secondary teachers see the purpose to involve problem solving and examination preparation.*
3. *Almost all of the pre-service primary teachers see the purpose of skill development to involve interest and enjoyment, compared to approximately half of the secondary teachers and experienced primary teachers, holding this view.*

Guided Inquiry – The teacher directs the inquiry by posing the question, but the student is responsible for planning, conducting and interpreting the inquiry. The creativity of the student directs the approach to solving the pre-determined problem. Differing trends from Table 7 are as follows:

I. *An experienced primary teacher sees the purpose of guided inquiry to involve making and interpreting observations more than other teachers do.*
II. *Secondary teachers see the purpose of guided inquiry to involve problem solving, conducting investigations, and using scientific equipment more so than primary teachers. In fact, very few primary teachers perceive this to be a purpose at all.*
III. *Primary teachers tend to see the purpose of guided inquiry to be interest and enjoyment, scientific thinking and working cooperatively.*

Open Inquiry – The teacher does not pose the question. The student poses their own question, plans the inquiry, conducts the inquiry, and reflects upon the results to answer the question. The problem may be simple or it may be complex and time consuming. It is interesting to see that primary pre-service teachers perceive a wider purpose for the open inquiry. In all cases in Table 8, the pre-service teachers related more to each purpose than did the experienced teacher. This may be as a result of pre-service teachers being more familiar with open inquiry through their more recent university training. The only purpose a significant number of experienced primary teachers related to was that of giving training in solving problems & conducting investigations (60%).

Most secondary teachers see the purpose of the open inquiry to involve the discovery and verification of facts, scientific thinking, problem solving and conducting investigations, followed closely by the interest and enjoyment factor.

To conclude the discussion groups and telephone conversations, the teachers were asked if they felt ready to teach using inquiry-based pedagogies. One primary teacher, Maddy (Year 6 teacher, 7 years experience) indicated she was not:

Most definitely not, but having participated in today's chat, I see inquiry is in different forms. I thought it was just like open inquiry so I was really worried. Now that I see it can involve me being in-charge at times I am happier. But not ready. I have no idea how to do it. It would be good to have a teaching partner so we could learn it together. (Maddy, year 6 teacher).

71% of the primary teachers shared Maddy's feeling of not being prepared for the new approach and felt the need for some sort of professional development, not only to show them how to do it, but in some sort of behavioural checklist to show what questions to ask and when. Only 35% of the experienced primary teachers indicated they were happy to implement inquiry based teaching in their classrooms, but half of these teachers clarified that they would have to remove troublesome students first as:

I need to be sure the kids will respect the freedom. My school has a few students who always spoil it for the rest. So if I didn't have to worry about them, I would think 'ok, let's run with it'. I think I could cope with the behaviour management of 30 kids all trying to do something exciting and 'dangerous', but doing the right thing at the same time. (Dominick, Year 5 teacher, 10 years experience).

Behaviour management was a concern for 86% of all the pre-service teachers when considering readiness for inquiry teaching. Controlling the classroom when all students are supposedly working on the same task is a challenge for novice and beginning teachers, so having multiple tasks operating at the same time was considered very daunting. Some pre-service teachers in secondary schools did not have behaviour concerns as:

If a kid mucked up in my school in a practical lesson they are removed from the class and have to sit in with another year level, so a naughty Year 8 student has to go to a Year 12 class. It is a lot of fun when the older kids are removed to a younger class, as they have them teach the younger kids to get a taste for how good student behaviour is important in laboratories. (Jess, Pre-service Chemistry Teacher).

Table 8. The purpose of using open inquiry in science classrooms.

Type of practical work used in schools	Reasons for use of school practical work	**Primary (n=90)**		**Secondary (n=48)**	
		Pre-service % n= 70	In-service % n=20	Pre-service % n=28	In-service % n=20
Open Inquiry	To make science more interesting & enjoyable through actual experience	96	30	66	85
	To enable student to discover or verify facts & ideas for themselves	49	20	86	95
	To gain practice at making accurate observations & interpreting them	33	20	21	15
	To promote thinking in a scientific way	33	10	69	95
	To develop skills in working cooperatively with others	81	20	11	10
	To give training in solving problems & conducting investigations	81	60	80	95
	To gain experience in using scientific equipment	49	10	86	80

Other forms of support were also evident in most schools. Parents often come into primary classrooms to assist with special activities, and recent ASISTM Project involvement was mentioned by a number of teachers as providing a network of assistance they may be able to call upon. This outside support available to some schools may allow a teacher to use open and guided inquiry more easily.

A number of teachers indicated that their syllabus documents already mandated open inquiry in the post compulsory years of schooling. Such schools permit the use of laboratory technicians to help in the classes during practicals, and others allocate Teacher Aids (often a special needs teacher) to classes to increase the reduce the teacher : student ratio. One physics teacher did however voice her concerns:

I can run 2 classes of physics doing open inquiry, but we have to stagger our biology classes as there are four of them and not enough equipment. We are going to have huge resourcing issues if the whole school is doing guided or open inquiry. Our Lab tech guy will quit! Also we have nowhere to store equipment set up by the kids during data collection. At the moment we sort of shove it all to the side so another class has desk space. (Fiona, Senior Physics Teacher, 4 years experience).

Many of the pre-service teachers voiced their concerns regarding their readiness to teach using inquiry as they did not consider they had the content knowledge to begin an inquiry and guide the students. Almost all of the primary pre-service teachers thought it unfair they had to teach this way when they didn't have a science background, and were not interested in it:

It's not like I enjoy it or anything. I will probably do the minimum because there is so much else to do anyway. I should be able to cope if the kids are not geeks and not into something too deep. Like if I can read up on it the night before ...... umm ..... I should be OK, right? (Julie, Pre-service Primary).

In the present study, 138 participants identified 7 different forms of practical work in Australian schools. The participants then used 10 statements from Wilkinson and Ward (1997) to assist in defining the purpose of each form of practical work. A summary of this is provided in Table 9. It can be seen that that three purposes are present in all forms of hands-on practical work: the interest and enjoyment factor, making and interpreting observations, and scientific thinking. The purpose of exam preparation was the least common perception, and limited to secondary schools.

CONCLUSION

To conclude, this paper presents an historical overview of Australia's practical work in science classrooms. It was found that Australian education has always been guided by international curricula, but currently we are at a crossroads – we are about to embark on the teaching of our first Australian curriculum in science, mathematics, English and history. The unique aspect to the science curriculum is in the inquiry-based pedagogy the teachers will be required to adopt. Australian pre-service and in-service primary and secondary teachers were interviewed about the forms of practical work done in schools and about their readiness for inquiry-based pedagogies. In relation to the forms of practical work used in Australian schools, and the purpose of such work, it is convenient to inspect the trends from the primary school and secondary school divide, as well as the pre-service and in-service teacher divide. When using any form of practical work in an Australian primary school, it seems the most frequently considered purposes are to:

1. *promote scientific thinking*
2. *work cooperatively with others*
3. *give training in solving problems and conducting investigations*
4. *give practice in following a set of instructions*
5. *make science more interesting and enjoyable through actual experience*

When using any form of practical work in an Australian secondary school, it seems the most frequently considered purposes are to:

1. *promote scientific thinking*
2. *gain experience using scientific equipment*
3. *enable students to discover or verify facts and ideas for themselves*
4. *give training in solving problems and conducting investigations*
5. *help students understand theoretical parts of science*

Table 9. Most commonly perceived purposes for different forms of practical work

Purpose (from Wilkinson and Ward (1997))	Forms of practical work (n=7)
To make science more interesting and enjoyable through actual experience	7
To gain practice at making accurate observations and interpreting them	7
To promote thinking in a scientific way	7
To enable student to discover or verify facts and ideas for themselves	6
To develop skills in working cooperatively with others	6
To give training in solving problems and conducting investigations	6
To gain experience in using scientific equipment	6
To help students understand theoretical parts of science	5
To give practice in following a set of instructions	3
To prepare student for examinations (not in primary)	2

There are slight differences between the two educational settings. In primary school, the teachers are interested in developing not only the hands-on skills but also the social interactions of the students. Also, there is less an emphasis on knowledge and science content when compared to the secondary school.

In terms of the pre-service teacher and the in-service teacher perceptions, again there are slight differences. Pre-service teachers place greater emphasis on the interest and enjoyment factor than the experienced in-service teacher. The pre-service teacher also tends to place greater importance on practical work having the purpose of enabling the student to discover or verify facts and ideas for themselves than an experienced teacher would. It is interesting to note that experienced in-service teachers see much less purpose for guided inquiry than the pre-service teacher. The implications for this are great. Guided inquiry is less likely to be used in our schools, thus reducing the opportunity for pre-service teachers to develop such skills while on field placement. Also this may impact on the implementation of the Australian Curriculum: Science by existing teachers not having the skills for this particular pedagogy. Clearly professional development will be needed. Science by Doing is developing an ICT based professional development module Inquiry-Based Teaching so the timing is apt. It remains to be seen if an ICT module is sufficient to give all teachers confidence in teaching by inquiry.

It would therefore be reasonable to conclude that the teachers (pre-service and in-service alike) in this small study, drawn from all capital cities in Australia, from both primary and secondary schools, feel the purposes of hands-on practical work in our schools to be multifaceted, and dependent upon not only the age of the student, but also on the type of practical work being undertaken. For some forms of practical work, the purposes are many giving the teacher choice in what they want the emphasis to be. For example, the laboratory experiment can be used to develop knowledge and skills in the secondary school, but in the primary school also for practice in following a set of instructions. Irrespective of the setting, the laboratory experiment is used to promote thinking in a scientific way. In general, most teachers are not ready to teach using inquiry based pedagogy and cite lack of content knowledge, behaviour management, and lack of physical resources and availability of classroom space as key issues which will hinder their implementation of the inquiry component of Australia's pending curriculum in science.

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[i] Further details of Australia's '*Primary Connections: Linking science with literacy*' curriculum resources can be found at: http://www.science.org.au/primaryconnections/PrimaryConnections%20overview%20report.pdf

[ii] Further details of Australia's '*Science by Doing*' professional learning modules can be found at: www.science.org.au/sciencebydoing

[iii] Further details of Australia's ASISTM projects, can be found at: http://www.asistm.edu.au/asistm/asistm_home,17201.html

[iv] Further details of *Australian Curriculum*: *Science* can be found at: http://www.acara.edu.au/ curriculum.html.