

Science and Mathematics Education Centre

**Assessment of Teacher Professional Development as a Change Agent for the
Mining and Metallurgical Industries**

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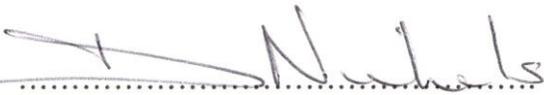
**This thesis is presented for the Degree of
Doctor of Philosophy
of
Curtin University**

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Declaration

To the best of my knowledge and belief this thesis contains no material previously published by any other person except where due acknowledgment has been made.

Further, this thesis contains no material which has been accepted for the award of any other degree or diploma in any university.

Signature: 

Date: 19/06/15.

ABSTRACT

Current curriculum documents used by science educators in their teaching practice require them to establish partnerships that link the school, community and work place (Queensland Department of Education, 2005). Science educators can set up their students to become lifelong learners by making links between the science they are teaching and the practical applications of science in the world around them. Science taught by making these links increases the relevance for the science educators and their students and makes the learning experience authentic (Matters, 2006). Expert science educators are able to inspire their students to become inquisitive about science and encourage them to continue this curiosity and continue learning throughout their lives.

The applied science program in the mining and mineral processing industries offers an opportunity for a real-life experience. The applied science is authentic and real-life examples from the industries can be used by science educators in their suite of teaching and learning experiences for their students. However, there is a need for science educators to confidently teach the applied science related to the mining and mineral processing industries and this is why professional development programs have been established in response to the established deficiency.

This research study examines a variety of science educators who attended professional development programs about the mining and mineral processing industries. The research study investigated the science educators' ability to apply their content knowledge of the applied science associated with the mining and mineral processing industries to the curriculum documents and in doing so whether they had a change in attitude about the mineral and mining process industries. A mixed method approach was used to collect primary data. This included qualitative data collected using the feedback survey which then informed the next step of data collection, being the clarification tool. This data collection tool comprised of follow-questions, interviews and documentation of science educators as they wrote the teaching resource.

The primary data collected from the science educators who attended the professional development programs showed that the science educators were able to report a change in their content knowledge of the mining and mineral processing industries. Further, they were able to apply their knowledge of the mining and mineral processing industries to the science curriculum documents and they reported a change in their attitude towards the mining and mineral processing industries. The science educators were also able to form professional networks with researchers and scientists working in the mining and mineral processing industries for the duration of the program. However, when the professional development program concluded, the professional partnerships that had been established during the program did not continue.

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CHAPTER ONE

INTRODUCTION AND OVERVIEW

1.1 INTRODUCTION

Science curriculum should be relevant to all students and, as changes occur to curriculum documents, relevance to students must remain. The science curriculum in Australia has always been in a state of change. However, the changes have intensified in the last 20 years. Recently, a number of significant changes have taken place in science education including the outcomes-based approach and then the more recent “Essential Learnings” approach. The national implementation of the Australian Curriculum is the latest change that science teachers are now experiencing. At the time of writing, all states in Australia had actioned the Australian Curriculum documents in junior science. However, at the time that the primary data were collected for this research study, while the decision to implement the Australian Curriculum had been made, the Australian states had only progressed as far as planning for its implementation. Now (September, 2014), the Australian Curriculum for the senior science subjects of biology, chemistry, earth and environmental science and physics has been approved and preparation is underway for the implementation of these subjects in the senior years of schooling. Even in this constant climate of change, science teachers still endeavour to engage their students in real-world science learning experiences by providing them with authentic examples to enhance the content of the subject that aligns with the new curriculum.

The embedding of authentic science content knowledge in science lessons engages students in learning. If teachers are able to embed authentic examples of science from the real-world and link these examples to science content in the new curriculum, their students can benefit from this exposure.

Also, the new curriculum allows for the inclusion of the work that scientists as individual scientists do. The actual scientists working on the authentic examples can also be included and highlighted in the new curriculum. This gives students a direct window

to the scientists and the way they work. Students who engage in science in this way may even consider choosing science as a viable career in the future.

To enable science teachers to continue to confidently provide authentic learning experiences in a climate of change, science teachers often seek out professional development programs to cater for their own learning needs. As science teachers are expected to adapt to continual changes in curriculum, support in the form of professional development is always welcome.

This research study focuses on data collected from science educators who participated in professional development events about real-world science (specifically, the mining and mineral processing industries). It investigates how they used the content knowledge derived from the professional development programs to make their science teaching relevant for their students, even when the curriculum documents were changing. The research study also collects data about the science educators' attitudes towards the mining and mineral processing industries. Finally, the science educators interacted with scientists and researchers working in the mining and mineral processing industries in the course of the professional development programs. These professional interactions are examined.

This research study contains a wide depth and scope of data. It was collected from three different professional development programs about the mining and mineral processing industries and the associated science content practised within those industries. Further, the professional development programs were delivered by three different professional development providers. Two were Australian professional development programs and one was from overseas (the United States of America). These programs were similar as they focused on science content knowledge about the mining and mineral processing industries and developed the linkage to science content in the science curriculum documents. The participants were science educators who self-selected to attend the professional development events. Another element that also added to the depth and scope of the data was that the participants came from primary and secondary schools in

both public and private sectors. So, the data were drawn from science teachers participating in professional development who came from a variety of backgrounds. This provided a rich data set for analysis.

Data for this research study data were collected using a variety of methods. Initially, it was collected from the participants of the professional development programs using the Feedback Survey. These data were examined and further data were collected using qualitative data collection tools. Consequently, both quantitative and qualitative data collection methods were used in a mixed method approach and this enabled a detailed examination of the data to be conducted and it also enabled assertions to be drawn.

1.2 RATIONALE FOR THE RESEARCH STUDY

This research study built on previous findings involving professional development of science teachers. However, it extended previous work as it focuses specifically on professional development programs delivered by different providers about the mining and mineral processing industries. It draws new associations between these professional development events and the teachers' content knowledge of the mining and mineral processing industries and also examines the professional interactions between science educators and scientists working in these industries. The research study used data collected by both quantitative and qualitative data collection methods and developed into a mixed method data collection approach as the study progressed. This enabled the researcher to drill down into the data sets and draw meaning from them during the analysis stage of the research.

Given that both human and financial resources are directed to the professional development of science educators in the content-rich area of the mining and mineral processing industries, it is desirable to research how teachers benefit from the professional events that they attend. Therefore, the overall aim of this thesis was to determine the outcomes of professional development programs in the mining and mineral processing industries for science teachers.

1.3 INFLUENCES THAT FORM THE BACKGROUND TO THE RESEARCH STUDY

There were two main influences on this research study that informed how the professional development for science educators should be conducted in the first place. The first influence was the decline in the numbers of students studying science in secondary and tertiary educational institutions and the follow-on effect of the decline in the number of scientists and researchers. This was particularly evident in the mining and mineral processing industries (Churach, 2004a).

The second influence was the changes that were happening in the science curriculum and the recognition that, to engage students in learning about science and keep them studying science, the science needed to be authentic and related to the real-world (Spotlight on Science, 2003). The proposition was that this approach could encourage science students to consider careers in science and in the mining and mineral processing industries. The professional development programs studied in this research program were provided for science educators to enable them make links between the science content knowledge from the mining and mineral processing industries and the curriculum documents.

1.3.1 Recent Changes in the Science Curriculum

One of the most significant changes for science educators in Australia is the development and implementation of the Australian Curriculum. Previously, all Australian states had their own separate curriculum documents, so this was a major change for all teachers. In 2009, the National Curriculum Board published a framing paper called the *Shape of the Australian Curriculum: Science* (National Curriculum Board, 2009) in preparation for the writing of the Australian Curriculum documents. The paper was prepared after analysis of extensive feedback from stakeholders in

Australia and from recent Australian and international science education research. Its purpose was to guide the writing of the Australian Science Curriculum K – 12 curriculum documents and to form the basis for the planning, teaching and assessing of school science within Australia. The *Shape of the Australian Curriculum: Science* (National Curriculum Board, 2009) paper acknowledged that the Australian Curriculum would have an impact on the way science teachers deliver the curriculum in the future. In particular, the paper recognised that the impact would be significant because it focused on improving school science learning and it acknowledged that students have different learning needs and interests and that students need to be engaged in science learning in meaningful ways. In the introduction this paper states:

The Australian science curriculum will provide the basis for learning science that will engage students in meaningful ways and, with the support of teachers, help them to develop their science understanding so that they can function effectively in a scientifically and technologically advanced society. (National Curriculum Board, 2009 p.4).

By engaging students and providing authentic science and scientific examples, this enables student engagement and a place is provided in the Australian Curriculum documents to embed content knowledge about the mining and mineral processing industries. Further, the *Shape of the Australian Curriculum: Science* (National Curriculum Board, 2009), drew attention to the importance of pathways to employment and the role that science education plays:

As well as preparing students to use science for life and active citizenship, school science should also provide a foundation for specific learning pathways leading to science and engineering courses at university and technical and vocations education and training. Senior secondary science opens up a wide range of careers in engineering, technology, medical and health professions, as well as careers in science and education. (National Curriculum Board, 2009 p.4).

This research study examine the content-rich professional development programs for science educators engaged in implementing aspects of the Australian Curriculum documents that focus on the applied science of the mining and mineral processing industries. Importance is attached to investigating the science educators’ attitudes about these industries and whether they would recommend the careers in this industry to their students. This research study acknowledges the influences of the preparation for the implementation of the Australian Curriculum and determines to collect and analyse associated data from the professional development programs about the mining and mineral processing industries that were being delivered to science educators during this time of change.

Guided by the *Shape of the Australian Curriculum: Science* (National Curriculum Board, 2009), the *Australian Curriculum – Science (Foundation to Year 10)* document has been written and staggered-implementation has occurred across the Australian States. This document is organised into these three interrelated strands: *Science understanding*, *Science as a human endeavour* and *Science inquiry skills*. *Science understanding* and *Science as a human endeavour* are the content strands while *Science inquiry skills* is the process strand. A set of sub-strands sits under each strand. Table 1.1 below shows an overview of the organisation of the strands and sub-strands.

Table 1.1

An Overview of the Australian Curriculum: Science (ACARA, 2010)

Science understanding	Science as a human endeavour	Science inquiry skills
Biological sciences	Nature and development of science	Questioning and predicting
Chemical sciences	Use and influence of science	Planning and conducting
Earth and space sciences		Processing and analysing data and information
Physical sciences		Evaluating
		Communicating

While the *Australian Curriculum – Science (Foundation to Year 10)* document gives scope for science teachers to give their students a solid foundation in science, it also provides many opportunities for them to engage their students in authentic learning experiences that can be applied to the mining and mineral processing industries. First, in all of the *Science understanding* sub-strands of Biological sciences, Chemical sciences, Earth and space sciences, and Physical sciences, the scientific content knowledge of energy resources, mining, the mining processes and rehabilitation and associated ecological issues can be addressed. Secondly, *Science as a human endeavour* strand provides scope for stewardship, ethical issues and careers associated with mining practice. Finally, all the sub-strands in *Science inquiry skills* can be related to the mining and mineral processing industries by providing opportunities for students to process and analyse authentic primary and secondary data and information generated from the mining and mineral processing industries, evaluate it and communicate that information.

At the time of writing (2014), the Australian Curriculum documents for junior science have been implemented, but not as yet in the senior science subjects. Currently, senior science teachers are teaching from senior State science syllabuses, however, preparation is underway for the planned implementation of the Australian Curriculum senior science subjects. The Australian Curriculum, Assessment and Reporting Authority (ACARA) has now released the curriculum documents for the senior Australian Curriculum Science subjects in readiness for the Australian states to implement. The senior science subjects to be implemented are, biology, chemistry, earth and environmental science and physics. Interestingly, the science concepts in the junior science content strands make a smooth transition to the senior science subjects (except for the senior *Earth and Space Sciences* in junior and *Earth and Environmental Science*). When the Australian Curriculum documents for the senior science subjects are implemented, the science teachers will need to be aware of this and make the appropriate adjustments for the seamless implementation for their students.

In spite of this, the Australian Curriculum documents for senior science offer further opportunities for in-depth study of the content associated with the mining and mineral processing industries. While the senior chemistry and senior physics subjects avail themselves for teachers to use examples of applied science from the mining and mineral processing industries, the new senior subject, *Earth and Environmental Science* is best placed for this role. This new subject will offer specific opportunities for teachers of this subject to engage their students in authentic learning opportunities about the mining and mineral processing industries. For example in *Unit 3: Living on Earth – extracting, using and managing Earth resources* the unit description states:

Earth resources are required to sustain life and provide infrastructure for living driving ongoing demand for biotic, mineral and energy resources. In this unit, students explore renewable and non-renewable resources and analyse the effects that resource extraction, use and consumption and associated waste removal have on Earth systems and human communities. (ACARA, 2013 p.3).

Therefore, this unit description outlines the topic that will be taught in this unit and makes way for the explicit teaching of science content knowledge in the mining and mineral processing industries.

Presently, as the Australian Curriculum has not been implemented in the senior school to date, state education departments using their state-based syllabuses continue to encourage senior science teachers to provide authentic examples that relate to real science. This will continue to make the curriculum relevant to students in the interim before the implementation of the senior Australian Curriculum documents.

The change to the Australian Curriculum is part of a major change to the Australian education scene. Change has always been a constant and teachers are required to adapt to change. Practising science teachers are required to respond to this fluid educational climate and are required to accommodate the greater pedagogical and content-knowledge demands created by the Australian Curriculum. Science teachers need to

have adequate content knowledge to confidently meet these demands and professional development programs can assist teachers to do this.

1.3.2 Shortage of Skilled People in the Mining and Mineral Processing Industries

In parallel with the changes occurring in science education and the implications that the changes have for teachers, fewer students are choosing to study physical sciences at the secondary level. The supply of young science graduates gaining academic credentials in that science, technology, engineering and mathematics needed to maintain a qualified workforce has dwindled (Bartier et al., 2003; Churach, 2004b). Further, the Australian mining and mineral processing industries have an increased demand for bright, qualified young people seeking research and leadership careers within the industry. This has led to a shortage of skilled people in the mining and mineral processing industries (Churach, 2005).

The need for improving science education has been identified, and governments throughout Australia are making commitments to ensure students have access to high-quality science education. This includes exposing students to complex, real-world problems in both industry and research institutions (Spotlight on Science, 2003). Government and industry-funded professional development programs provided for science educators gives them the tools to incorporate a realistic view of the mining and mineral processing industries into their science lessons. This may go some way towards addressing the issues of: a) fewer students studying physical sciences, and b) the mining and mineral processing industries requiring more students trained in these areas.

In general, teachers are held in high regard by their students and have influence over their students. This means that science teachers are well positioned to positively influence their students' attitudes towards science. They also can encourage them to consider science careers that could include careers in the mining and mineral processing industries (Churach & Rickards, 2003). Over a period of time, it would seem natural for teachers to gradually integrate their knowledge about the mining and mineral processing

industries, gained from professional development events, into their teaching program. As a result, it would be expected that this should have a positive impact on their students' perceptions of the mining and mineral processing industries. Increased positive outcomes occur when career options become infused into the curriculum, rather than teaching them as separate items. Accordingly, at the same time, professional development for teachers should be provided to accommodate this approach (Millar, 1995; Churach & Rickards 2006).

1.4 PARTICIPANTS IN THE RESEARCH STUDY

There is also a need for science teachers to confidently teach applied science and outline its links to industry. Science teaching that makes these links increases the relevance for teachers and their students, and makes the learning experience authentic (Matters, 2006). However, teachers cannot engage their students if they do not have industrial knowledge themselves. If science teachers attend “real world” professional development events (including industrial laboratory work and field trips) that are aimed at increasing their knowledge of industry practices, it will help them to build their confidence (Nichols, 2009).

The science educators who contributed to the research study came mainly from education systems within Australia. However, there was one international cohort from the USA. In Australia, the science educators came from both the public and private sectors and from both primary and secondary schools within those sectors. This gave the first level of diversity to the research study. Additional diversity came from the USA teachers who contributed to the research study. Not only did they come from an education system that was very different to those within the Australian states, they came from a different multi-cultural country. Also, the USA cohort included teachers from across the elementary, secondary and tertiary sectors. This gave the study a truly international, and quite diverse, character.

All the teachers in the research study self-selected to participate in a professional development program and they each attended one or more of the professional development events that made up that program. All the professional development programs targeted both content knowledge about the mining and mineral processing industries and how that knowledge could be incorporated into authentic educational experiences in the science teachers' classrooms.

1.5 THE RESEARCHER'S PERSONAL EXPERIENCE AND ROLE IN THE RESEARCH STUDY

As a science educator myself, I took on the role of researcher for this research study. The content of the study and my practical experience in schools was familiar to me and I was comfortable in this role. Also, I had lived in mining towns and developed a network of professional colleagues there. This allowed me to gain inside knowledge into the science-related aspects of the mining and mineral processing industries. Further, because of my links in both these areas, I had the access I needed as a researcher to collect the required data. This then enabled me to interact freely with a) the professional development providers who were aiming to increase content knowledge about the mining and mineral processing industries, b) the industries themselves and c) the science educators who participated in the professional development programs.

Before I embarked on this research project, I had administrative involvement in professional development programs for science educators. My skills were enhanced during completion of my Master of Science degree. During this post-graduate degree program, I started gaining research skills specific to science education. I then applied these skills to a number of government-funded professional development projects for science educators, including the Australian Government Quality Teacher Program (AGQTP) and the Department of Education, Science and Training (DEST) science and literacy project. In both of these projects, I worked in partnership with Central Queensland University and my roles included:

- leading several clusters of science teachers;

- designing professional development events for professional development programs;
- collecting primary data from participants;
- working with university staff to analyse the data; and
- co-authoring the report on the success of the work done with the science teacher clusters.

The skills that I developed from these experiences enabled me to take on the role of researcher in this research project.

In this research study, as the researcher, I began by gaining an insight into the professional development events that were being run during the roll-out of the professional development programs in Australia. These professional development events included workshops and field trips. At this time I interacted with the participants and, at the end of the professional development events, I administered the Feedback Survey quantitative data collection tool.

I had a greater role in the Queensland Centre for Advanced Technologies (QCAT) and Education Queensland. The QCAT/Education Queensland professional development programs. Initially, I attended the professional development events and interacted with the professional development providers and participants and administered the Feedback Survey. But, as time progressed, I was invited to give input into the professional development program. I was able to offer advice about moving the professional development events from workshop-style sessions and field trips to linking the science content knowledge to the curriculum documents and providing a climate for the teachers to develop a teaching resource based on the content knowledge that they had gleaned from the professional development events. As a researcher, I followed this journey with the science educators and documented it as qualitative data for this research study.

The Colorado Mining Association Education Foundation and Colorado School of Mines Office of Special Programs and Continuing Education was the only professional

development in which I had no input. On a research tour in 2005, I met with the professional development providers in these USA organisations and they agreed to administer the Feedback Survey for me at their professional development events and then they sent me the completed surveys so that I could collate the data and analyse it.

1.6 RESEARCH QUESTIONS

Churach (2005) identified that, in the Australian mining and mineral processing industries, there was a gap between the number of vacant positions and the number of qualified people to fill these positions. This led Churach (2005) to propose and then implement, on-going professional development programs for secondary science teachers to address the issue in their role as teachers. Once the science teachers understood the science content knowledge involved in the mining and mineral processing industries, they could influence their students (Churach & Welham, 2007). Further, Churach (2005) argued that this was a method that could influence a broader range of people to fill the available positions in the mining and mineral processing industries. The Centre for Sustainable Resource Processing (CSRP) pioneered this professional development project and data were collected from the participants via the Feedback Survey.

This research study acknowledges Churach's original research and extends it by continuing to investigate the CSRP professional development program. This was done first, by including two other professional development programs that also focused on increasing science educators' science content knowledge about the mining and mineral processing industries. These were the Colorado Mining Association Education Foundation/Colorado School of Mines Office of Special Programs and Continuing Education and the QCAT/Education Queensland professional development programs. Secondly, the data collection method was expanded from merely using the Feedback Survey tool, to include a range of qualitative data collection tools that enable meaning to be drawn from the quantitative data collected via the Clarification Tool. The Clarification Tool is a device that I developed that is used to collect additional data so

that the quality of the responses from the participants in the development events can be analysed.

The first research question investigated in this research study is:

1. Is a mixed method approach using the Feedback Survey and the Clarification Tool a valuable and useful way to collect primary data from science educators attending professional development programs about the mining and mineral processing industries?

The second research question addresses the purpose of the professional development programs. The professional development programs were content-rich in the applied science that is associated with the mining and mineral processing industries. The aim of these programs was to increase the science educators' content knowledge of the mining and mineral processing industries so that they could use this content knowledge in their science classrooms. After the professional development program, the science educators who attended were invited to complete the Feedback Survey.

This Feedback Survey tool enabled the researcher to investigate the second research question, which is:

2. Can science educators report a change in their science content knowledge about the mining and mineral processing industries after targeted professional development in that area?

The professional development programs not only provided the science educators with content knowledge about the mining and mineral processing industries, they also link this applied science content knowledge to the curriculum documents. The science educators could then use this applied science content knowledge in their own science classrooms and provide their students with authentic examples from the mining and

mineral processing industries. So the research study investigated the science educators' ability to apply their learnings in a practical way using the Clarification Tool.

The third research question is:

3. Are science educators able to apply their knowledge of the mining and mineral processing industries to science curriculum after their engagement in professional development programs about science content in the mining and mineral processing industries?

Because the professional development programs were content-rich and because they were specifically about the mining and mineral processing industries, teachers may have changed their attitude towards these industries during their learning process. This research study investigates this proposal by using the Feedback Survey. Further, the teachers may also influence their students as they have gained knowledge about the mining and mineral processing industries themselves.

The fourth research question is:

4. Can science educators report a change in their attitude towards the mining and mineral processing industries after participation in a content-rich professional development program about the mining and mineral processing industries?

Central to the design of the professional development programs was the platform for researchers and scientists working in the mining and mineral processing industries to interact professionally with the science educators participating in the professional development programs. During the course of the professional development programs, the researchers and scientists presented lectures and workshops, conducted tours and field trips and made themselves available for informal interactions with the science educators. The intention was for the professional relationships developed during the professional development program to continue after the program ended.

The fifth research question is:

5. Are science educators able to form professional networks with researchers and scientists working in the mining and mineral processing industries?

1.7 ORGANISATION OF THE THESIS

This thesis is organised into five chapters. Chapter One introduces the thesis and outlines the research questions. It describes the changing nature of science education and the science educators' responses to the changes, including the need to embed authentic learning experiences into their teaching practice. Details of the professional development programs and their rationale for implementation are given. The researcher's position in the research project is also identified and discussed.

A literature review is detailed in Chapter Two. It outlines previous studies into the complex role that professional development plays in keeping practicing science educators abreast of the changes in curriculum and practice. It also outlines the attempts governing bodies have made to address the professional development needs of science educators in a climate of change. Reports commissioned by government departments, including studies involving the researcher's participation, are also outlined to show the progression of findings that influenced this research study. Further, research into the cyclic nature of the mining and mineral processing industries, along with attempts to address the need for qualified people to work in these industries is identified and explored. When the issues of effective professional development for science educators and the people shortage in the mining and mineral processing industries are examined together there is scope for research into this topic. The literature review demonstrates that there is a deficiency in the research about professional development for science teaching involving applied science in the mining and mineral processing industries. In particular, there is a gap in knowledge about the ability of science educators to link the applied science to their curriculum documents. Further, after they have attended a relevant professional development event, it is not known whether or not science

educators recommend careers in the mining and mineral processing industries to their students.

Chapter Three outlines the methodology used in this research study. Along with descriptions of the professional development providers, detailed descriptions of the professional development programs are given. The reason that both quantitative and qualitative data were collected in a mixed method approach is explained. A model of the methodology used in this research study is depicted diagrammatically to outline the data collection process.

It is important to understand that the methodology for this research study was flexible and it developed and changed as the professional development programs were being rolled out to the science educators. However, the common thread to this research study is that all of the science educators who attended the professional development events completed the Feedback Survey. However, the one group of science educators who participated in the Queensland Centre for Advanced Technologies (QCAT) also provided additional qualitative data for the study. These data were in the form of the Clarification Tool which consisted of follow-up questions, interviews and time-lines. Finally, a small group of teachers was followed as they took the content knowledge they had obtained from the professional development events to create a resource to be used by other teachers. The interviews from these teachers and the analysis of the resource complete the data set and enabled the research questions to be examined in detail.

Following a detailed description of the methodology used in this research study, Chapter Four presents the results from this research study. The research questions are addressed by presenting the quantitative data from the Feedback Survey and then the qualitative data was used to give explanations about the shifts in average differences in this data. A richer understanding of the data was achieved in the findings by using this method and it was shown to be valid and useful. The conclusions gained by using this method enabled science educators to report a change in their content knowledge about the mining and mineral processing industries. It also enabled them to report an ability to apply their

content knowledge of the mining and mineral processing industries to the curriculum documents. Further, the science educators were able to report a change in attitude towards the mining and mineral processing industries. Finally, while supported, the science educators and scientists were able to form professional relationships.

Chapter Five concludes this research study and offers recommendations. Each research question is revisited and addressed. The recommendations for further research into areas that have been exposed in this research study are also identified.

CHAPTER TWO

LITERATURE REVIEW

2.1 INTRODUCTION

Chapter one details the constant changes that have occurred in science education over the recent years and the impact that this has had on science teachers as they attempt to accommodate these changes in their teaching practice. As well as changes in curriculum documents, the *Australian Teacher Performance and Development Framework* (2012) has been developed to improve the quality of teaching in Australia. Despite these changes, science teachers endeavour to ensure that their teaching remains challenging and engaging for their students while including authentic examples of the latest scientific technological discoveries and applications in their classes to ensure that their teaching is relevant. Content-rich professional development programs about the mining and mineral processing industries were devised to provide opportunities for science teachers to attend and learn about the industry links to the science curriculum. These professional development programs provided links to curriculum documents and scientists and researchers working in those industries. After the professional development programs, the science educators gained a suite of examples from the mining and mineral processing industries that they could use in their delivery of the science curriculum.

This research study collected data from the participants of the professional development programs using a mixed method data collection approach. Following this, there were three requirements in analysing the data. The first requirement was to determine if there was a change in the science educators' content knowledge of the mining industry and mineral processing industries and if they were able to apply their knowledge of the mining and mineral processing industries to curriculum documents. The second was to identify the science educators' views of the mining and mineral processing industries as science teachers have an influence on their students. Finally, the research study was designed to determine whether professional

networks were formed between the science educators and the scientists working in the mining and mineral processing industries.

In this chapter, the theoretical background for this research study is investigated through a literature review. This includes an assessment of the present state of science teaching in Australia and the recommendations that have been made regarding professional development for science educators. Previous studies and the findings about addressing science teachers' content knowledge are presented, together with professional development model for content-rich professional development programs. Because it is where the professional development programs were conducted, the chapter then focuses specifically on the mining and mineral processing industries and examines the science teacher's role in addressing the issues raised. There is a gap in the literature where there is a lack of content-rich professional development about the mining and mineral processing industries and the use of a mixed method data collection approach to determine change. This gap is also highlighted in this chapter.

This is an important consideration as, during the roll out of the implementation of the Australian Curriculum, science teachers will be called upon to teach the *Earth and Space Sciences* in junior science and *Earth and Environmental Science* in senior science. There may be a lack of qualified science teachers to fulfill this teaching role.

2.2 THE NEED FOR ONGOING PROFESSIONAL LEARNING FOR SCIENCE EDUCATORS TO FULFILL THEIR CHALLENGING ROLE

The role of a science teacher is varied and complex. Not only is a science teacher required to have an in-depth content knowledge and the associated pedagogy of their subject area, but they also are required to carry out administrative and pastoral care roles. Education Queensland outlines what is expected of teachers employed in its system in a document stating their role descriptions (Education Queensland, 2013).

This makes it very clear on what is expected of teachers as they step into the classroom and start teaching.

In Australia, the *National Framework for Professional Standards for Teaching* (Teacher Quality and Educational Leadership Taskforce, 2003) recognises the ongoing need for teachers to continue their learning and embodies this concept in the standards at a national level. Professional knowledge, professional practice, professional values and professional relationships are all acknowledged as interdependent and overlapping categories that are common and recognisable professional elements. The National Framework for Professional Standards for Teaching (Teacher Quality and Educational Leadership Taskforce, 2003) states:

Teachers know and understand the fundamental ideas, principles and structure of the disciplines they teach. They know and understand the links to other content areas and are able to integrate learning across and between content areas. They know how to effectively teach that content, and understand the prompts and barriers to learning likely to be encountered by students. (p 11).

The *National Framework for Professional Standards for Teaching* (Teacher Quality and Educational Leadership Taskforce, 2003), requires teachers to continue their learning throughout their teaching career, additional specific learning may be necessary in the science content areas where there is a deficit in the teachers' content knowledge.

As well as having a strong content knowledge base in their chosen field, there is a complexity in the role that relates specifically to science educators. Rodrigues (2005) acknowledges this complexity and lists the requirements that effective science teaching practice is expected to fulfill. Science teachers are required to:

- understand and effectively interpret the curriculum;
- have a repertoire of pedagogical strategies;
- value student experience and expertise;
- possess subject content knowledge and the associated pedagogy; and

- understand the notion of progression.

To maintain all that is expected of them in their role, science teachers cannot expect that their pre-service university course will sustain them at this aspirational level. They will need to embark on a learning journey themselves as they progress through their teaching career.

Further, this professional learning journey is a continuous and ongoing process where learning occurs at different levels and rates throughout a teacher's career. The *Professional Standards for Teachers* (Queensland Department of Education, 2005) states that teacher commitment to reflective practice and professional renewal underlines the ongoing contribution teachers make to the teaching profession. So, not only do teachers need to recognise that professional learning is important, systems recognise this as well. But, ultimately teachers need to be responsible for their own learning and monitoring of their professional learning needs. (Australian Institute for Teaching and School Leadership, 2014).

School curricula are designed to assist students to become lifelong learners (Queensland School Curriculum Council, 1999). However, science educators also need to become lifelong learners themselves to help maintain what is expected of them in their complex role. Teachers can draw on the prior knowledge that they have obtained through their university courses. However, further learning about the content of their subject and its associated pedagogical practice is a means to deepen their pedagogical content knowledge (PCK) of science (Schulman, 1987). Further, Smith and Neale (1989) state that, for teachers to demonstrate high levels of PCK, they must have sufficient content knowledge of the subject matter that they are teaching. Magnusson et al., (1999) showed that there are different types of knowledge (including content knowledge, pedagogical knowledge and knowledge about context), but that these are closely related. Science teachers hone their own knowledge as they progress through their career and this knowledge can be supported by targeted professional development.

Professional development for science teachers can take many forms, but these all cater to the needs of the science educators. There are times when professional

development events may have limited aims (e.g., when a change of policy is introduced or an IT program is to be implemented). Because no attempt is being made to shift teachers' attitudes and beliefs, at these times a simple one-off professional development event can achieve the desirable outcome. However, if deep-seated changes in pedagogical practices are required, a more complex approach is required and cannot be brought about without addressing both individuals' fundamental attitudes to teaching and learning within the context of a school environment that values local knowledge and practices (Adey, 2004). So, for professional development programs to be of intrinsic value to science teachers, they need to be able to incorporate their own new content knowledge and incorporate it into their pedagogical practice. However, they also need to attend to the other system requirements and participate in professional activities with limited aims to fulfill their stated role description.

2.3 ADDRESSING PRE-SERVICE CONTENT KNOWLEDGE OF SCIENCE EDUCATORS IN AUSTRALIA

Science teachers gain the deep understanding of the content of their subject in pre-service preparation for teaching in their university degrees. There is no single, direct entry into science teaching in Australia. Teachers who want to teach science enter the profession from a variety of backgrounds. Some teachers have a science degree while others study science as part of an education degree. As a consequence, the science content knowledge of science teachers varies from the start and this depends on the path that they choose to enter the teaching profession. This has had a direct impact on both the quantity and quality of science content knowledge that teachers currently teaching science have.

In their report commissioned for the *Australian Council of Deans of Science*, Harris et al. (2005) examined the characteristics of teachers currently teaching science in Australian secondary schools. Because of the type of survey and the amount of data generated, this was a significant study. Responses were received from 1207 teachers across multiple sectors (namely from government, Catholic and independent schools). The number of participants was estimated to be a representation of 9% of

the science teachers in Australia. Most participants surveyed reported that they held 'science based' degrees (72%) while 21% held Bachelor of Education degrees.

Further, this study found that the majority of the survey respondents (85%) held a minor or a major in at least one of the senior science subject areas of biology, chemistry, physics or geology. However, when the number of years that the participants studied the science subject was also considered, participants who studied their subject for four years or more were biology 14.0%, chemistry 9.0%, physics 5.7% and geology 2.0%. The science heads of department who were also surveyed in this study defined a major in a science discipline as the minimum satisfactory level for tertiary teaching. A first year tertiary study in a particular science discipline was seen as an inadequate qualification for teaching science at a senior secondary level. Both science heads of department and teachers expressed the view that science teachers need strong, discipline-specific qualifications in science.

The same study found that virtually all the heads of department surveyed believed that junior secondary school science teachers should have studied some science at university and half (50%) stated that first year study was insufficient. However, of the science teachers surveyed who only taught junior science, nearly one in five (nearly 20%) had not studied biology, chemistry or physics at university. One of the report's key findings about the qualifications of science teachers was that science teachers who lacked knowledge in their discipline were "manifestly" unprepared. This situation may be amplified when the roll out of the Australian Curriculum senior Earth and Environmental Science subject occurs.

A different study, *Participation in Science, Mathematics and Technology in Australian Education* (Ainley et al., 2008) also reported on the characteristics of the teaching workforce in Australia, including both science and non-science teachers. For science teachers, the report found that the qualifications for some of the teachers were not in the physical sciences, but were in science-related fields such as psychology and physiology. It appeared that these teachers were recruited because of the shortage of appropriately qualified teachers of the physical sciences in Australia. Consequently, there was a definite need for this portion of the science

teaching community to have their qualifications augmented by science-based professional development.

Additionally, those teachers with physical science qualifications are required to keep up with research and advances in technology. The report recommended three ways that science teacher expertise can be deepened, including:

- recruiting a greater proportion of people into teaching with backgrounds in science;
- enhancing the science-base of existing teachers; and
- developing core teachers in primary schools with expertise in science.

These recommendations support the notion that science teachers need a strong content base in the science areas that they teach.

Science educators need a strong content knowledge base to confidently teach their subject area. Ainley et al. (2008) also found that strengthening school science education in Australia depends on deepening teacher expertise in science. Appleton (1997; 2003) highlighted this for primary school science teachers as they have a tendency to focus on non-science studies in their undergraduate courses. Because they have not studied science extensively in their teacher preparation courses, they perceive that they have lack of a deep science knowledge base. This causes them to become reluctant in teaching science and constrains their teaching approaches.

Professional development to enable these primary school science teachers to gain a deep knowledge base has been considered to be imperative to address the factors that constrain them (Appleton, 1997; Skamp, 1991). Coolahan (2002) also states that the knowledge base on which a teaching career is founded had to be deepened and teachers need to engage in lifelong learning to address this.

Goodrum et al. (2001) investigated the current status and quality of teaching and learning of science in Australia. In this study, an examination of the “ideal” and the “actual” state of science in Australian schools was carried out. From the report’s findings, recommendations were developed to close the gap between the ideal situation and the actual situation in Australian schools. The research team made strong recommendations for improved professional development for science

teachers, especially by giving science teachers the “tools” to make links between science discipline knowledge and its real world application.

It is clear that science teachers need a strong content base to effectively meet the demands placed on them to fulfill their complex role that includes different, but closely-related, science knowledge (Magnusson et al., 1999). To do this, science teachers need a sound grounding in the content area of their chosen discipline at an undergraduate level. If their science content knowledge is lacking due to only studying a science major for one year, or due to studying science related fields rather than the physical sciences, intervention in the form of professional development is desirable. Harris et al., (2005), Ainley et al., (2008) and Goodrum et al., (2001) amongst other findings, all see content-rich professional development is a way that this could be addressed for science teachers after they enter the teaching profession.

2.4 PROFESSIONAL DEVELOPMENT FOR SCIENCE EDUCATORS

There is complexity in providing professional development for science teachers to cater for their learning needs and to deepen their expertise in science. Tyler’s (2007) findings indicate that primary and secondary teachers of science have different needs and Bainer and Wright (2000) suggest that learning needs vary greatly between individual teachers no matter what the sector. Therefore, professional development programs need to target specific teacher learning needs while supporting them in the process of their knowledge construction.

Based on research studies, different education systems have taken various approaches to teacher professional development to address current and prospective circumstances in science education. Further, researchers including Hoban (1997), Loucks-Horsley et al., (2003) and Sparks and Hirsh (1997) have outlined best practices for effective professional development programs. Adey (2004) has modelled factors that influence the effectiveness of professional development programs for teachers and he has shown that there are a number of factors or “blocks” involved which include: the nature of innovation, the quality of the PD program, the school senior management and the department or other group. Adey

(2004) also states that these blocks must be set in a positive condition to be effective and to cause a change in student learning. If any one of these blocks is set negatively, there will be little or no effect on the teachers participating in the professional development programs and, therefore, on their students. These research studies have led to different delivery methods that are based on best practice and tailored to the professional development programs' specific focus and aims. This tackles the complex issue of teachers reflecting on their prior content knowledge, further-developing their pedagogical content knowledge and incorporating their new learnings into their own classroom practice.

Over the years, issues associated with professional development have been identified and education systems and professional development providers have attempted to address them. The *Queensland School Reform Longitudinal Study* (Lingard et al, 2001) suggested that professional development for teachers can build teachers' individual capacities which, in turn, builds the school's overall capacity. Professional development programs have also had researchers documenting the focus and aims of these programs, determining whether the providers have achieved their stated objectives and reporting on their findings. Reports have also been written for government bodies and have been used to develop policies and direct funding for professional development programs.

Tytler (2007), stated that professional development for science teachers is required to enable teachers to move from the a simple transmission of scientific knowledge to their students to a pedagogical process that gives students more agency to develop new scientific knowledge's. This could require a change in teachers' set of beliefs about the nature and purposes of science education. Science teachers would need to develop pedagogical skills that would support the move from the rehearsals of well-known scientific knowledge to engaging their students to examine new possibilities and construct scientific knowledge. The professional development required for science teachers to support this concept is far more complex than simple delivery models allow. Rather, a professional development program should encompass both resource development and a significant professional learning approach that allows local control and contextual variation that attends to teacher beliefs and is supported in local areas through networks and consultants (Tytler, 2007).

Such a professional development program was developed in Central Queensland in 1999 to improve science teachers' science content knowledge and teaching strategies to give them the skills they believed they required to implement the new science syllabus. A grant was secured from the Quality Teacher Program that enabled the primary and secondary teachers in the cohort to commit to a professional learning partnership with a local university. Using a consultative process, each teacher designed a content and pedagogical study to identify and meet their individual learning needs and the local university advisor provided intellectual resources together with critical and formative feedback. Because the new syllabus was based on the constructivist approach to teaching science, most of the professional development provided in this program focused on assisting the science teachers to develop their skills around the constructivist approach. The teachers identified a need to successfully implement the constructivist syllabus therefore requiring an increase in their PCK as a component of their professional knowledge. Both individual and collaborative professional development events were produced and the teachers accessed the professional development events that aligned with their stated learning needs.

When sustained, long-term professional development was provided to science teachers, such as in the Quality Teacher Program, it gave them the freedom to choose areas that align with their perceived needs. Consequently, the science teachers gained confidence and used the new content knowledge and pedagogical teaching skills in their teaching practice. Further, if science teachers recognise that the content knowledge is beneficial to them and their students, motivated teachers will choose to learn new science content and pedagogies and, so, address deficiencies in their own skills (Harrison & Nichols, 2002). Available models of science teacher education insist that for professional development to be successful, teachers need to choose the best in-service for their learning needs and the locus of learning control must rest with the teacher (Wallace & Loudon, 2002). When the locus of learning control rested with the teachers in science content-rich professional development that aligned with literacy demands, participating teachers gained a greater understanding of both science and literacy, functioned productively as a member of a learning community and were able to successfully implement both science and literacy into

their science lessons (Nichols & Appleton, 2008). Further, Nichols et al. (2007) demonstrated a positive change in attitude when the teachers attended a content-rich professional development event of their choice. Tunks (1997) also reported that when teachers are treated as professionals and given power to determine their learning experiences, they exhibit a willingness to change their practice.

In 2002, the Department of Education, Science and Training (DEST) commissioned a report called *Beyond the Middle: A report about literacy and numeracy development of target group students in the middle years of schooling* (Luke, 2003). It focused on the current teaching practices of literacy in the middle school. While not specifically about science content knowledge professional development, its findings are still relevant to the issues associated with professional development in science education. The report found that professional development was often piecemeal and unconnected. The case studies that were quoted in the report showed that the programs were offered in response to an immediate need, rather than to an overall strategic approach. However, some case studies did highlight the importance of school, or district, cluster-based professional development networks as being essential for ongoing, connected professional development. A focus on teacher learning which works towards the goal of enhancing student learning outcomes, along with the investigative orientation of many school-based professional learning communities, seems to establish a climate for embedded and sustainable change at the school and classroom level (Luke, 2003).

The DEST Report, *Beyond the Middle: A report about literacy and numeracy development of target group students in the middle years of schooling* (Luke, 2003) influenced a further major research study into literacy and numeracy in the middle years of schooling undertaken by the Australian Government in 2005. This project report was called *Literacy and Numeracy in the Middle Years of Schooling – Queensland Project Report: Meeting in the middle – assessment, pedagogy, learning and educational disadvantage* and it sought to link the research findings on curriculum literacies with insights from the previous DEST Report. It was also guided by contemporary research on:

- the middle phase of learning;
- assessment, literacy and numeracy;
- effective professional learning; and
- educational disadvantage (DEEWR, 2007).

The focus of the project was to increase teachers' knowledge, understanding and professional skill development about best practices in literacy and numeracy assessment, curriculum and teaching instruction in the middle years of schooling so that teachers could respond to the learning needs of disadvantaged students. It supported the development of teachers' professional capacity to assess and teach curriculum literacies and numeracies (DEEWR, 2007) and provided professional development opportunities for the teacher participants in these areas. In particular, professional development was required for teacher learning for a new conceptualisation called "curriculum literacies". This term was introduced to represent the interface between specific curriculum and its literacies (Cumming et al., 1998; Wyatt-Smith & Cumming, 2003) and is defined as:

"...those literate capabilities which students need to have if they are to successfully learn in the learning areas. Curriculum literacies interface with a body of knowledge such as Key Learning Areas or subjects. For example, in Science, students may need to write science reports after undertaking investigations or experiments. This requires using language systems, including specialized text and language structures, vocabulary and graphics, that are specific to constructing knowledge in Science that may not be learnt in other areas of learning." (DEEWR, 2007 p5)

The project provided professional development for the teachers in structured opportunities for professional sharing and learning within clusters across Queensland. In the cluster groupings, the teachers' experience and expertise was valued and shared. The clusters took the initiative to identify deficiencies in their knowledge, especially in curriculum literacies, and called for additional professional development from outside sources. The professional development program was adapted to deliver professional learning programs cater for the local cluster's

identified learning needs. The clusters operated at a local level, but interacted with other clusters via teleconferences and the internet at key points in the life of the project. Teachers also participated in teacher forums that were held at the end of the project.

The findings from the project provided evidence to show that, when teachers consider literacy in assessment tasks, the assessment, pedagogy and curriculum have enhanced alignment. This benefits all students, including students who are disadvantaged (DEEWR, 2007). The professional development model used enabled the teachers to engage in professional conversations about assessment and standards. This enabled them to develop strong understandings about assessment, curricular knowledge and curriculum literacies/numeracies and was valued by all participants. Critical reflection, both personally and collaboratively, was an important aspect of the professional development program. Teachers need time and space out of their busy schedules to enable this to occur.

One cluster, comprised of both primary and secondary science teachers, focused on curriculum literacies in science and taught literacy using science as a host. The participants developed a unit of work and assessment task that aligned literacy with assessment, pedagogy and curriculum. The author was associated with this project and was a teacher participant in one of the clusters, worked with the researchers on the project to collect and analyse the qualitative data, and also co-authored the cluster report that was included as an appendix in the final report (Nichols & Appleton, 2008).

2.5 RESEARCH-BASED PROFESSIONAL DEVELOPMENT GUIDELINES AND HOW THEY RELATE TO THIS RESEARCH STUDY

There are a number of models for professional development that have a strong theoretical basis and impact on the design of professional development programs. The professional development programs specific to the mining and minerals processing industries that were investigated in this research study are fully outlined

in the next chapter (Chapter Three) of this thesis. However, the aspects of the theoretical models used to develop those programs are covered in this chapter.

Hoban (1997) grouped professional development models as “Outside-in”, “Inside-in” and “Inside/Outside”. This information was tabulated to show the details of each model. In the table, examples for each model were matched with their knowledge source, strengths and limitations. As can be seen in Table 2.1, displaying the information about the models in this way enables a clear comparison of these different models.

Table 2.1

Summary of Professional Development Models Showing Examples, Knowledge Source and Strengths and Limitations (Hoban, 1997)

Professional Development Group	Examples	Knowledge Source	Strengths	Limitations
Outside-in Models	1. Training Model	Formal Knowledge	<ol style="list-style-type: none"> 1. New knowledge presented beyond teachers' experience 2. Convenient and economical to organise 	<ol style="list-style-type: none"> 1. Existing practice often not considered 2. Knowledge often decontextual to setting 3. Usually short term with little follow up support
Inside-in Models	<ol style="list-style-type: none"> 1. Individually Guided Model 2. Observation/ Assessment Model 3. Development/ Improvement Model 4. Inquiry Staff Development Model 	<ol style="list-style-type: none"> Personal experience Data from classroom observations 	<ol style="list-style-type: none"> 1. Teachers have responsibility to control workplace learning 2. Long term encouraging teacher reflection to clarify beliefs 3. Teachers understand data they collect 4. Alternative perspective from other colleagues 	<ol style="list-style-type: none"> 1. Teachers interpret data they gather according to the way they frame their existing practice 2. Teachers may view clinical supervision as a form of evaluation 3. Need for 'alternative' perspectives from other school contexts to extend teachers' experiences
Inside/Outside Models	<ol style="list-style-type: none"> 1. Inside/Outside Model for pre-service Teachers 2. Inside/Outside Model for in-service Teachers 	<ol style="list-style-type: none"> Shared experiences/ Formal Knowledge/Teacher research Shared experiences/Formal Knowledge/Teacher research 	<ol style="list-style-type: none"> 1. Long term Encouraging teacher reflection to clarify beliefs 2. Introduces different perspectives as evident from inside and outside of school context 3. Controlled by participants to share ideas as a community possibly leading to a learning organisation 	<ol style="list-style-type: none"> 1. Friction due to different agendas of groups 2. Time and effort to sustain the community 3. Different interests related to varied school and university cultures

When Hoban's table is applied to the professional development programs in this study, they fall mainly into the outside-in category. These programs follow this training model category because they impart formal content knowledge about the mining and mineral processing industries that is beyond the teachers' experience. However, the limitations that Hoban describes in the table were not encountered in the professional development programs undertaken in this study. Rather than using the classical outside-in approach, these programs considered the pedagogical aspects on the science content knowledge about the mining and mineral processing industries and nested them in the existing science curriculum documents that the teachers were currently using. Also, the professional development programs were conducted longitudinally over a number of professional development events and this enabled follow-up to occur with the participants. As a result, the limitations normally found with the outside-in approach were minimised.

The professional development programs in this study also had elements of Hoban's inside/outside models for in-service teachers. The knowledge source came initially from the scientists and researchers working in the mining and mineral processing industries. However, it also came from the shared teachers' pedagogical experiences. Because it introduced different perspectives from the scientists and researchers from outside the school context and blended this with the teachers' perspectives from inside the school, this was considered to be a strength.

The principles for the design of effective professional development (Hawley & Valli, 1999) can also be related to this research study. Following their research and consultation, Hawley and Valli developed a list of research-based principles for the design of effective professional development that focused on the effects of professional development programs on student learning. The nine principles are listed in Table 2.2.

Elements of all the nine principles from Hawley and Valli's list were present in the content-rich professional development programs in this research study. However, principle one, "The content of professional development focuses on what students

are to learn and how to address the different problems students may have in learning the material.” and principle eight “Professional development should provide opportunities to gain an understanding of the theory underlying the knowledge and skills being learned” are closely related.

Table 2.2

Principles for the Design of Effective Professional Development (Hawley & Valli, 1999)

Principles for the Design of Effective Professional Development (Hawley & Valli, 1999)

1. The content of professional development (PD) focuses on what students are to learn and how to address the different problems students may have in learning the material.
 2. Professional development should be based on analyses of the differences between (a) actual student performance and (b) goals and standard for student learning.
 3. Professional development should involve teachers in the identification of what they need to learn and in the development of the learning experiences in which they will be involved.
 4. Professional development should be primarily school-based and built into the day-to-day work of teaching.
 5. Professional development should be organised around collaborative problem solving.
 6. Professional development should be continuous and on-going, involving follow-up support for further learning-including support from sources external to the school that can provide necessary resources and new perspectives.
 7. Professional development should incorporate evaluation of multiple sources of information on (a) outcomes for students and (b) the instruction and other processes that are involved in implementing the lessons learned through professional development.
 8. Professional development should provide opportunities to gain an understanding of the theory underlying the knowledge and skills being learned.
 9. Professional development should be connected to a comprehensive change focused on improving student learning.
-

These were embedded in the professional development programs for this study to help the science educators gain new content knowledge and address how they would take their newfound content knowledge and use it in their classroom practice.

Another researcher who also examined professional development programs for their effectiveness was Loucks-Horsley (1989). Professional development programs for science educators can take many forms, but according to Loucks-Horsley (1989), professional development programs are most effective if they contain the following elements:

- the development of a coherent plan;
- in-depth and long-term programs such as intensive courses or institutes;
- substantial follow-up as teachers return to the classroom;
- a critical mass of teachers and/or administrators to build internal support structures; and
- the use of teachers in training and support roles.

These elements enable teachers to take new content knowledge from the professional development program and identify ways to translate their learnings into the classroom. In turn, this helps teachers to improve their teaching practices (Loucks-Horsley, 1989).

Consequently, these elements were important to this research study. The professional development programs were content-rich and the stated aims were to encourage the science educators who attended to embed examples from the mining and mineral processing industries as they taught the associated science content knowledge. So, even though the professional development programs are intended to change the science educators' content knowledge of the mining and mineral processing industries, from Loucks-Horsley's research, a change in other areas of teaching practice could also occur.

Loucks-Horsley initially developed a design framework for professional development in science and mathematics. However, this earlier design was

rethought after further analysis and it was modified (Loucks-Horsley et al., 2003). The modification of the genetic framework addressed the complexity of designing professional development for science educators and accommodated their individual learning needs. The framework incorporates a planning sequence that shows a horizontal connection between the elements “commit to vision and standards”, “analyse student learning and other data”, “set goals”, “do” and “evaluate”.

This is an analogue for the classic perpetual “Plan-Do-Check-Act” (PDCA) model used in quality systems management (Deming, 1986). Therefore, Loucks-Horsley’s model is virtually a continuous quality improvement system for professional development programs. An example of how the PDCA technique was applied at a school level is given on the ASQ’s (American Society for Quality) website (Tague, 2004). The importance in this model is its continuous nature, which is a valued aspect in professional development for science educators.

However, in education systems, professional development programs are quite often discontinuous. This lack of continuity is related to several factors:

- the source (whether from industry or government) and amount of available funding for programs;
- how well-marketed and well-organised the programs are and, therefore, how attractive they are to educators;
- the availability of quality instructors (i.e., educators with the required level of expertise and experience in their field of study);
- the enthusiasm of the participants;
- the availability of the participants and whether or not the time is made available during work or them to attend; and
- the existence of a champion for the program in, or close to, the workplace.

It has been argued that industry should pay for the courses that influence and meet industry-related needs. Because of their perceived capacity to generate wealth, this is especially the case in the mining and minerals processing industries. Industry, in turn, argues that because they pay their royalties and taxes, they should not be expected to fund education legislated by government. In any case, as discussed

previously in this chapter, the mining and minerals processing industries are cyclic in nature and, subsequently, the funding available from these industries for any professional development events follows this trend. These issues have a flow-on effect to the continuity of funding available for professional development.

Funding via the public treasury tends to be more continuous, but it can fluctuate too. While this fluctuation can be related to economic cycles, it is related more to intangible effects such as policy and perceived needs at the time.

If professional development programs are not ongoing, they will be far less effective in ensuring that teachers maintain their interest, enthusiasm and currency. Like the life-cycle of a star, programs tend to follow a pattern of ignition, waxing, waning and extinction, only to be reborn again later in the same, or a different, form. This can be related to the funding available, perceived or actual value that the program offers, changing levels of enthusiasm, loss of a champion, or other effects.

Following a continuous improvement process, such as the Loucks-Horsley model, can help to minimise the cyclicity in provision of professional development programs. Also, it can help to justify the provision of funding and maintain the perception of necessity of professional development programs. Once a professional development program becomes recognised as being important for or, better still as essential to, the development of teachers by both teachers themselves and educators at the management level (e.g., principals, policy developers, etc.), it becomes easier to maintain.

A good example of this is the sustained mining and minerals processing program run by the Colorado School of Mines (2007) in the USA. This program is run at regular intervals and targets an audience that ranges from primary to tertiary educators. It is highly respected in education circles within the USA and enjoys a sustained high participation rate.

In this research study, data were collected from a teacher cohort that participated in this Colorado School of Mines professional development program and this program is still being run continuously. However, as soon as the other programs from which

data were collected in this research study achieved their objectives, funding was not renewed and they were discontinued.

The complexity of the process is shown in the model by including the inputs into the design process that can influence and inform the design of the professional development and show what the designers of the professional development need to consider. These include “knowledge and beliefs”, “context”, “strategies”, “critical issues” and “strategies (Loucks-Horsley et al, 2003). The model of a design framework for professional development showing the knowledge and beliefs supporting effective professional development is shown in Figure 2.1.

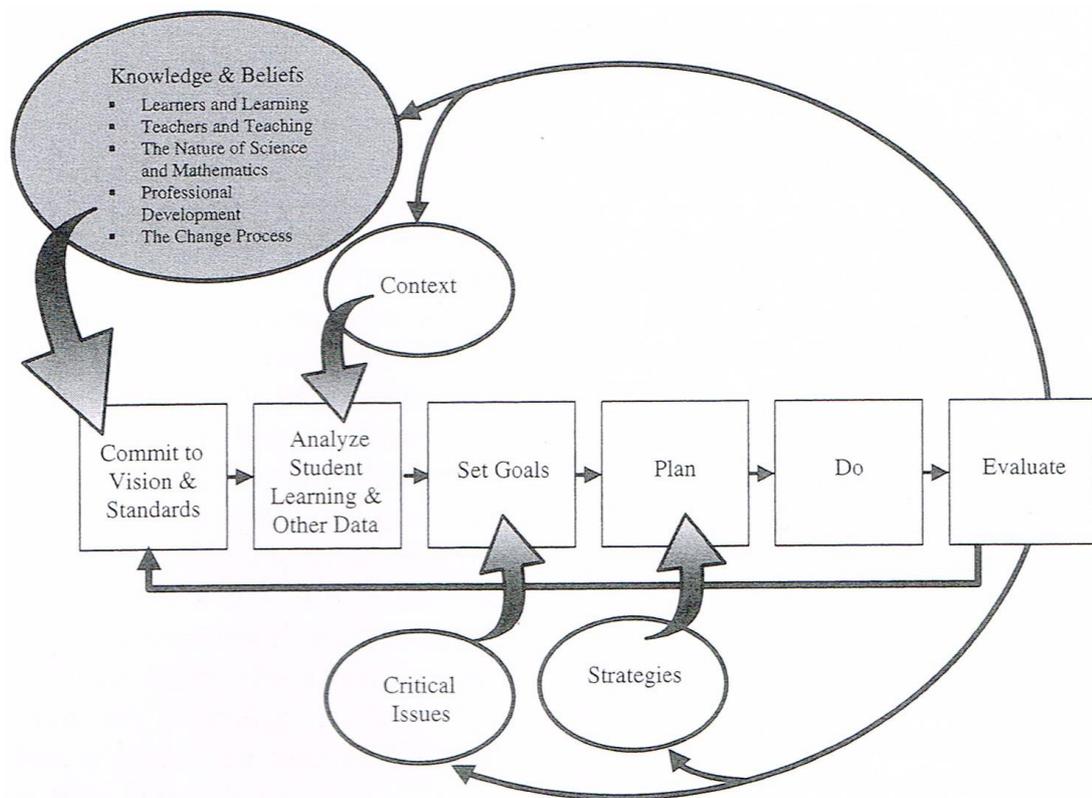


Figure 2.1

Knowledge and beliefs supporting effective professional development (Loucks-Hawley et al., 2003).

The professional development programs in this research study were designed and implemented by three different professional development providers and it is clear that elements of the Loucks-Horsley design framework have been used in their design. In particular, as the professional development programs were content-rich

about the mining and mineral processing industries, the knowledge and beliefs of the teachers who were the participants in these programs were the inputs to be considered in the commitment to vision and standards and the initial stage of the design. So, even though the participants in the professional development programs may have had varied levels of content knowledge of the mining and mineral processing industries, they would have had a knowledge-base on how their students learn science. What the science educators already know will influence their own learning and, like their students, they will construct new knowledge themselves (Loucks-Horsley, 2003).

This research project focused on the professional development programs about the content knowledge associated with the mining and mineral processing industries and linked this content knowledge through professional development programs. However, among other models of professional development, it contained aspects of Hoban's models, Hawley and Valli's principles of effective professional development and Loucks-Horsley's design framework for professional development. One of the professional development programs in this research study took the presentation of the content-rich professional development program further. Rather than just linking authentic examples of the mining and mineral processing industries with hands-on activities and interaction with scientists, it included supported writing opportunities for the participants. This final step moved the locus of control to the teachers and, in doing so, it incorporated Hoban's inside-in model into the professional development design. It also incorporated other elements of Hawley and Valli's principles of design for effective professional development and made a stronger link between Loucks-Horsley's "Knowledge and Beliefs" to "Commit to Vision and Standards".

2.6 THE CYCLIC NATURE OF THE MINING AND MINERAL PROCESSING INDUSTRY AND ITS IMPACT ON EDUCATION AND CAREERS

Australia operates within a cyclic global economy (Bartholomeusz, 2012). The mining and mineral processing industries are exposed to global market influences

and, consequently, they are cyclic in nature. In the past decade, Australia has experienced a resource boom and the mining and mineral processing industries have expanded at an increasing rate. Even though China's demand for Australian resources has slowed somewhat recently, this demand is expected to continue into the future, though at a slower pace. The combined size of the populations in China and other Asian countries is huge and the number of individuals in those countries aspiring to a better material standard of living and move out of poverty has fueled the demand for resources (Ericsson, 2012).

The demand for Australian resources has also lead to a demand for qualified people to fill the expanding number of career positions in the mining and mineral processing industries. Simultaneously, the supply of young university science graduates gaining academic credentials in science, technology, engineering and mathematics that is required to maintain a qualified workforce, continues to dwindle within Australia and this trend is expected to continue to into the foreseeable future. This problem has been well documented, but no easy solution has become apparent (Bartier, et al, 2003; Churach & Nichols, 2007; Nicol & Woffenden, 2002).

To compound the issue at the university level, fewer students are choosing to study physics, chemistry and biology at the secondary level. This decline has implications for the number of future scientists in Australia (Lyons & Quinn, 2010). A science background, particularly in the physical sciences, is an essential prerequisite if a secondary student is considering a science-related career. This has a direct impact on the number of people available to choose careers in the mining and mineral processing industries.

The decline in students studying science has been one of the many challenges that science teachers face as they negotiate the increasing complexity of their role (Rodrigues, 2004). Governments around Australia acknowledge that there is a need to address the decline in students choosing to study science leading to the shortage of qualified people available to work in the expanding science-based industries. To address these issues, governments have made commitments to ensure students have access to high-quality science education. One such initiative was made by the Queensland Government in the *Spotlight on Science* program that produced a set of

directions and principles for the future action of science education. The vision for Spotlight on Science (2003) stated:

Science education at all levels has a key role in meeting the challenges and opportunities presented by the technological and knowledge era. We need to strongly support science educators to produce a scientifically literate society and the researchers, innovators, entrepreneurs and educators of the future. (p 1).

The Spotlight on Science (2003) initiative developed a six-step plan to:

- improve the scientific literacy of Queenslanders;
- encourage more young people to aspire to careers in science; and
- improve the overall quality of science education in Queensland. (Science State – Smart State, 2003).

While all of the Spotlight on Science (2003) six-step action plan relate to this research study, three of the six-steps are particularly relevant: Step 2 – Inspiring Science, Step 3 – Connecting Science and Step 5 Partners in Science. A dot point explanation from the Spotlight on Science (2003) document about how the steps were intended to be actioned is listed below:

Step 2 – Inspiring Science

- a workforce of enthusiastic and competent teachers who provide exiting and relevant science experiences for students; and
- all teachers engaging in continuous professional development and updating their knowledge and skills in science education.

Step 3 – Connecting Science

- science will be taught as a continuing process of practical inquiry into real-world issues and problems; and
- more opportunities for teachers and students to engage in experiences beyond the classroom

Step 5 – Partners in Science

- more productive science partnerships between industry, business, government, research and educational institutions; and
- increased investment in Queensland science education (Spotlight on Science, 2003).

The Spotlight on Science (2003) intended actions align with the aims of the professional development programs that were investigated in this research study. The three professional development programs in this study were funded by government and industry and they exposed the science educators to complex, “real world” problems (and their solutions) in both industry and research institutions. This, in turn, afforded the science educators an opportunity to provide their students with a realistic view of the mining and mineral processing industries.

Further, as time progresses, it is expected that there will be continuing major advances in science and technology, especially in the mining and mineral processing industries. Consequently, science teachers will need to keep their knowledge up-to-date to enable them to teach scientific concepts to their students that are based upon the latest industry examples. Interestingly, in the *Australian Council of Dean of Science Report* (Harris, 2005), 5% of respondents suggested that more teachers would be attracted to the teaching profession if links to science research and industry could be maintained. These links could prevent teachers’ scientific knowledge and expertise from becoming stale. Also, in the *Australian Council for Educational Research Report* (Ainley, 2008), it was noted that there is a sense that school science is not sufficiently connected to recent developments in science. Professional development that links the applied science conducted in industry with the science taught in science classrooms could help to establish and maintain this connection.

Relevance is important for students studying science, it needs to link to their lives, their interests and their aspirations (Tytler et al, 2008). Science that is taught by making these links increases the relevance for teachers and their students and makes the learning experience authentic (Matters, 2006). Teachers need to be able to confidently teach applied science and relate its links to industry. However, teachers cannot engage their students if they do not have the correct industry knowledge

themselves. Science teachers who have the opportunity to attend “real world” professional development events, including industrial laboratory work and field trips that are aimed at increasing their knowledge of industry practices, will also build their confidence in teaching science.

The concept of teaching authentic industry applications in their science classes may be new to some teachers and this may mean that they could require specific content knowledge and access to information about industry practices. Teachers may feel the need to make industry visits and establish links with scientists to gain content knowledge to confidently teach it. They may not be aware of the opportunities available to them and may not have the time to find out. To enable teachers to affect students’ perceptions about industry, teachers need to be exposed to a variety of hands-on experiences and industry visits. Because science teachers have the opportunity to attend “real world” professional development events (including industrial laboratory work and field trips) aimed at increasing their knowledge of industry practices, this will allow teachers to build their confidence (Nichols, et al, 2009).

2.7 CURRICULUM DOCUMENTS AND THEIR LINKS TO AUTHENTIC SCIENCE AND INDUSTRY

Historically, the junior science curriculum documents in all Australian states have embedded statements in them to ensure that science teachers provide opportunities for their students to demonstrate their learning, with an emphasis on “Working Scientifically”. In Queensland, in the Years 1 to 10 Science Syllabus (1999) and the Essential Learnings (2007), the intention is for students (supported by their science teachers) to develop their ability to work scientifically in the way that scientists work, i.e. by investigating, understanding and communicating in real life contexts. This construct has continued in the Australian Curriculum documents that have superseded all the previous state curriculum documents and it has already been implemented in junior science in all states in Australia.

The Australian Curriculum documents provide a vehicle for teachers to include examples of industry practices, along with the associated science, into their curriculum. The science strands of *Science Understanding*, *Science as a Human Endeavour* and *Science Inquiry Skills* all provide a platform for teachers to include authentic learning experiences. The emphasis to provide these opportunities for students are embedded into the curriculum document and this is emphasised in the Australian Curriculum support statements like the Years 7-10 Curriculum Focus: explaining phenomena involving science and its applications. It states:

During these years, students continue to develop their understanding of important science concepts across the major science disciplines. It is important to include contemporary contexts in which a richer understanding of science can be enhanced. Current science research, and its human application, motivates and engages students. (ACARA, 2010).

The senior syllabuses in all Australian states are, at the time of writing, administered by State Boards and each state has a separate syllabus. These syllabuses provide opportunities for senior science teachers to use authentic contemporary contexts in their teaching. There are some senior science subjects that lend themselves to embedding examples from the mining and mineral processing industries and linking them to the associated science content knowledge. As well, there are opportunities in the existing Physics, Chemistry and Earth Science syllabuses for this to occur and, when the new Australian Curriculum senior science subjects come on line, this opportunity will continue.

2.8 SCIENCE TEACHERS' INFLUENCE ON THEIR STUDENTS

Churach and Fisher (2001) found that the use of the internet as a tool to provide authentic learning experiences not only had a positive effect on the classroom environment, but it enhanced the constructivist nature of the science classroom as well. Further, the role of the teacher was instrumental in keeping the students on task and influenced the students' progress in their learning and assessment tasks. In addition, learning environments impact on student behaviour and achievement in

school settings (Fraser & Walberg, 1991). If science teachers strive to develop supportive relationships with their students, they enhance their students' learning. By providing supportive learning environments and authentic learning experiences based on real-life science examples, science teachers can motivate and engage their students.

Teachers are often unaware of the influence that they have on their students. In their study about why students choose science, Lyons and Quinn (2010) found that around 80% of Year 10 students rate their most recent experiences in science classes as the biggest influence in choosing to study science in their senior years. Teachers can also influence their students about career choices in science-related careers. Because of this, Lyons & Quinn (2010) recommended that science teachers should be made aware of the strong influences that they have on their students' decisions about choosing science as they are influenced by their teachers' attitude and advice. When scientists themselves were surveyed about the reasons that they chose to study science, among the reasons that were reported, school science lessons and particular science teachers were stated as important factors (Venville et al., 2013).

Churach & Nichols (2007) also found that teachers are well positioned to positively influence their students' attitudes towards science and encourage them to consider careers in science and science-related industry. Over a period of time, it would seem natural for teachers to gradually integrate their newfound knowledge into the curriculum and to have positive impacts on their students' perceptions of the mining and mineral processing industries. In 1995, a Canadian project in Alberta indicated that there were increased positive outcomes when career options became infused into the curriculum, rather than these being taught as separate items. It recommended that professional development should be provided for teachers to accommodate this approach (Millar, 1995).

The Australian Cooperative Research Centre for Sustainable Resource Processing (CSRCP) conducted research into the mining and mineral processing industries and viewed the 'people shortage' as a particular concern. CSRCP wanted to raise community awareness of the mining and mineral processing industries. Operating under the assumption that there can be no research without researchers (or no

employer without employees), CSRP sought a method to involve the minerals processing and energy industry with the community at large and looked for the most effective method to reach the community. In particular, for young people who may be interested in the mining and mineral processing industries as a career choice, CSRP was looking for a method to deliver correct and up-to-date information in an efficient and cost effective manner.

To find out where young people receive their information from and whom they turn to when they are looking for information, CSRP believed that the answer could be found in the *Western Australian Government's Youth Survey* (2003). In this study, 7,919 young people aged 12-25 years, across all socio-economic backgrounds and educational circumstances, were surveyed. The study showed that teachers are held in high regard and that they definitely have influence over their students' lives. Teachers are well positioned to positively influence their students' attitudes towards science and to encourage them to consider careers in science and industry (Churach, 2005).

In a sense, these findings support the well-believed notion that "the best sales method is word of mouth". Why does word of mouth carry such weight? Simply put, most people place a stronger value of influence on input from those whom they know best and with whom they have a longstanding relationship. Parents and friends rank one and two as the most influential on opinions held by young people (Coleman & Coleman, 2003). In the same sense, the high ranking of teachers as opinion-influencers is understandable. For the most part, young people spend their "working days" in the company of teachers and, in many cases, they interact with some teachers for more hours per week than they would normally interact with a parent.

It transpires then, that the primary target audience to be reached is parents and friends. However, in terms of numbers, this presents a problem. For example, there is little leverage to be gained in attempting to reach 20,000 parents in order to influence 30,000 children (a ratio of 1:1.5). A much more economical alternative is through the teacher-student relationship where each teacher could have influence over up to 25 students in each of their classes (a ratio of 1:25). This teacher-to-student exposure ratio is nearly 17 times greater than the parent-to-child ratio.

Churach and Rickards (2003) studied the teacher-student relationship and how the teacher influence goes beyond the classroom. In their study, they investigated the motivational factors that affect career choice in the mining and mineral resource industry sector and devised a questionnaire (Feedback Survey) that explores career drivers. Though the questionnaire features 36 questions divided into six scales (financial, academic, relationship, lifestyle, altruistic and personal esteem), it also includes several open-ended questions concerning influences of teachers on career decisions. At the time that this pilot study was conducted, 82% of respondents were working in the mining and metallurgical industries while the remaining 18% were tertiary students of either metallurgy, chemical engineering or mining engineering.

The study also found that 46% of all respondents took additional time to volunteer the positive effect that one or more of their teachers had on their career choice. Their responses included statements like: “My high school science teacher always encouraged me and challenged me to ask why...”). 16% of those in this sample spoke of teachers having a negative effect (e.g., “I wanted to prove that I could do it even though my high school chemistry teacher said I never could.”). These data seem to indicate that, for these people working within the mineral and energy sector, science teachers had influence over the decisions they made (whether positive or negative).

Over a number of years, the Centre for Sustainable Resources Processing and Murdoch University (Western Australia) collaborated with a range of industries to offer an array of educational activities for secondary science teachers, initially in Western Australia and more recently in Queensland. The project placed the emphasis on the on-going nature of the program and was based on the idea that, in order to have long term effects on student perception of the industry, participating teachers need to undergo a variety of experiences involved with resource processing. Ideally, teachers were expected to gain the greatest benefit from being exposed to a variety of both academic experiences (e.g., hands-on laboratory work and lecture-type offerings) and industrial experiences (e.g., plant and mine tours and work experiences) over a period of time. This was to allow the teachers involved to

develop relationships with scientists and industrialists to a point where they felt comfortable to ask questions and share experiences (Churach, 2004b).

2.9 SCIENCE TEACHERS AND SCIENTISTS IN PROFESSIONAL RELATIONSHIPS

Science teachers provide the science content knowledge, but they also have a role in translating science practice in their classrooms (Hofstein & Lunetta, 2004). They replicate the scientific processes in their classrooms in the same way that scientists do, but the teachers' role is that of an educator, rather than a scientist. While scientists generate new scientific knowledge, science educators generate learning about science (Wong & Hodson, 2009). In fact, the school science laboratory is a unique classroom environment that can be used to enhance the teaching and learning of science (Hofstein, 2006). However, the school science laboratory is a very different environment to the one that industrial scientists work in and the science teachers' practice is very different to industrial scientists' practice. In the school science laboratory environment, science teachers can improve their students' science content knowledge by engaging them in authentic learning experiences and practical investigations based on the work that scientists do (Hobson, 1993).

In order for science educators to have access to the work that scientists do and to the data that they collect in their research, programs have been set up to enable science educators to interact with scientists who work in all fields of science. Proposals have been made about the benefits for science teachers to work with scientists who work in industry or research laboratories and form professional relationships with them (Spotlight on Science, 2003). Programs that enable interaction between science teachers and "real world" scientists have taken various forms, ranging from the mentoring of teachers by scientists (Hughes et al., 2012) to teachers working one-on-one with a scientist in the science classroom as is practiced in the Scientists in Schools Project (Rennie, 2012). Whatever their form, these initiatives were intended to bring science teachers and scientists into contact with each other for the benefit of science students.

The role for scientists proposed in this research study was different to the mentoring and in-class interaction previously described. In this research project, the scientists working in the mining and mineral processing industries were viewed as a resource for content and were made available for the teachers to contact when they wished to check their own content knowledge and their knowledge of its application in the mining and mineral processing industries. The science educators in the QCAT/Education Queensland cohort initially interacted with the CSIRO scientists as part of the workshop presentations, but this role expanded to the CSIRO scientists becoming content knowledge advisors to the science teachers as they wrote the unit of work and the teaching resource. The science teachers produced drafts of their work and the CSIRO scientists offered advice and further examples about the mining and mineral processing industries, thereby ensuring that the content in the teachers' documents was correct. As the teachers gained knowledge of the mining and mineral processing industries and embedded the authentic content knowledge into their teaching documents and teaching resource, they grew to know the scientists and formed professional relationships with them.

It then follows that, in order to have long term effects on student perception of the industry, participating teachers need to undergo a variety of experiences involved with the mining and mineral processing industries. Teachers were expected to gain benefit from being exposed to a variety of academic and industrial experiences over a period of time. It was intended to have the teachers develop relationships with scientists to a point where they felt comfortable in asking questions and sharing experiences (Churach, 2004b).

2.10 CONCLUSION

Professional development is seen as an important component of teachers' professional practice and the Australian Teacher Performance and Development Framework (2012) supports teacher professional learning. The changes in the science curriculum and the associated pedagogical practices required to enact the implementation of the Australian Curriculum require teachers to engage in continuous professional development. Science teachers enter the teaching profession from varying backgrounds, varying strengths in science and varying levels of

undergraduate study in science and this is a challenge that needs to be overcome. Effective professional development programs need to cater for the science teachers learning needs.

The specific items to note from the literature reviewed in this chapter are:

- 1) teachers can definitely influence the career choices that their students make and there is significant career-choice capital to be gained by investing in teachers through the provision of professional development opportunities in science-related fields (in this case, mining and minerals processing);
- 2) there is more to be gained by capitalising on the teacher-student ratio to ensure that the maximum target audience is reached for influencing students in their career choices (especially with respect to the mining and minerals processing industries);
- 3) there is a need to ensure that professional development programs are continuous and continuously improved; and
- 4) science teachers' knowledge becomes stale if they do not keep up-to-date with progress in real world science.

The chapters following this one will build on the previous work done by others that is outlined in this literature review. This previous work was valuable and provided a good foundation for the work completed in this research study. However, it is clear that there is a gap in the research, specifically about content-rich professional development for science teachers who are teaching about the mining and mineral processing industries. Further, the mixed method used to collect primary data enabled deep understanding to be drawn from the process. Therefore, the research conducted for this thesis is unique and original and will make a contribution to the body of knowledge in science education research. The next chapter outlines the methodology used in this research study.

CHAPTER THREE

METHODOLOGY

3.1 INTRODUCTION

This chapter details the methodology of the research project. The data were collected via a strategic mix of quantitative and qualitative methods applied in a flexible manner to ensure explicit meaning could be drawn from the data sets. Quantitative data were collected first via Churach's (2005) "Feedback Survey", then an additional "Clarification Tool" was designed and used to collect the qualitative data required to maximise meaning from both data types. Together, these tools produced a dataset. This chapter will outline the reasons why this mixed-method approach to data collection was taken and the clarity it gave to that data.

This chapter also describes in detail, the professional development events that the science educators attended, and the aims and methods used in presenting the professional development events are also described. The number of science educators attending each professional development event are tabulated and described. Finally, a description of the processes that the science educators used in writing the teaching resource after they had been exposed to the initial professional development events has been documented.

3.2 OUTLINE OF THE METHODOLOGY OF THE STUDY

The research method for this study was designed to identify if there was an increase in teachers' content knowledge after participating in professional development programs and then to determine how the teachers applied that content knowledge by linking the content from the professional development events to their existing curriculum documents. Teachers' views about the mining and mineral processing industries were also investigated; and finally, the research project was evaluated in terms of its efficacy in establishing professional learning partnerships between the teachers and scientists.

In this study, the science educators participated in content-rich professional development events about the applied science related to the mining and mineral processing industries. The professional development events were administered by different profession organisations involved in the mining and mineral processing industries. Often, in the professional development programs, the presentations and workshops were conducted by the actual scientists who work in the mining and mineral processing industries. This enabled the science educators and the scientists to interact at a professional level. Even though each professional development program was different in its approach, length of time and delivery method, the aims of all the professional development programs were similar.

The data were collected over a six-year period and were derived from the science educators who attended these professional development programs. Initially, the science educators completed only the quantitative data collection tool (Feedback Survey) after the professional development event. However, as the study progressed more data were collected to further elicit information and to contextualise the original data that had been collected. These additional data were required to determine the reasons for the initial answers that were given on the Feedback Survey. By using this method, an added element of flexibility was afforded to the project and it also allowed the researcher to delve deeper into the reasons why the participants gave the answers they did to the questions in the survey.

A number of qualitative data collection methods were devised (including follow-up questions, interviews and documentation) and were used to distill further meaning from the data in the Feedback Survey. The data collection process developed into a complementary mixture of using both quantitative and qualitative methods. By using a mixture of quantitative and qualitative data collection methods, the researcher has an advantage over using only quantitative or only qualitative methods by themselves as it enables richer meaning to be drawn from the data. Fraser and Tobin (1991) used both quantitative and qualitative data collection methods in classroom environment research and they were able to show that a mix of data collection mechanisms contributed to their ability to draw meaning from the data that they had collected for their research. Similarly, the research performed in this thesis study benefited from using a mix of data collection methods.

3.3 A MIXED METHOD DESIGN

The research design for this study used a mixed method approach where data collecting, analysis and “mixing” both quantitative and qualitative data contributed to understanding the aims and objectives of the study. Brewer and Hunter (1989) identified “mixing” both quantitative and qualitative data in a single study as a legitimate research approach. Moreover, a mixed method research approach can have a number of different designs. Creswell (2005) explains these methods as “Triangulation Design”, Explanatory Design” and Exploratory Design”. These categories are based on the priority or weight the researcher gives to the quantitative and qualitative data collection, the sequence of collecting the quantitative and qualitative data and the actual analysis of the collected data. The data analysis method used in this research study aligns closest to the “Explanatory Design” mixed methods design.

While traditional “Explanatory Design” places priority on the quantitative data collection and analysis, both the quantitative and qualitative data in this research study were considered to be of equal value, even though the Feedback Survey was completed first and was the largest data set. The qualitative data, being the follow-up questions and the interviews, followed as the second phase of the research study. These qualitative data were used to refine and make sense of the data collected in the Feedback Survey. It enabled the data to be clarified and probed in more detail to elicit the reasons why the science educators responded to the statement sets in the Feedback Survey in the manner in which they did. Figure 3.1 presents a summary of how data for this research study were collected using a mix of both quantitative and qualitative data collection methods.

The Attitude Inventory Process

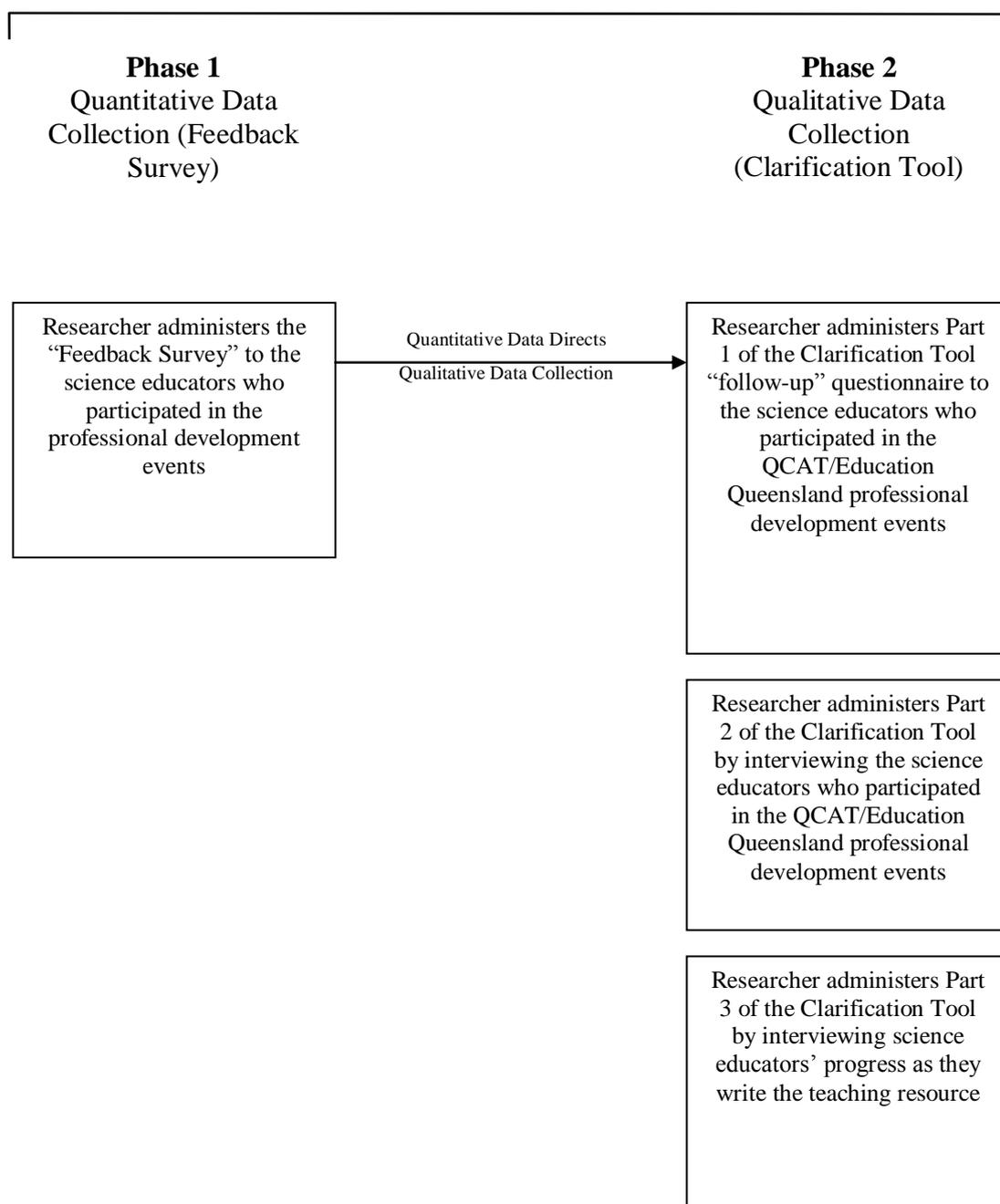


Figure 3.1

Flow chart outlining the methodology for the research study

3.4 HOW THE RESEARCH METHOD ENABLED THE RESEARCH QUESTIONS TO BE ANSWERED

The Feedback Survey enabled the initial data to be collected. Once collected, these data were then tabulated and graphed. The graphical representation of the data made

areas of interest easy to pinpoint and allowed the qualitative data collection Clarification Tool to be developed for drilling down into the initial data in increasing detail. This process enabled the study to move from a quantitative data collection tool to a Clarification Tool that included a number of qualitative data collection instruments consisting of follow-up questions and interviews. The Clarification Tool identifies the salient areas that can be probed further by the researcher to determine why the participants answered they way they did. In this regard, the Feedback Survey can become a valuable and useful mechanism that enables precise quantitative data to be collected and used to inform the direction of the study. The full suite of quantitative and qualitative tools used in the entire process are what the researcher has termed the Attitude Inventory process and the resulting data set is what forms the Attitude Inventory itself.

The mixed method design approach enables measurement of science educators reporting an increase in their knowledge of the mining and mineral processing industries. The tabulation and graphing of the quantitative data and the science educators' quotes derived from the qualitative data collection methods enables assumptions to be drawn about targeted professional development programs about the mining and mineral processing industries. It is assumed that science educators' knowledge of the mining and mineral processing industries can be increased through targeted professional development and this assumption can be tested using the mixed method design approach taken in this study.

This mixed method design approach also provides a vehicle for documentation and data collection from the science teachers who wrote the unit of work and the teaching resource about the mining and mineral processing industries called "Energy Today and Tomorrow: Learning about coal and clean coal technologies". Data collected from this process enabled assumptions to be drawn about science educators' ability to apply their knowledge of the mining and mineral processing industries to the science curriculum.

While science educators' views of the mining and mineral processing industries can vary greatly, a suite of data collection tools is valuable when determining their views about the mining and mineral processing industries. It is even better if a data

collection tool enables a change to be identified. The mixed method design approach also enables quantitative data to be collected to determine why a science educator has reported a change. Not only does the Attitude Inventory process enable a reported change to be identified, it also enables the data to be tabulated and graphed, and then interpreted in much greater detail.

Data collection about ongoing professional interaction between the science educators and the scientists working in the mining and mineral processing industries can also be derived using the mixed method design approach. Specific follow-up questions were also given to the science educators who worked on the unit of work and the teaching resource. Data from both these sources formed the Attitude Inventory and the ensuing results enabled assumptions to be made in this study about science educators forming professional networks with scientists working in the mining and mineral processing industries. Questions about this topic appear on the Feedback Survey enabling science educators to report their attitude before and after the professional development event.

3.5 PROFESSIONAL DEVELOPMENT EVENTS, THE NUMBER OF PARTICIPANTS AND THE DATA TYPE COLLECTED

This study collected quantitative and qualitative data from science educators who attended professional development programs conducted by the following organisations:

- Centre for Sustainable Resources Processing (CSRP) and Murdoch University,
- Colorado Mining Association Education Foundation and Colorado School of Mines Office of Special Programs and Continuing Education, and
- Queensland Centre for Advanced Technologies (QCAT) and Education Queensland.

Table 3.1 below shows the numbers of science educators who attended a professional development program conducted by one of the organisations and completed the

Feedback Survey. The data sourced from the Feedback Survey forms the quantitative component of this research study.

Table 3.1

Professional Development Events and the Number of Science Educators who Participated and Completed the Feedback Survey, Follow-up Questions and Interviews

Years that the Professional Development Events were Conducted	Professional Development Programs	Number of science educators who completed the Feedback Survey	Number of science educators who completed the “follow-up” questions	Number of science educators who were interviewed	Number of science educators who wrote the teaching resource
2003-2006	CSRP and Murdoch University	64			
2007	Colorado Mining Association Education Foundation and Colorado School of Mines Office of Special Programs & Continuing Education	22			
2008-2009	QCAT and Education Queensland	25	25	10	4
	Total number of participants in the research study	111			

The total number of participants in the research study was 111. All participants completed a Feedback Survey while 25 of those participants completed Clarification Tool “Follow-up” questions. Additionally, using the Clarification Tool, ten were interviewed and four were interviewed as they wrote their teaching resource. This

gave the research project a mixed-method approach and enabled the researcher to drill down into the dataset produced from the Feedback Survey.

3.6 DESCRIPTION OF THE PROFESSIONAL DEVELOPMENT EVENTS

The science educators that provided data for this study participated in one of the three different professional development programs. Even though the professional development programs were different in their delivery and approach, their aim was the same, i.e. to increase teachers' knowledge of the mining and mineral processing industries so that they could use this content knowledge in their science classroom and provide their students with authentic applied science examples. In their principles for the design of effective professional development, Hawley and Valli (1999) identify that the content of professional development focuses on what students are to learn and how to address the different problems students have in learning the material as their first principle. This principle also forms the basis of each professional development event in this study.

Further, each professional development program was open to science educators who had identified a gap in their content knowledge about the mining and mineral processing industries. They wanted to use authentic applied science examples from the mining and mineral processing industries in their teaching and were looking for ways to do this. Teachers self-nominated to join the professional development programs and their attendance at the professional development events within the professional development program was voluntary (APPENDIX A – Permission Letter).

The following section describes each of the professional development programs that the science educators attended.

3.6.1 Description of the Professional Development Events Delivered by the Centre for Sustainable Resource Processing and Murdoch University

The CSRP developed industry-sponsored professional development programs that provided real-world examples of science and its applications. Science teachers then participated in professional development events provided by the CSRP in partnership with Murdoch University (Western Australia).

The CSRP and Murdoch University collaborated with a number of different mining and mineral processing industries to offer an array of educational activities for secondary science teachers, initially in Western Australia and subsequently in Queensland and Victoria. The professional development program was designed to allow participants to access a number of professional development events over a period of time. This was to enable them gain a variety of experiences including academic experiences such as, hands-on laboratory and lecture-style sessions, and industrial experiences such as plant and mine tours and work experience. The on-going nature of the program was emphasised and the science teachers were encouraged to attend multiple professional development events. The aim was to enable the science teachers to develop professional relationships with scientists and industrialists involved in delivering the program to a point where they felt comfortable in asking questions and sharing experiences about the mining and mineral processing industries (Nichols, 2009).

The professional development events that comprised the program included:

- short courses and workshops entitled - “The chemistry and physics of extractive metallurgy”, “Advanced extractive metallurgy”, “On-line interactive learning: Providing a minerals industry context for secondary learning”, “Geology and mineralogy in the resource sector”;
- research facility and industry tours including: atomic force microscopy, CSIRO Minerals Research Centre tour, gold mine tour, bauxite mine tour, alumina processing tour;
- a variety of resource processing public lectures; and

- mini sessions for science teachers focusing on the mining and mineral processing industries.

The number of teachers participating in the professional development events varied depending on the activity and some teachers participated in more than one event. In some cases, individual teachers took part in five or more events. Teachers were encouraged to remain in touch via e-mail, both with other participating teachers and with the scientists conducting the event.

Several of the teachers who participated in the professional development events delivered by the CSRP were surveyed using the full suite of tools in the Attitude Inventory process.

3.6.2 Description of the Professional Development Events Delivered by the Colorado Mining Association Education Foundation and the Colorado School of Mines Office of Special Programs and Continuing Education

Every year, the Colorado Mining Association Education and the Colorado School of Mines Office of Special Programs and Continuing Education run a professional development program for K-12 science teachers. This long-standing professional development program was developed in response to a recognised need to give science educators a good understanding of the importance of metals, industrial minerals, aggregates and energy industries. Entitled “All About Mining – A Total Concept of the Mining Industry,” the professional development program is an intensive four-week summer training course that provides a comprehensive overview of all phases of the mining and mineral processing industries. Topics such as geology, geophysics, exploration, mining methods, metallurgical operations, metal applications, research, marketing, careers, economics, recycling and environment are covered. Scientists and industry experts deliver the content of the course via lectures and field trips (<http://www.allaboutmining.org/>). The field trips are considered integral to the course and they include mine and site visits, museum workshops and laboratory fieldwork.

The providers of the professional development program (the Colorado Mining Association Education Foundation and the Colorado School of Mines Office of Special Programs and Continuing Education) identified possible ways that the guiding principles for the professional development program could be achieved. The aim for the professional development program was to expand the science educators' knowledge about the mining and mineral processing industries so that they could use this content knowledge in their science classroom and provide their students with authentic applied science examples from the content covered in the professional development program. The guiding principles that were used to develop the professional development program were:

- accessing up-to-date information about America's mining and mineral processing industries;
- identifying ways that the mining and mineral processing industries approach environmental issues and rehabilitation;
- interacting with scientists and industry experts leading to the science educators forming professional relationships with them;
- learning about the mining and mineral processing industries by participating in field trip visits to operating mines, laboratories and plants;
- exchanging ideas embedding authentic examples about the mining and mineral processing industries into the curriculum with other participants; and
- developing lesson plans with other participants that align to the science curriculum that can be used on the participants return to the classroom.

The science educators who participated in one of these summer schools delivered by the Colorado School of Mines Office of Special Programs and Continuing Education in 2007 completed the Feedback Survey.

3.6.3 Description of the Professional Development Events Delivered by the Queensland Centre for Advanced Technologies and Education Queensland

QCAT is the Commonwealth Science and Industrial Research Organisation's (CSIRO) research facility based at Pinjarra Hills in Brisbane, Queensland. The centre was set up to support research in the mining and mineral processing industries and is the largest research and development precinct in Australia (<http://www.qcat.csiro.au/>). As well as scientific research, QCAT promotes science education and provides outreach to science teachers in the belief that teachers and scientists can benefit from a program that engages both groups. The QCAT precinct is in close proximity to a number of schools and the scientists working at the centre were willing to form professional partnerships with the teachers. This enabled the professional development program to be established. QCAT was keen to raise awareness of their scientific research with the local community and a professional partnership with teachers from Education Queensland was seen as an ideal way to achieve this.

At the same time, a series of recommendations was proposed by the Queensland Government to ensure that school students had access to high-quality science education (Spotlight on Science, 2003). In a six-step action plan, building productive partnerships between schools and research organisations was seen as a way to achieve this aim. It was recognised that there would be benefits for both science educators and science researchers and that it would work if a professional mentoring relationship could be developed between the two sectors.

As time progressed, the Queensland Government reviewed Spotlight on Science (2003) recommendations and from that review, it developed the Science Education Strategy (2006-2009). As a direct outcome of this strategy, Senior Science Officers (SSOs) were employed by Education Queensland to liaise with industry and research organisations to create professional development programs that helped teachers increase their knowledge and skills in their teaching of science. They were charged with identifying real-life science learning experiences for teachers, with the aim of enabling the teachers to engage in this experience and take their newfound knowledge back into their classrooms. The science teachers who had been part of the professional development programs were then encouraged to teach science using the authentic industry examples that they had encountered during their professional development experience.

The “Education Queensland - Clean Energy” professional development program was one of the programs designed under the Science Education Strategy 2006-2009. The professional development programs planned by the SSOs were set up to meet specific aims but also to be flexible enough so that, if teachers wished to contribute or tailor the program to their own individual learning needs, that could also be accommodated. However, the general aim of the professional development program was to increase teachers’ knowledge of the mining and mineral processing industries so that they could use this content knowledge in their science classroom and provide their students with authentic applied science examples.

The general aim for the program was distilled further into the following specific aims:

- improve teacher’s content knowledge about the mining and mineral processing industries;
- provide teachers with real-world examples of scientists “working scientifically” in the mining and mineral processing industries;
- provide resources for teachers to write curriculum documents using their new content knowledge about the mining and mineral processing industries; and
- foster continuing interaction between teachers and scientists in an attempt to develop professional partnerships between the two groups.

The SSOs were instrumental in planning and implementing this professional development program and it was intended to be a continuous program that engaged science teachers over a two-year period. While the specific aims of the program outlined above were fixed, each SSO was given the flexibility to deliver the program in their own way to ensure that they catered for the individual needs of the participating teachers. The SSO that was involved in this study took a novel approach. From the start, the SSO engaged all stakeholders in order to foster a shared understanding of the aims and outcomes of the professional development program. These stakeholders included representatives from QCAT, a Head of Department of Science at a local high school, teacher representatives from the

schools who were intending to participate in the program (both primary and high school), an industry representative and the Education Advisor from the Queensland Resources Council (QRC). The SSO drew from this broad pool of expertise and designed the professional development program by taking their advice into account as the Education Queensland – Clean Energy professional development program was developed.

The Education Queensland – Clean Energy professional development program enabled the teachers to experience a variety of academic and industrial workshops involving the mining and mineral processing industries. The teachers were introduced to the scientists who were doing research in these areas in the hope that teachers would get to know the scientists and develop professional relationships with them. Previously, Churach (2004) had shown that this arrangement allowed the teachers to develop relationships with scientists to a point where they feel comfortable in asking questions and sharing experiences. In this new Education Queensland professional development program, it was hoped that a professional relationship would develop with the scientists from QCAT.

A series of professional development events formed the “Education Queensland – Clean Energy” professional development program. Initially, teachers attended a half-day session where they were introduced to some of the current research projects (including virtual fences and coal gasification) carried out by QCAT and met the scientists doing the research. The teachers were able to ask questions about the research and were able to discuss the projects with the scientists. The teachers were then taken on a tour of the QCAT complex to look at other research projects including clean coal technology, robotics, minerals processing and light metal research. Also, at that initial half-day session, the Education Advisor from QRC gave the teachers teaching resources related to the research that the teachers had seen during their visit.

After the initial professional development event, the SSO asked the participating teachers for feedback which would be used to determine the direction of the future professional development events in the program. A planning meeting was then called with the original stakeholders to examine the teachers’ feedback. The

feedback from the secondary science teachers was positive and catered for their learning needs. However, the feedback from the primary teachers was that the science content knowledge needed to be modified to make it suitable for their learning needs. Also, the primary teachers did not have the same laboratory access that the secondary teachers did so practical activities would need to be modified if they were to incorporate the “Working Scientifically” component into their unit plans using examples from the science research that they had engaged in at the QCAT facility. These issues were taken into account and were used by the SSO to direct the future planning of the professional development events.

The next professional development event was a content-rich program based around energy obtained from coal. To accommodate the primary teachers, the Education Advisor from QRC had produced a teaching resource that would link the content to a primary context. Two low emissions technology and mining systems scientists from QCAT gave presentations about coal research they were currently working on. At this session, the teachers were again encouraged to ask questions and to interact with the scientists. The Education Advisor from QCAT was also on hand to link the research back to the classroom.

The next professional development session engaged the teachers in thinking about how the mining and mineral processing industries content knowledge could be incorporated into unit plans to enable teachers to engage their students in as many hands-on practical science activities as possible about these industries. A secondary teacher had work-shadowed a scientist at QCAT and she gave a presentation recounting the experience and describing how the work shadowing experience had translated into teaching practice. She described how she incorporated the content knowledge that she had encountered and how she had embedded learning experiences into her units of work when she returned to school. At the same session, a primary teacher gave a presentation on how the “Primary Connections” lesson format could be used as a template to write lesson plans to incorporate content knowledge about the mining and mineral processing industries. The session concluded with group discussion consisting of both primary and secondary teachers. They decided on an aspect of coal mining and technology that could be incorporated and sketched a rough outline of how the teaching plan could evolve. These ideas

were presented to all the participants and discussion followed each presentation. The teachers were invited to think about becoming a member of a writing team that would complete the teaching units.

Four teachers volunteered to be a member of the writing team. The SSO organised time for two writing days to be held off-campus to enable the teachers to focus on the task and not be disrupted by the day-to-day running of the school. During the writing process, the teachers were able to access the scientists from QCAT and use them as a resource. They also had access to other secondary data sources, including digital resources. As the teachers wrote the teaching unit, it became clear to them that they needed teaching resources to support their teaching. So, while they were writing the teaching unit, they also developed the support materials for teachers to teach it effectively.

The SSO supported the writing team by arranging for the draft teaching resources to be reviewed by the QCAT scientists and the Education Advisor from the QRC. They were able to give the teachers advice about the content knowledge in the teaching resource by ensuring that the science they were incorporating into it (about the mining and mineral processing industries) was correct. They also provided assistance to the teachers by helping them to obtain permission to use animations and PowerPoint presentations that were incorporated into the teaching resource.

The outcome from the professional development events was that the teachers wrote a unit of work and this resulted in the teaching resource called “Energy Today and Tomorrow: Learning about coal and clean coal technologies”. All the teachers who participated in the “Education Queensland - Clean Energy” professional development program were surveyed using the Feedback Survey. As well as this, the researcher followed the teachers’ progress as they attended the professional development events in the program where they also completed follow-up questions and were interviewed about their contribution to the teaching resource. This process was also documented by the researcher.

3.7 DATA COLLECTION METHODS USED IN THE RESEARCH PROJECT

In an attempt to assess how a professional development program affected changes in teacher attitudes towards the Mining and Minerals Processing Industries, Churach (2005) developed a “Feedback Survey” questionnaire that provided quantitative responses. This Feedback Survey has been enhanced by adding a qualitative data collection technique and, together, they provided a dataset known as the “Attitude Inventory”.

The researcher was familiar with the aims and purposes of the three professional development programs and attended the majority of the professional development events. Each professional development program provided a rich source of data (initially quantitative and later qualitative) that the researcher used for analysis. Participants of all three professional development programs provided quantitative data via the Feedback Survey while the professional development program provided by QCAT and Education Queensland provided both quantitative and qualitative data for the research project.

3.7.1 Feedback Survey Quantitative Data Collection – Phase 1 of the Attitude Inventory Process

Phase 1 of the Attitude Inventory process, known as the “Feedback Survey”, was the quantitative data collection instrument used in this research study. Developed by Churach in 2003 (Churach, 2005), the Feedback Survey tool was reviewed and approved for use by academic staff at both Murdoch University, Extractive Metallurgy Department and Curtin University, Science and Mathematics Centre (SMEC). This questionnaire enables quantitative data to be collected by means of a survey based on the Likert scale. Likert devised this polytomous scale to allow the participants to select from a range of responses for each question or statement. These responses are then given a numeral value to allow for mathematical or statistical analysis to be applied. Churach reported that this instrument was a reliable and valid data collection instrument to determine knowledge and attitudinal change in the mining and mineral processing industries (Churach, 2005).

Although Popham & Sirotnik (1973) argue that greater power and flexibility can be gained from using parametric statistical tests, the data in this study were subjected to non-parametric testing to determine the difference between the two related (matched) samples, namely before the professional development event and after the professional development event. In this research study, the data consists of two groups of matched pairs measuring the same individuals in a pre- and post-test comparison. The matched pairs were subjected to statistical analysis to show that the correlation between them was valid. This statistical analysis is covered in Chapter 4.

The Feedback Survey used in this study was designed to enable data to be collected from science educators on their *relative* knowledge and attitude levels about the mining and mineral processing industries both prior to, and then following, their involvement in a professional development event. In each case, the Feedback Survey (asking for both “before” and “after” responses) was only given to the science educators to complete after they had completed their professional development event. This approach gave the respondents a better idea of their *actual* relative knowledge and attitudes before and after professional development.

For the responses, a 5-point Likert Scale was used with 1 being “Strongly Disagree”, 2 being “Disagree”, 3 being “No Opinion”, 4 being “Agree” and 5 being “Strongly Agree”. The odd-number of points in this Likert Scale ensures that there is a mid-point that can be used for a neutral response.

Participants were asked to respond to each of the 16 items from their point of view before their first professional development and then again from their point of view after undergoing whatever number of professional development events they completed within the professional development program this not only gives the direction of the change, but also measures the amount or “relative magnitude” of the change. By giving these data a numerical value they can be tabulated and graphed.

The questions used in the Feedback Survey (APPENDIX B) addressed sixteen statements that were considered important for success in the professional development programs. Each participant responded to the statements by indicating

their position on the Likert Scale (from 1 to 5) for both before and after the professional development event. The statements in the Feedback Survey for the science educators to rate were:

1. My overall knowledge of the mining and mineral resource industry is very extensive.
2. I believe that careers in the mining and mineral resource industry are worthwhile recommending to my students.
3. I have a very positive attitude towards the mining and mineral resource industry in Australia.
4. I believe an excellent way to solve environmental problems can be found through mining and mineral resource research.
5. I use examples of the mining and mineral resource industry in my classes frequently.
6. I know a scientist I can email or phone to get information concerning a mineral processing or chemistry question.
7. I consider mining and mineral resource industries in Australia to be modern and high-tech.
8. I think that mining and mineral resource industries offer exciting career paths for young people.
9. I talk to colleagues and friends about issues concerning the mining and mineral resource industry in Australia.
10. I believe that people in the mining and mineral resource industry care about the natural environment.
11. The more teachers do hands-on activities, the better they will understand the mining and mineral resource industry.
12. I provide information to students concerning the possibility of a mining and mineral resource major at university.
13. I have a positive view of career researchers and scientists in the mining and mineral resource industry.
14. Getting a bit of an “inside view” of the mining and mineral resource industry makes me a better teacher.
15. Getting a bit of an “inside view” of any Australian industry makes me a better teacher.
16. Professional development programs that offer a maximum amount of science content-oriented material make me a better classroom teacher.

The results of all the surveys from the individual teachers before were tabulated and tallied, both before and after the respondents participated in the professional development events was determined. The data averages for each of the questions from the teacher responses were then tabulated and graphed to highlight if there were any changes in attitude before and after the professional development event. The responses showed that there were shifts of different amounts depending on the statement set.

Though actual values of responses cannot be taken as a meaningful reflection on the professional development program, the shift in average response can be interpreted as a change in teacher attitude towards mining and mineral processing industries. A positive shift in score is interpreted as a positive shift in teacher attitude towards the industry while a negative shift in score is viewed as a negative shift in teacher attitude towards the industry.

While the data collected from the Feedback Survey enable the participant to give a range of responses with numerical values that can be graphed to show a magnitude of difference, there is no way of checking why the participant chose a particular number for each statement set. For this research study, it is also important to discover why a participant answered the way they did. Additional qualitative data could provide this information and increase the richness of the quantitative data collected from the Feedback Survey. This is why mixed methods to collect data were used in this research study.

3.7.2 Clarification Tool Qualitative Data Collection – Phase 2 of the Attitude Inventory Process

The statements in the Feedback Survey were hard-wired and there was no way of determining why the participants gave the responses that they did. Because of this, it became evident that the responses required further investigation so that they could be probed for further detail. When the data from the Feedback Survey were graphed, it was evident that there was a greater shift in some statement sets than in others. The statement sets with the greatest shift were chosen for further investigation i.e., statements 1, 5, 6 and 12. Statement 16 was also included as it had the smallest shift. The science educators who attended the QCAT/Education Queensland professional development program were given the follow-up questions to complete. Table 3.2 below shows the follow-up questions and the related statement set that forms Phase 2 of the Attitude Inventory process. Further, the same science educators who attended the QCAT/Education Queensland were also interviewed to clarify their answers in the follow-up questions and they were also asked to provide teaching examples to illustrate their answers.

Table 3.2

Follow-Up Questions and the Related Statement Set in the Feedback Survey

Follow-up Question Number	Question	Associated statement number linked to the Feedback Survey
1	List the new things that you learnt from the scientists in the PD QCAR workshop.	1. My overall knowledge of the mining and mineral resource industry is very extensive.
2	Have you been able to use any examples from the workshop to enhance your teaching? What examples have you used?	5. I use examples of the mining and mineral resource industry in my classes frequently.
3	Since the workshop, have you been in touch with either of the scientists that spoke at the workshop? In general terms why did you contact them? If you haven't contacted them yet, are you intending to?	6. I know a scientist I can email or phone to get information concerning a mineral processing or chemistry question.
4	Do you believe that you have a role as a classroom teacher in giving career education to your students? Do you talk to your students about career choices in general? Do you specifically talk about career choices in the mining and mineral processing industries? Can you give some examples of how you go about teaching career choices with your students?	12. I provide information to students concerning the possibility of a mining and mineral resource major at university.
5	How has the content about the mining and mineral processing industries that you learnt from the workshop helped you plan a unit of work for your students?	16. Professional development programs that offer a maximum amount of science content-oriented material make me a better classroom teacher.
6	How has your participation in the workshop enhanced you students' learning?	16. Professional development programs that offer a maximum amount of science content-oriented material make me a better classroom teacher.

In order to obtain a consistent picture of the teachers' experiences and changed perceptions, the qualitative data were collated and cross-referenced back to the trends shown on the graphs. Data reduction occurred by inductively identifying themes and assigning statements to the identified themes that refined and substantiated their validity (Cohen, Manion, & Morrison, 2000). From these qualitative instruments, greater insight was gained into the actual changes that the teachers were reporting and they allowed the reasons for these shifts to be deduced.

Qualitative data were collected using written questions and interviews from the group of teachers involved in the QCAT/Education Queensland professional

development events. The follow-up questions and interviews were used to clarify the teachers' responses to the Feedback Survey and this provided the information required to complete the Attitude Inventory in full.

3.8 CONCLUSION

This chapter has outlined the methodology for obtaining the data that has been used in this research study. The initial data were quantitative and collected by using the Feedback Survey. Following analysis of this data, it became obvious that qualitative data in the form of the Clarification Tool follow-up questions and interviews were also required to make sense of the quantitative data, allowing a rich data set to be established.

This chapter has also outlined the professional development events that the science educators attended and how the data collected from the participants contributed to quantitative and qualitative data set of this research study. Because they produced good data sets for both quantitative and qualitative information, a higher level of detail was paid to the results from the science educators who attended the QCAT and Education Queensland professional development events.

Finally, the chapter has described how the mixed method design for collecting data enabled the researcher to delve into the reasons for the shifts in the Feedback Survey results and how it enabled the first phase of the research to be developed further into Phase 2 of the Attitude Inventory process and produced the Clarification Tool.

CHAPTER FOUR

RESULTS

4.1 INTRODUCTION

The preceding chapters have outlined the theoretical basis for this research study and described how secondary data underpin its framework and methodology. The theoretical basis also informed the design of the process for the way the data would be collected. Creswell (2005) states that quantitative data alone is not sufficient to explain why respondents give the answers they do. It became very evident from the results of the quantitative data collected in this study that there were distinctly larger shifts in the average differences for four of the questions than for the rest of the questions. To explain these distinct differences, it was decided to use an approach where, rather than collecting quantitative data alone, both quantitative and qualitative data were collected. This mixed-method research approach to data collection is better because it produces a richer data set that allows a more in-depth analysis to be performed (Creswell, 2005).

This chapter examines the primary data collected using the “Feedback Survey” survey tool for each of the professional development programs run at several institutions including the Centre for Sustainable Resources Processing (CSRP)/Murdoch University, the Colorado Mining Association Education Foundation/Colorado School of Mines Office of Special Programs and Continuing Education, and the Queensland Centre for Advanced Technologies (QCAT)/Education Queensland. All the quantitative data collected during these professional development programs were tabulated and graphed as a whole to enable visualisation of the changes in the set of statements before and after a professional development event. Then, the quantitative data set is examined through the lens of the research questions. Finally, the quantitative and qualitative data collected from the QCAT/Education Queensland professional development program were considered together and inferences drawn from these data.

4.2 COLLECTION OF QUANTITATIVE DATA AND PRELIMINARY STATISTICAL CALCULATIONS

In this research study, participants completed their answers for the Feedback Survey questionnaire (both before and after PD) together in one sitting. As described in Chapter 4, the word responses were converted to numbers via a polytomous, 5-point Likert Scale that matched each of the responses strongly disagree/disagree/neutral/agree/strongly agree (Cohen, Manion, & Morrison, 2000) with 1 being “Strongly Disagree”, 2 being “Disagree”, 3 being “No Opinion”, 4 being “Agree” and 5 being “Strongly Agree”.

Scale analysis was then applied to the quantitative data results from the Feedback Survey. The statistical means and standard deviations were derived for the pooled Likert scale results for each of the questions in the Feedback Survey. The item mean for each of the questions is the average of the combined scaled responses (numeric datasets) for each of the questions both before and after the PD event. In a similar fashion, the item sd (standard deviation) shows the standard deviation of these datasets. These data were then graphed to see whether or not visual conclusions could be made about the change (shift) in the responses both before (pre) and after (post) a professional development event.

4.3 STATISTICAL VALIDATION OF THE QUANTITATIVE DATA COLLECTED IN THE STUDY

In this study, numerical quantitative data were collected about science educators’ perceptions of the professional development programs on a ranking scale from 1 to 5 (Likert Scale). The first question is: how do you interpret these data? Traditionally, means and standard deviations have been used to interpret numerical results. However, in this case, the numerical results are qualitative and are confined to a defined and restricted range. So, the challenge was to determine what statistical techniques are available that are both analytically valid and that can provide meaningful inferences? Also, the statistical techniques have to be valid for data that have small sample numbers and that may not be normally distributed.

Even though the data were limited to a five-point range, means and standard deviations can legitimately be determined from the pre and post PD event data sets that were collected. However, rather than being hard, fixed and defined values that are a measure of some physical property that has a particular application in a technical sense, the means and standard deviations derived from the data collected in this study represent a measure of the spread of the scores within the pre-PD event data and the spread of scores in post-PD event data. A comparison can be made between these spreads of scores to see if they are just randomly related (related purely by chance) or if there is some valid relationship between them.

The second question is: how big an effect has the PD event had on the participants? Where data are collected from the same participants each time, the study is deemed to have been done by “repeated measures design”. A study where data are collected from two or more separate groups with different participants in each group (as is the case for this research work) is called an “independent measures design” study. The Feedback Survey is the survey tool that was developed as a direct result of the independent measures design done for this research work.

The quantitative data collected via the Feedback Survey from each of the three sets of educators from CSRP/Murdoch (2003-2006, $n = 64$), Colorado School of Mines (2007, $n = 22$) and QCAT/EQ (2008-2009, $n = 25$) were entered onto separate worksheets in a Microsoft Excel spreadsheet. Finally, these three separate datasets were combined on a single worksheet in the same spreadsheet to give a total dataset of ($n = 111$) science educators who using the Feedback Survey in this study were collated in a raw data worksheet, a Microsoft Excel spreadsheet, and tabulated to enable them to be displayed clearly and to allow visual comparisons to be made between the scales. Both the tabulated data and the graphical data seemed to look realistic and there were some obvious trends in the graphical results. However, rather than simply accepting that these data were reasonable, it was decided that it should be tested statistically to determine whether the “before” and “after” results were valid or not.

One advantage of independent measures design is that more participants are used in the overall experiment and, compared to repeated measures design, it increases external validity (i.e. the extent to which the results of a study can be generalised to other situations and to other people) (Cohen, Manion, & Morrison, 2000).

A disadvantage of using independent measures design is the potential for error resulting from the individual differences of the participants, because they do not match those in other groups, which could affect the results and, therefore, the internal validity (reliability). The participants no longer become a control variable because two different groups of people are being used and it could be said that the results turned out the way they did because of other factors present in each group before the experiment even took place (Cohen, Manion, & Morrison, 2000). This is especially true where there is a low number of participants and, ideally, the number of participants should be greater than 20. In this research study, this disadvantage was overcome by using both a larger number of participants ($n = 111$) and by collecting qualitative data to help give clear reasons why participants answered the way they did on the Feedback Survey.

To check whether differences between item means for pre and post PD events were statistically significant, a non-parametric statistical analysis was performed for each question. In this case, the appropriate analysis methods chosen to apply to the data to determine significance and confirm that it was valid was the Mann-Whitney test which defines the “ U ” statistic (Cohen, Manion, & Morrison, 2000).

The Mann-Whitney U test is specifically designed for the analysis of data collected via independent measures design. It is a non-parametric test of the null hypothesis that the results from two separate populations are similar for a two-condition test, especially where one particular population tends to have larger values than the other (Cohen, Manion, & Morrison, 2000). Put simply, it is used to determine if a difference exists between the groups that are being studied. The Mann-Whitney U test is often viewed as the non-parametric equivalent of the student's t-Test. The main difference between the Mann-Whitney U test and the student's t-Test is that normal distribution of data is not necessary for use of the Mann-Whitney U test (MacFarland, 1998).

The p statistic is a measure of how well the data distributions overlap each other. It also gives the probability that the null hypothesis can or cannot be rejected (StatsDirect, 2000-2013). The null hypothesis in this case is that: *there is no change in content knowledge and attitude about the minerals and processing industries after undergoing a PD event.*

For each of the 16 items, the Mann-Whitney Difference (U) was found to be statistically highly significant ($p < 0.001$). This p value indicates that there is less than one in a thousand chance of failing to reject the null hypothesis being. When presenting p values, as well as quoting the p value itself, statisticians find it helpful to use the asterisk rating system because this avoids the imprecise term "significant" (nb. in this system, the asterisks should not be used without showing the p values themselves). This is why the U statistics have been displayed in this manner.

Now, to further check the validity of the results derived from the Mann-Whitney and p -statistic analysis methods, Cohen's d statistic gives a measure of how big an effect there has been on the pre vs post PD results.

Cohen's effect size (d) measures the size of the effect of an intervention and it is used to investigate the combination or interaction of a group of independent studies: for example, a series of effect sizes from similar studies conducted at different centres (StatsDirect, 2000-2013). In this research study, the intervention was a professional development event or program and the different centres included interstate and overseas locations. The effect size can vary in magnitude from -1 to 1 , with -1 indicating a perfect negative linear relation, 1 indicating a perfect positive linear relation, and 0 indicating no linear relation between two variables. Cohen (1977) gives the following guidelines for the effect size in the social sciences:

Effect size	d
Small	0.20
Medium	0.30
Large	0.50

All collation and initial statistical analysis (means and standard deviations) of the data was performed in a Microsoft Excel spreadsheet. The Mann-Whitney U and Cohen's Effect Size (d) calculations were performed in the online statistical analysis package provided by Curtin University of Technology, Science Mathematics Centre (SMEC).

4.4 TABULATION AND GRAPHICAL PRESENTATION OF RESULTS

The quantitative data from the Feedback Survey were then tabulated. The full text questions have been reduced to only a few words to enable them to fit into the table. Consequently, column 1 (Item) in Table 4.1 shows the shortened version of the questions asked in the Feedback Survey.

As shown in Table 4.1, all of the differences between the data collected pre-PD and post-PD are statistically significant at the level of $p < 0.001$. This means that there is less than one chance in a thousand that the increase in the means is by chance alone. This can be interpreted as indicating that the changes in attitudes shown by the science educators in the study were much more likely to have been associated with the professional development programs they had attended rather than any kind of chance occurrence. Because the qualitative data collected from the Feedback Survey is seen to be statically valid, it can be used to support a set of assumptions about shifts in science educators' attitudes before and after the professional development programs in which they participated. The qualitative data can then be displayed in such a way to clearly show the set of assumptions. In this case, the data were tabulated and plotted on graphs for clarity. This process enables the data to be analysed and inferences can be drawn from it. It also enables the data to be classified into different sets in-depth analysis can be performed and greater insight into the original quantitative data set can be gained.

Table 4.1

Item Mean and Standard Deviation for Pre-Post Differences in Science Educators' Attitudes on each Item of the Feedback Survey

Item	Item Mean		Item SD		Difference	
	Pre	Post	Pre	Post	U	Effect Size (<i>d</i>)
1. Knowledge	2.35	3.71	1.09	1.00	7.66***	0.54
2. Recommend career	3.67	4.41	1.03	0.69	6.01***	0.38
3. View of industry	3.64	4.27	0.99	0.71	6.17***	0.34
4. Help environment	3.18	3.98	1.08	0.78	6.47***	0.38
5. Use class examples	2.80	3.90	1.26	0.89	7.35***	0.45
6. Knows a scientist	2.62	4.11	1.28	1.00	7.61***	0.55
7. High-tech industry	3.55	4.45	1.03	0.56	6.86***	0.47
8. Offers exciting career	3.61	4.47	1.08	0.55	6.83***	0.44
9. Talk to colleagues	2.82	3.82	1.14	0.96	6.72***	0.43
10. Cares for environment	3.08	3.89	1.06	0.80	6.40***	0.39
11. Hands-on helps	3.95	4.47	0.78	0.71	6.73***	0.33
12. Recommend Uni major	2.79	3.91	1.18	0.92	7.52***	0.46
13. View of researchers	3.54	4.41	1.02	0.62	7.01***	0.44
14. M&MP PD good	3.58	4.38	1.02	0.71	7.21***	0.41
15. Any industry PD good	3.77	4.37	0.93	0.66	6.04***	0.34
16. Content PDs good	3.94	4.39	0.99	0.75	5.18***	0.25

*** $p < 0.001$ ($n = 111$)

4.5 FINDINGS FROM THE QUANTITATIVE DATA FOR THE WHOLE COHORT

Once the validity of the quantitative data had been established, another data table was devised. In this table, the quantitative data were tabulated under the following headings: Item (which was the statement topic from the Feedback Survey), the mean before the professional development program (PD), the mean after the professional development program (PD) and the mean shift. This arrangement of the data set enabled the mean shifts for each statement to be compared. The data table showed that for every statement in the Feedback Survey, there was a positive mean shift and no negative mean shift. This is shown in Table 4.2.

Table 4.2

Item Mean before PD and after PD and the Mean Shift for the Science Educators' Attitudes on each Item (Statement on the Feedback Survey) for the whole cohort

Item	Before PDs	After PDs	Shift
1. Knowledge	2.35	3.71	+1.36
2. Recommend career	3.67	4.41	+0.74
3. View of industry	3.64	4.27	+0.63
4. Help environment	3.18	3.98	+0.80
5. Use class examples	2.80	3.90	+1.10
6. Knows a scientist	2.62	4.11	+1.49
7. High-tech industry	3.55	4.45	+0.90
8. Offers exciting career	3.61	4.47	+0.86
9. Talk to colleagues	2.82	3.82	+1.00
10. Cares for environment	3.08	3.89	+0.81
11. Hands-on helps	3.95	4.47	+0.52
12. Recommend uni major	2.79	3.91	+1.12
13. View of researchers	3.54	4.41	+0.86
14. M&MR PD good	3.58	4.38	+0.80
15. Any industry PD good	3.77	4.37	+0.59
16. Content PDs good	3.94	4.39	+0.45

($n = 111$)

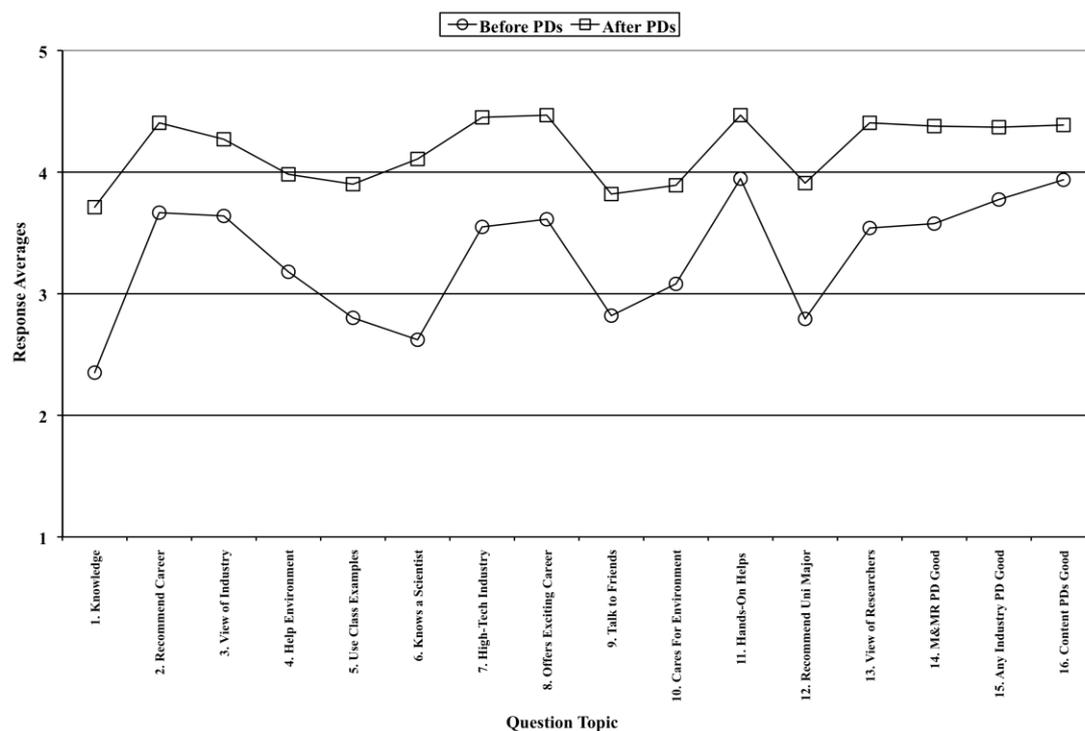
From this table, the mean before the PDs and the mean after the PDs for each scale were graphed. By graphing these two components, a visual representation of the shifts in the means could clearly be displayed, enabling the comparisons of the scales to be made. This visual representation shows that there has been a positive shift in each of the means for the statements in the Feedback Survey. Importantly, there were no zero movements (i.e. where the mean remained the same) or negative shifts in any of the means for any statement in the Feedback Survey. This is shown in Figure 4.1.

The shifts are not uniform and some shifts have been greater than others. For example, the mean shift for statement 16 “Content PDs Good” is the smallest, but the mean starts at a high position initially. Statement 1 “Knowledge” and statement 6

“Know scientist” are the largest shifts, but their means start from a low initial point. However, the size of the shift is not strictly related to the starting level of the mean for each question topic. For example, some statements whose pre-PD mean started at a higher level (statements 7, 8 & 13) also had quite large shifts.

Figure 4.1

Item mean before PD and after PD and the mean shift for the science educators’ attitudes on each item (Statement on the Feedback Survey) for the whole cohort shown as a graph



Some mean shifts were small, especially where the initial mean had already been scored as high. For example, statement 16, “Professional development programs that offer a maximum amount of science content-oriented material make me a better classroom teacher” had a +0.45 positive mean shift. But was scored as 3.94 before the PD and scored 4.39 after the PD. Similarly, the initial score for statement 11, “The more teachers do hands-on activities, the better they will understand the mining and mineral resource industry” had a +0.52 positive shift but also started from a high initial mean. This can be interpreted as the science educators who completed the Feedback Survey already had a positive attitude to the statements in the Feedback Survey before the PD programs and increased their positive attitude to these

statements after the PD programs. This then resulted in a small positive mean shift for these statements.

The Feedback Survey was used as tool to collect quantitative data from the whole cohort and can be manipulated to show mean shifts, but it could not identify why the science educators scored the statements the way that they did. The Feedback Survey provided a valuable starting point to examine the quantitative data but, to make sense of it, qualitative data was also required. So, the mixed method approach using the Clarification Tool (combined quantitative and qualitative data collection) became a useful way to collect data from the science educators attending professional development programs for science educators about the mining and mineral processing industries.

Selected statements from the Feedback Survey were used to answer the research question for this study. The specific questions can be identified and the mean shifts for each question can be presented and analysed. While some statements demonstrate evidence for support of the answer to the research question, other research questions need qualitative data to give more evidence in support of the answer. This will be outlined in the following paragraphs.

4.5.1 Science Educators' Knowledge of the Mining and Mineral Processing Industries after Professional Development Programs

The selected statements from the Feedback Survey used to determine the science educators' knowledge of the mining and mineral processing industries after the professional development programs were:

- statement 1 “My overall knowledge of the mining and mineral resource industry is very extensive”,
- statement 14 “Getting a bit of an “inside view” of the mining and mineral resource industry makes me a better teacher”
- statement 15 “Getting a bit of an ‘inside view’ of any Australian industry makes me a better teacher”, and

- statement 16 “Professional development programs that offer a maximum amount of science content-oriented material make me a better classroom teacher”.

The lowest mean for the before PDs results was for statement 1. Its mean of 2.35 shifted to a mean of 3.71 after the PDs making it a mean shift of +1.36. This seems to indicate that the science educators believed that there was a positive change in their overall knowledge of the mining and mineral resource industry after the professional development program. Even though the mean shifts for the other scales about the science content were not as large, the shift for statement 14 had a mean shift of +0.80 and statement 15 had a mean shift of +0.59. While statement 16 had a smaller mean shift of +0.45, it still was a positive shift. As the professional development programs were content-rich and specifically targeted the science content about the mining and mineral processing industries, a positive mean shift shows that they were achieving the professional development programs’ stated aims. It is clear that science educators’ knowledge of the mining and mineral processing industries improved through targeted professional development programs.

4.5.2 Application of Content Knowledge to the Curriculum Documents

While the Feedback Survey enabled a conclusion to be drawn about the increase in science educators’ content knowledge about the mining and mineral processing industries, it did not give any indication about whether science educators were able to link their newfound knowledge to curriculum documents. At this stage of the research project, a conclusion about content knowledge to curriculum documents could not be reached. An additional step was required that qualified the quantitative data.

By using the mixed method approach (Clarification Tool) for data collection to investigate this research question, a definite conclusion could be reached. The QCAT/Education Queensland cohort was used to collect qualitative data about the science educators’ ability to apply the science content associated with the mining and mineral processing industries to the curriculum documents. This cohort of science educators, were given follow-up questions and were interviewed and this qualitative data set provided evidence to show that they were able to give reasons about why

they answered the Feedback Survey questions in the way that they did. When this qualitative, mixed method approach was applied, a definite conclusion emerged.

All of the professional development programs had a practical component, including laboratory work and field trips, embedded into the program. In this context, the PD event provided participants with authentic hands-on experience in science content knowledge and its relationship to the mining and mineral processing industry. The results from the Clarification Tool showed that they took these examples and linked them to the curriculum documents and applied this in their classrooms. Statement 5 on the Feedback Survey (“I use examples of the mining and mineral resource industry in my classes frequently”) relates this application of authentic examples of applied science in the mining and mineral processing industries to the curriculum documents and authentic learning activities in the classroom. It started with a low initial mean of 2.80 before the PDs and increased to a mean shift of 3.90 after the PDs, a relatively large shift of +1.10.

Examples of science content also included the technologies associated with processing minerals and environmental testing and rehabilitation. This could be interpreted as the science educators’ not having examples of applied science in the mining and mineral processing industries in their teaching repertoire before the PDs, gaining the examples during the PD event and then, after PD, applying them in the classroom with their students. This is further examined in the qualitative data set analysis in Section 4.9.

Statement 11 (“The more teachers do hands-on activities, the better they will understand the mining and mineral resource industry”) is also related to science educators’ ability to apply content knowledge of the mining and mineral processing industries to the curriculum documents. On the Feedback Survey, the science educators already agreed with this statement pre-PD and this resulted in a mean of 3.95. After the PDs, there was a positive shift in the mean of +0.52 to 4.47. Also, the qualitative data collected using the Clarification Tool phase concluded that the science educators were able to apply their content knowledge of the mining and mineral processing industries to the curriculum documents (see Section 4.9).

4.5.3 Content-rich Professional Development Programs and Science Educators' Attitudes about the Mining and Mineral Processing Industries

The science educators scored a positive mean shift for all the statements related to their attitude about the mining and mineral processing industries. These statements not only included their attitude about the mining and mineral processing industries, but also included statements about their perceptions of the mining industry's stewardship towards the natural environment and it being a high tech industry. The results also showed that there was a positive shift in the mean for talking to colleagues and friends about mining and mineral processing issues.

The science educators' view of the mining and mineral processing industries was high before the PDs. Statement 3, "I have a very positive attitude towards the mining and mineral resource industry in Australia" was scored with a mean of 3.64. This shifted to a mean of 4.27 after the PDs with a positive shift of +0.74. This would suggest that the PDs increased the science educators' positive view of the mining and mineral processing industries.

Statement 7, "I consider mining and mineral resource industries in Australia to be modern and high-tech" can also be considered to contributing to a positive attitude of the mining and mineral processing industries. Before the PDs, the mean for this statement was 3.55 and after the PD event the mean was 4.45 with a positive mean shift of +0.90. It could be concluded that the science educators already considered the mining and mineral processing industries to be high tech before the PDs. Following the PD event, their views were not only confirmed, but they were consolidated further.

The two other statements about attitude contributed to a positive mean shift in the science educators' attitude towards the mining and mineral processing industries however, this time it was about the environment. Statement 4, "I believe an excellent way to solve environmental problems can be found through mining and mineral resource research" and statement 10, "I believe that people in the mining and mineral resource industry care about the natural environment". These showed a positive

mean shift of +0.80 and +0.81 respectively. Therefore, in this case the content rich professional development programs about the mining and mineral processing industries did cause an attitude change about the mining and mineral processing industries and their environmental stewardship.

Finally, statement 9, “I talk to colleagues and friends about issues concerning the mining and mineral resource industry” can also be used as an indicator of attitude change on the Feedback Survey. The science educators in the whole cohort scored this statement with a mean of 2.82 before the PDs. After the PDs the mean was 3.82 resulting in a positive mean shift of +1.00 for talking to colleagues and friends. The qualitative data collected from the QCAT/Education Queensland gave further meaning to this statement as this professional development program enabled the science educators to work with their colleagues as they wrote the unit of work. This provided a forum for dialogue for these participants and a vehicle for them to talk to their colleagues as they worked together.

4.5.4 Know a Scientist or Researcher in the Mining and Mineral Processing Industries

The largest mean shift for the whole cohort was in the scale for statement 6, “I know a scientist I can email or phone to get information concerning a mineral processing or chemistry question”. The mean before PDs was 2.62 and the mean after PDs shifted to 4.11, which produced a positive mean shift of +1.49. All the professional development programs in this research study included scientists and researchers talking to the science educators about their scientific work and provided authentic examples and hands-on activities related to the mining and mineral processing industries. The scientists and researchers who worked with the science educators during the professional development programs gave them their contact details in case they had any further questions about the science content of their industry when they taught the science content and used industry examples. After the PD program, the science educators were in a position where they could contact a scientist or researcher in that field. The professional development providers intended that the scientists and researchers from the mining and mineral processing industries could build rapport with the science educators and from ongoing professional relationships

with them. Further, there was also a positive mean shift in the science educators' view of researchers. Statement 13, "I have a positive view of career researchers and scientists in the mining and mineral resource industry" already had a high mean before the PDs of 3.54. After the PDs it was 4.41 resulting in a positive mean shift of +0.86.

These findings go some way in answering whether the science educators were able to form professional networks with scientists working in the mining and mineral processing industries. However, just because the science educators had contact details of the scientists and researchers, the Feedback Survey tool was unable to show whether or not the science educators actually did contact them at all or, further, whether they continued to remain in contact with them. Further data using the Clarification Tool was required to completely answer this research question.

Before the PDs, statement 12 "I provide information to students concerning the possibility of a mining and mineral resource major at university," the science educators scored this statement quite low with a mean of 2.79. This mean shifted to 3.91 after the PDs resulting in a positive mean shift of +1.12. This indicates science educators would consider providing information to their students about university study in the mining and minerals processing industries and, taking into account other statements, they believe that the mining and mineral processing industries offer an exciting career and would recommend it as a worthwhile career choice.

Further, statement 8 "I think that mining and mineral resource industries offer exciting career paths for young people" had a positive mean shift of +0.86, while statement 2 "I believe that careers in the mining and mineral resource industry are worthwhile recommending to my students" had a smaller positive mean shift of +0.74. This could be interpreted as that because the science educators had been interacting with the scientists and researchers during the PDs they were better placed to understand what the scientists do and would be therefore inclined to recommend a career in the mining and mineral processing industries to their students. This concept was further investigated through the qualitative data in Section 4.7.

4.6 LINKING THE QUANTITATIVE DATA TO THE QUALITATIVE DATA

It must be recognised that it was essential that the quantitative data had to be collected first so that it could inform the design of the way that the qualitative data was collected. It was these representations of the data that gave the study the direction to focus the qualitative data collection by using follow-up questions and interviews. The qualitative data collection tools were able to give greater insight to the initial quantitative data and aided a better understanding to answer the research questions. The two phases of the data collection process are detailed in Figure 4.2.

So, the hard, quantitative data had been collected to show that professional development events do indeed affect an attitudinal change in the science educators themselves. But, the question is: how do we know that this attitudinal change was being translated into practical use by the educators when they returned to their workplace? What were they doing with their newfound knowledge? Were they applying their knowledge of the mining and mineral processing industries to the science curriculum? Also, did they really understand the information that they had gleaned? And, for example, did they actually form, and maintain, professional networks with scientists in the mining and mineral processing industries?

The quantitative data alone does not give the full picture and cannot completely clarify these questions. One way of testing this is to follow the science educators in their post-professional development journey and see if, and how, the information is written into their curriculum documents. It is only when this information is applied by the educators into these documents that you can tell if:

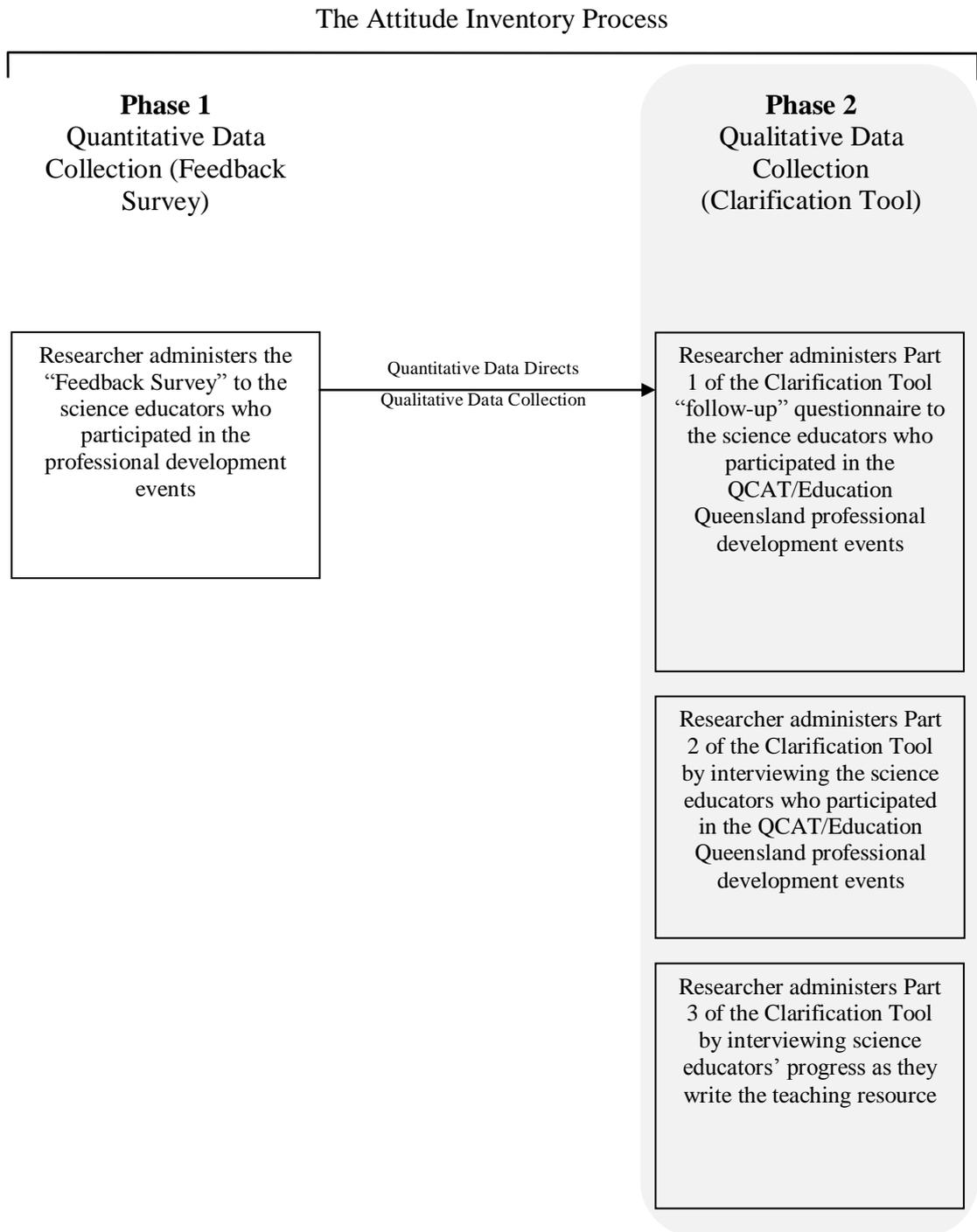
- a) they understood what they experienced in the professional development events; and
- b) they were able to apply the information correctly.

The Clarification Tool does this via two means. The first element is to conduct a series of follow-up interviews with educators using the targeted, open, non-structured questions of the Clarification Tool. The educators are allowed to express themselves freely to give a full and honest opinion about why they rated their answers in the Feedback Survey the way that they did. The second element entails following the

educators that are involved in writing curriculum documentation and answering the related suite of questions in the Clarification Tool.

Figure 4.2

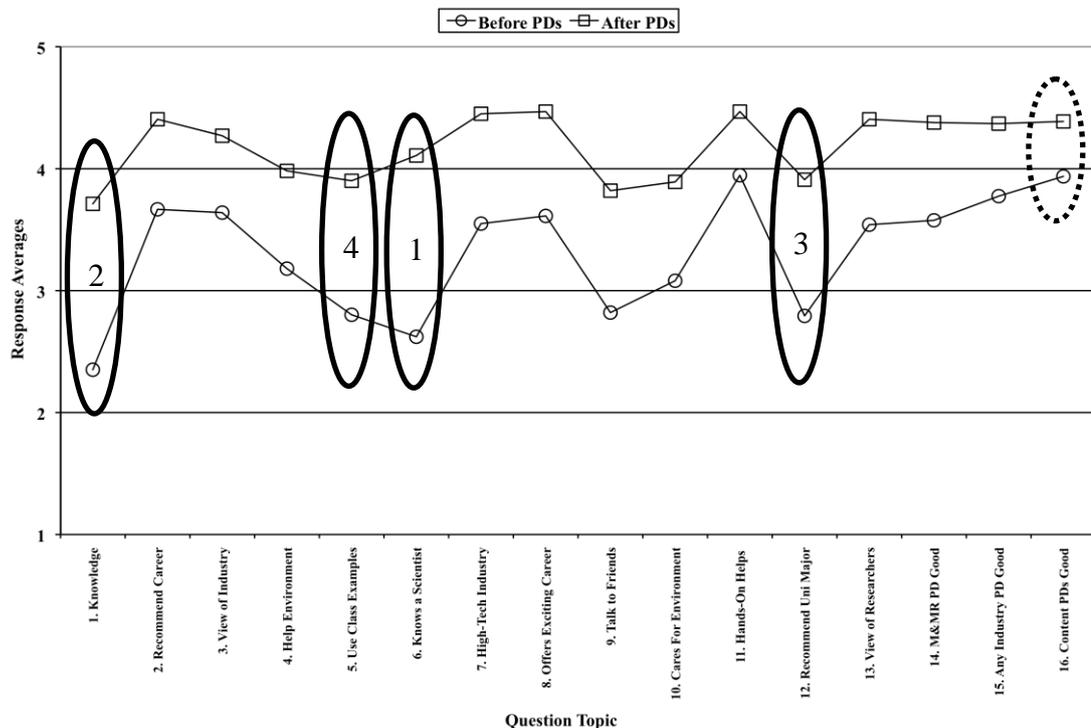
Flow chart outlining the steps involved in collecting the primary data highlighting the parts in Phase 2 of the qualitative data collection process.



So, going back to the qualitative data from the Feedback Survey, some statements stood out as being more significant than others. Some statements had a greater mean shift than all the other statements. In order in the shift of their mean, these were identified as statement 6 Knows a scientist, statement 1 Knowledge, statement 12 Recommend uni major and statement 5 Use class examples. Further, there was one statement that had the lowest shift. This was statement 16 Content PDs good. These statements were identified as being of interest and were worthy of further investigation in the qualitative data collection. They are identified and circled on the following graph in Figure 4.3.

Figure 4.3

Item mean before PD and after PD and the mean shift for the science educators' attitudes on each scale – (Statement on the Feedback Survey) for the whole cohort shown as a graph with the statements with the four highest shifts in the mean circled with a solid line and the statement with the lowest shift in the mean circled in a dashed line.



As these statements were considered to be of interest, they were explored further through a purpose-designed extension of the initial research program. The QCAT/Education Queensland cohort was readily available to the researcher. In

addition, the participants from it continued to meet and work together both on a unit of work and on a teaching resource about the mining and mineral processing industries. So, it was a logical and easy step to extend the professional development program and collect the required qualitative data via follow-up questions and interviews with the participants in this cohort.

4.7 THE DATA SET FROM THE CLARIFICATION TOOL

The qualitative data was collected in phase two of the data collection process using the Clarification Tool. This was then tabulated under themes derived from the quotes from the science educators in the QCAT/Education Queensland cohort. Assertions were then made about the qualitative data and this contributed to the completeness in answering the research questions.

4.8 ASSERTIONS DRAWN FROM THE QUALITATIVE DATA USING THE CLARIFICATION TOOL

The results from the Feedback Survey informed the direction of the questions and interviews that comprised the qualitative data and from this data four assertions were able to be made. Only a selected number of the responses made by science educators collected via the Clarification Tool are included in the body text of this thesis to justify these assertions. A full list of responses is available in APPENDIX C.

4.8.1 Science educators' content knowledge about the mining and mineral processing industries had improved as a result of participating in the professional development events.

Technological advances in the mining and mineral processing industries have been rapid and the science educators in the project were learning about these advances for the first time. The science educators realised that after the professional development events, their content knowledge had increased. When the science educators were asked about the specific content knowledge that they gained from the professional development events, they listed a range of science content associated with the professional development events.

I had never heard of gasification. AA

I was exposed to the new concept of clean coal. RR

I have seen different kinds of science and learnt much about mining. GH

Science educators felt that they had gained confidence in teaching science units because of their involvement in the program.

I felt more confident about teaching the Earth science unit because of the knowledge that I had gained from the workshops. MW

My knowledge about mining had improved. I believe this to be a direct benefit to my students, as I am able now use this knowledge in class when I am teaching the units. HH

4.8.2 Science educators were willing to provide real world examples of mining and mineral processing and careers in the industry when it suited their specific teaching needs.

In their interaction with the scientists, science educators were able to identify how scientists “Work Scientifically”. Science educators then wanted to incorporate opportunities to “Work Scientifically” for their students using mining and mineral processing examples.

After touring the QCAT facility, I now see what scientists are doing and understand how they work. AA

When I get the question ‘what’s the point of this’ or ‘how do we know that’ we talk about how scientists discovered things. JP

I like to use real examples of what scientists are doing when it relates to my teaching topic. The interactions with these scientists has allowed me to do that. MW

The science educators were also willing to talk about careers in the mining and mineral processing industries as examples of exciting and interesting scientific opportunities.

That's the whole point – they are in school. I'm often talking to them about academic success to make kids realise that some people do the activities, e.g. in science, for their work... to point out people can pursue their passions as a career. DF

However, the science educators did not lose sight of their teaching role to cater for the learning needs of their students. The science educators were aware of the individual learning needs of their students and were mindful to adapt any new ideas to benefit their students.

My students are engaging with new concepts about mining and I find that planning hands-on activities for the student is very beneficial. ES

Teachers are able to use the information to cater for the different learning styles and learning needs in their classes. DR

4.8.3 Science educators were able to write curriculum documents and teaching resources using material from the professional development events.

After the professional development events, a group of science educators (the QCAT/Education Queensland cohort) independently decided to write a resource, based on the mining and mineral processing industry, to enable them to teach the new content. Also, pedagogical skills were included in the resource to aid in the teaching process. Even though this outcome was not the original intention of the project, the SSO was able to facilitate the development of the resource and support the science educators in this endeavour. The resource has been distributed to the science educators involved in the project and now other science educators, who were not involved in the project, have been given copies to use when they are teaching “Earth and Beyond”.

I feel confident in writing teacher resources about mining. I changed some old activities to suit the new content. MG

Given the nature of the unit tasks we have written, we were able to adapt assessment tasks to fit the new content about mining and the processing of minerals. ES

The components of the resource have been used to re-develop a Year 9 unit. ES

4.8.4 Science educators had not initiated any further contact with the scientists after the professional development events, even though they believed that it would be beneficial.

Because they were participating in the project, the science educators were allocated time during normal work hours to attend away from their classes. This enabled them to have uninterrupted interaction with the scientists during the course of the PD events. However, when the professional development events were finished, the science educators returned to their normal (busy) routine. So, even though the science educators thought that such a relationship would be beneficial, the ability for them to have an ongoing professional relationship with the scientists did not eventuate.

I can see that links can be developed between the school and QCAT. AA

I was interested in the scientist's background and how they became involved in their career. AC

Science educators cited time constraints as the reason for not contacting the scientists.

The scientists at QCAT are busy and I haven't had time to contact them either. AB

That's the whole point – we are in school and the scientists are working at QCAT. We are both really busy. DP

However, science educators did indicate that they would contact the scientists in the future if required.

Its handy to have access to materials, e.g. coal, if I need it. RR

Access to the scientists and their knowledge is valuable and I know who to contact if I need to. RH

The group of science educators that wrote the unit plan and teaching resource about the mining and mineral processing industries did have further contact with the scientists. They interacted with the scientists during the writing phase and consulted with them when they wanted to check their content knowledge about the mining and mineral processing industries. This enabled them to feel confident about the accuracy of the content of the resource before it was published and used by other science educators but once the professional development program came to an end the interaction between the science educators and the scientists also ended.

The assertions made from the qualitative data were:

1. Science educators' content knowledge about the mining and mineral processing industries had improved as a result of participating in the professional development events.
2. Science educators were willing to provide real world examples of mining and mineral processing and careers in the industry when it suited their specific teaching needs.
3. Science educators were able to write curriculum documents and teaching resources using material from the professional development events.
4. Science educators had not initiated any further contact with the scientists after the professional development events, even though they believed that it would be beneficial.

4.9 CONCLUSION

Due to the methodology used and following analysis of the data collected, the research questions can now be answered.

4.9.1 Valuable and Useful Data Collection Tools

Using quantitative data in the form of the Feedback Survey did effectively measure the change in attitude of the science educators surveyed. More importantly, when these results were used in conjunction with the qualitative data using the Clarification Tool, a clear indication emerged about why their attitudes changed. So, the data collected in this research study supports the notion that using the Feedback Survey and the Clarification Tool together was a valuable and useful way to collect primary data from science educators who attended the professional development programs outlined in this thesis.

4.9.2 Science Educators' Content Knowledge of the Mining and Mineral Processing Industries after Professional Development Programs

Following their attendance at the professional development programs about the mining and mineral processing industries, the science educators reported a change in their science content knowledge about the applied science associated with these industries. The positive mean shift in statements 1, 14, 15 and 16 from the Feedback Survey supported this conclusion. Further, the qualitative data from the Clarification Tool pinpointed specific content that they had gained due to the professional development program. The science educators felt that they had gained confidence in teaching the applied science due to their participation in the professional development program and this would benefit their students.

4.9.3 Application of Content Knowledge to the Curriculum Documents

The Feedback Survey provided quantitative data about the science educators' application of content knowledge of the mining and mineral processing industries to the curriculum documents. Statement 5 and statement 11 both had a positive mean

shift which supports this conclusion. However, it was the Clarification Tool that provided the evidence to show how the science educators made the application of the content knowledge to the curriculum documents after they attended the professional development program. The science educators were willing to provide real world examples of applied science associated with the mining and mineral processing industries in their teaching practice from the examples that they experienced in the professional development program. Because the science educators had experienced the work that the scientists and researchers did in the mining and mineral processing industries and understood it, they were willing to explore careers within those industries with their students. They were also willing to adapt the content knowledge about the mining and mineral processing industries for their students to cater for their students' learning styles.

Further evidence to show that the science educators were able to apply their knowledge of the mining and mineral processing industries to the science curriculum came from the writing of the writing of the teaching resource. The mere fact that they were able to write the resource is evidence in itself (APPENDIX D). The resource linked the content knowledge from the mining and mineral processing industries with the pedagogical skills required to teach and assess the content knowledge.

4.9.4 Content-rich Professional Development Programs and Science Educators' Attitudes about the Mining and Mineral Processing Industries

The science educators were able to report a change in their attitude towards the mining and mineral processing industries after they participated in the professional development programs. The Feedback Survey was solely used to determine the answer to this research question. All the statements in the survey tool had a positive mean shift after the professional development program. However, statement 3 specifically targeted the science educators' change of attitude and this statement provided evidence that there had been a positive change in attitude. Also, statements 7, 4 and 10 had positive mean shifts. This confirmed the science educators' notion that the industries were high tech and that the industries responded to environmental

issues in an appropriate manner. These responses were also used to determine attitude to the mining and mineral processing industries.

4.9.5 Know a Scientist or Researcher in the Mining and Mineral Processing Industries

Finally, this research study showed that, while the science educators were able to form professional networks with the researchers and scientists throughout the duration of their PD program, they were not able to sustain these networks once they had returned to their normal job routine. Statement 6 from the Feedback Survey had the largest mean shift indicated that after the professional development program, the science educators had gained the researchers and scientists details if they required information about the mining and mineral processing industries. Further, statement 13 had a positive mean shift indicating that the science educators had a positive view of the researchers and scientists working in the mining and mineral processing industries.

The data collected via the Clarification Tool showed that relationships with the researchers and scientists did not continue. The QCAT/Education Queensland professional development program enabled the science educators and the scientists to work together and form a professional relationship during the writing of the teaching resource. The data from the Clarification Tool indicated that the science educators believed that they benefited professionally from the interaction. Time constraint was the major factor that prevented further interaction after the professional development program ceased. However, they knew that they had the scientists' details if they did require content knowledge about the mining and mineral processing industries in the future.

CHAPTER FIVE

CONCLUSIONS AND RECOMMENDATIONS

5.1 INTRODUCTION

This chapter will presents a review of the thesis, summarises the chapters within the thesis and draws conclusions about the data collected. It will also make recommendations for further research that could build upon the findings of this research study.

There has been a decline in the number of students studying secondary science (Lyons & Quinn, 2010). Further, science educators have been impacted by continual changes to the science curriculum (ACARA, 2010) and the role changes for science educators in their education systems (Rodrigues, 2004). To keep abreast of the changes and to try to stem the decline in student numbers, science educators seek out professional development programs to cater for their own learning needs.

This research study investigated professional development programs for the delivery of information about science and the mining and mineral processing industries to science teachers. Using government and industry funding, science teachers participated in a range of professional development events targeting different mining and mineral processing industries that exposed teachers to the high-tech nature and career possibilities of those industries for their students. The study traces the interaction of teachers involved in content-rich professional development events based around the mining and mineral processing industries. In particular, the research study investigated the science educators' change in the following areas:

- science educators reporting an increase in content knowledge about the mining and mineral processing industries
- science educators reporting a change in attitude towards the mining and mineral processing industries; and
- science educators reporting an ability to form networks with scientists in industry and with other science teachers.

Primary data were collected from participants who attended professional development programs. These professional development programs focused on science curriculum documents that link with the applied science being carried out in the mining and mineral processing industries. This study focused on three different professional development programs and collected primary data from the science educators who participated. Even though these content-rich programs were different in nature, the aims and focus of the professional development programs were similar to each other. An initial, rich data set was collected using the Feedback Survey to provide quantitative data from the whole cohort of participants. Then, the Clarification Tool was used to collect qualitative data from one cohort.

The entire quantitative dataset from the whole cohort was tabulated, then the means for each statement were derived and graphed which showed that there was a distinct increase in the means. Following this process, areas of interest were identified and examined further using the Clarification Tool. This enabled conclusions to be drawn from the data and for the research questions to be answered.

5.2 OVERVIEW OF THE RESEARCH STUDY

This thesis presents the findings of the research study aimed at determining the outcomes of content-rich professional development programs about the mining and mineral processing industries.

Chapter One introduces the research study and outlines its significance. Two main issues for science educators are identified, those being the changes to the curriculum documents and the shortage of qualified people in the mining and mineral processing industries. These issues run concurrently and science educators attempt to address them by providing authentic teaching and learning experiences for their students. By attending the professional development programs, science educators become the participants in this research study that aimed at addressing these issues. Further,

Chapter One outlines the researcher's role in the professional development programs and states the research questions that the study was designed to answer.

The literature review in Chapter Two outlines the theoretical basis for the research study. It establishes the reasons why science educators should engage in professional development programs as they continue their learning journey and fulfill their complex role. Science educators enter the teaching profession from a wide variety of backgrounds and the science content knowledge varies from educator to educator. This impacts on their teaching of science. It also determines the professional development programs that science educators choose to attend. This, in turn, poses an interesting situation for professional development providers who attempt to cater for the learning needs of the science educators.

Reports and research about professional development models and their effectiveness to address these issues were examined, including Hoban's (1997) *Summary of Professional Development Models* that identifies the strengths and weaknesses of each of these. Previous research shows that for a professional development program to be successful, science educators need the freedom to choose programs that address content knowledge issues that they have identified, particularly deficiencies in their own content knowledge and their pedagogical skills (Harrison & Nichols, 2002; Wallace & Loudon, 2002). Further, the elements of the models presented in previous research studies that were similar to the professional development programs in this research study were identified and compared.

Chapter Two also explores the nature of the mining and mineral processing industries and how this impacts on science education generally. It also explores how science educators embed authentic learning experiences into their teaching practice. Curriculum documents make provision for such embedding of authentic science experiences. Chapter Two covers how the curriculum documents can be linked to what actually happens in industry. The literature suggests that when teachers link these documents to industry practice, it can impact on the science students who study mining-related science at school and at university. This, in turn, can help to stem the decline in the number of students choosing to study science and could help to address the issue of people-shortages in the mining and mineral processing industries.

Chapter Two discusses the notion that science educators have a strong influence on their students (Churach, 2005) and that the literature suggests that this influence includes having an impact on the career choices that their students make. Finally, it goes on to examine the literature associated with the benefits of professional relationships that can be fostered between science educators and scientists and researchers.

The literature review identified a gap in research associated with content-rich professional development that focuses on the mining and mineral processing industries. There was no previous research that: a) specifically linked the applied science of the mining and mineral processing industries to the curriculum documents; and b) used a mixed method approach for primary data collection from the participants. Further, changes in science content knowledge about these industries, application of the participants' content knowledge, change in attitude, and finally formation of professional networks, had not been investigated. This deficiency provided the impetus for the results of the investigation in this research to help close the gap.

Chapter Three outlines the methodology used in the research study. A flow chart was developed to show the progression path for the primary data collection. Initially, a quantitative data collection tool (the Feedback Survey) was used to collect data from the whole cohort. The results from analysis of this data then determined that an additional phase of data collection was required. This required a different type of data (qualitative) to be collected and, therefore, a different mechanism (the Clarification Tool) had to be developed. With the Clarification Tool the qualitative data were collected using written follow-up questions and interviews. The follow-up questions were used to clarify the teachers' responses to the Feedback Survey. When the data from the Feedback Survey were graphed, it was evident that there was a greater shift in the results for some of the statements than for others. Some of these statement results stood out and they were earmarked for further investigation. This formed the basis for the design of the targeted interview questions in the Clarification Tool. These questions were needed to help gain a greater insight into the actual

changes that the teachers were experiencing and to draw out the reasons behind these particularly interesting shifts in results.

Qualitative data was collated and cross-referenced in order to obtain a consistent picture of the teachers' experiences and changing perceptions. Data reduction occurred by inductively identifying themes and assigning statements to those identified themes that refined and substantiated their validity (Cohen, Manion, & Morrison, 2000). So, this became a mixed method approach for collecting data and provided a rich dataset for analysis.

The results of the research study were presented in Chapter Four. Results from the Feedback Survey are given first in both tabulated and graphical form. Both presentations are used to show the shifts in the means of the results for each statement and each shift was analysed to address each one of the research questions. The qualitative data from the Clarification Tool were then invoked to make meaning from the Feedback Survey and fill in the gaps. All the statements in the Feedback Survey had a positive shift in their mean result following the professional development programs. However, the shifts in the mean for some of the statements were greater than for others. Statements of interest were identified and examined and this enabled the quantitative data results to be fully explained.

5.3 MAJOR FINDINGS OF THE STUDY

The major findings of this research study are summarised in order of the research questions presented in Chapter One.

5.3.1 Valuable and Useful Data Collection Tools

The first research question proposed in this research study was:

Is a mixed method approach using the Feedback Survey and the Clarification Tool a valuable and useful way to collect primary data from science educators attending professional development programs for science educators about the mining and mineral processing industries?

It can be concluded that generally the Feedback Survey was a reliable survey tool. The means for the results for the data collected pre-PD and post PD were statistically significant ($p < 0.001$). This confirmed that a valid approach was being used and that the results could be used with a high degree of confidence in the research study. The quantitative data collected in the Feedback Survey were tabulated and graphed and this presented the data in a suitable form for clearly displaying and easily identifying the shifts in the statement means. However, some shifts in the mean results were larger than others. So the four largest shifts in the mean results and the smallest shift in the mean result were chosen for further investigation via the Clarification Tool.

When the Feedback Survey and the Clarification Tool were used together, all of the research questions were able to be answered. This showed that a mixed method approach is a valuable and useful way to collect primary data for this type of research study.

5.3.2 Science Educators' Content Knowledge of the Mining and Mineral Processing Industries after Professional Development Programs

The second research question posed in this research study was:

Can science educators' knowledge of the mining and mineral processing industries be increased through targeted professional development?

Statements from the Feedback Study were used to answer this research question. There was a positive shift in the means of the results for statements 1, 14, 15 and 16. In the Feedback Survey, science educators reported an increase in their overall knowledge of the mining and mineral processing industries after a PD event. They also reported an increase in them becoming a better classroom teacher after a PD event. From this, it can be concluded that the stated aims of the professional programs had been achieved.

The Clarification Tool contributed qualitative data to support the assertion that the science educators' content knowledge had improved as a result of participating in the professional development programs. Further, they were able to identify the areas of content that they had gained increased knowledge in and that they had gained confidence in teaching this content because of the knowledge that they had gained from participating in the professional development program.

5.3.3 Application of Content Knowledge to the Curriculum Documents

The third research question posed in this research study was:

Are science educators able to apply their knowledge of the mining and mineral processing industries to science curriculum after their engagement in professional development programs about science content in the mining and mineral processing industries?

Data used to answer this research question could not be drawn solely from the Feedback Survey. However, post-PD, there was a positive shift in the mean result for statement 5 (*I use examples of the mining and mineral resource industry in my classes frequently*). It can be concluded that after the professional development program, the science educators had been shown examples that they could now use. Also, there was a positive shift in the mean result for statement 11. After the professional development program, the science educators agreed that better understanding of the mining and mineral processing industries could be gained from hands-on activities.

To understand exactly how the science educators applied the content knowledge about the mining and mineral processing industries to the curriculum documents, qualitative data was drawn from the Clarification Tool. Statements from the science educators were used to support the assertion that they were willing to provide real world examples of mining and mineral processing industries when it suited their specific teaching needs. Further, the Clarification Tool provided evidence that they were able to write curriculum documents and teaching resources using content gained from the professional development programs.

5.3.4 Content-rich Professional Development Programs and Science Educators' Attitudes about the Mining and Mineral Processing Industries

The fourth research question posed in this research study was:

Can content-rich professional development programs about the mining and mineral processing industries change science educators' attitudes about the mining and mineral processing industries?

Data from the Feedback Survey were used to answer this research question. Statement 3 directly addressed the issue of attitude. There was a positive shift in the mean result for this statement and this can be interpreted that the professional development programs increased the science educators' positive view of the mining and mineral processing industries. Other positive shifts in the mean results from the Feedback Survey for statement 7 – *High tech industry*, statement 4 – *Help environment* and statement 9 – *Talk to colleagues* also provides evidence that the science educators had a post-PD change of attitude about the mining and mineral processing industries.

5.3.5 Know a Scientist or Researcher in the Mining and Mineral Processing Industries

The fifth research question posed in this research study was:

Are science educators able to form professional networks with scientists working in the mining and mineral processing industries?

The largest positive shift in the mean result in the whole Feedback Survey was for statement 6 – *Knows a scientist*. This could be due to the structure of the professional development program and the interactions during the program between the science educators and the scientists working in the mining and mineral processing industries. The scientists gave the science educators their contact details

and encouraged them to stay in touch. They stated that if the science educators required any further information about the mining and mineral processing industries that they would supply it for them.

The Clarification Tool was also used to answer this research question. The science educators in the QCAT/Education Queensland cohort enjoyed the interaction with the scientists. They used the scientists as a sounding board to check that their content about the mining and mineral processing industries was correct and that it was appropriate to go into the teaching resource. However, when the teaching resource was written and the program came to an end, the teachers did not feel the need to remain in contact with the scientists. However, they did appreciate the fact that they knew where to contact a scientist if they needed to confer with one in the future.

5.4 IMPLICATIONS OF THE RESEARCH STUDY FOR SCIENCE EDUCATORS

Change is always part of the science education landscape. A substantial change that is coming for all senior science educators in Australia is the roll-out of the Australian Curriculum for the senior science subjects of Physics, Chemistry, Biology, and Earth and Environmental Science. While Physics, Chemistry and Biology are already similar to the existing senior sciences, Earth and Environmental Science is considered to be different and is a new subject. Specialised Earth and Environmental Science teachers will be required to teach this new subject and Professional Development will be required for teachers already in education systems to teach this new subject. Content-rich professional development programs about the mining and mineral processing industries that link to the curriculum documents could be seen as a viable option for these teachers to give them confidence to teach the new subject. Further, universities will need to offer courses for their pre-service teachers who are intending to teach Earth and Environmental Science. The findings from this research study could help to ensure that professional development providers plan the required professional development programs for these science educators. The Feedback Survey, used in parallel with the Clarification Tool, would provide valuable insight into the effectiveness of any professional development program

A key finding was that science educators found it very beneficial to develop a relationship with an industry professional. However, once the professional development program ceased, they found it very difficult to maintain this relationship. The main obstacle was time – they found that the amount of time required to keep in touch with, and organise school visits by, the industry professionals encroached excessively into their school work hours. Also, because industry involvement is not catered for in the current curriculum, it is very hard to justify allocating time to maintaining these relationships.

5.5 IMPLICATIONS OF THE RESEARCH STUDY FOR PROFESSIONAL DEVELOPMENT PROVIDERS

One of the aims for each of the professional development programs that were investigated in this research study was to bring science educators and scientists together. They were encouraged to form long-lasting professional relationships so that the science educators had a “go to” person to contact if they required further content knowledge about the applied science in the mining and mineral processing industries. The applied science from the mining and mineral processing industries could then be embedded into the teachers’ teaching documents and resources. The science educators in the QCAT/Education Queensland cohort did interact with the scientists during the course of the program, but this did not continue after the program was completed. Professional development providers could keep the support in place for the science educators and the scientists after the professional development program is finished.

5.6 LIMITATIONS OF THE STUDY

The professional development programs examined in this research study were innovative. The professional development providers made a considered effort to ensure that the participants had many opportunities to engage and participate in enriching hands-on learning experiences. The science educators were willing participants and enjoyed the interaction between them and the scientists. There were however, some limitations to the research study that collected primary data from the science educators and these limitations will now be identified.

To attend the professional development programs, the science educators had to either take time off away from their classes or attend in their own time. Both of these scenarios are prohibitive and not all science educators could attend, even if they had wanted to. From a research point of view, this limited the sample size of the participants in the study. In turn, if the sample size is limited, it may affect the representativeness of the results.

The Feedback Survey was used to collect quantitative data from the whole cohort. However, the qualitative data were only collected from the QCAT/Education Queensland cohort. This may affect the representativeness of the qualitative data sample. Further, time constraints applied to the researcher and conducting interviews are time-demanding for both interviewer and interviewee.

As the research study finished at the same time the professional development programs did, there is no way to do further follow-up work on the effectiveness of the professional development events. Therefore, it is difficult to know whether the positive shifts in the mean result continued after the professional development programs ended. Further, the research study ended at the point where a resource was written for teachers to implement in their classrooms – further research could be done into how the delivery of the resource in the classroom progressed.

5.7 FUTURE RESEARCH

The sample size in this research study was 111 participants. A larger number of participants in the study to collect both quantitative and qualitative data could broaden the scope of the research. Future research could collect data from other disparate groups, not just from Australia and USA. Non-English-speaking countries could also be included in the dataset and so could data collection from developing countries which are resource rich and are attempting to establish mining and mineral processing industries.

The statements on the Feedback Survey were grouped to enable the research questions for this research study to be answered. In addition, when more data were

required, the Clarification Tool was used to collect qualitative data relating to the themes of the research questions. The Feedback Survey is a valuable qualitative data collection tool and can be used in a flexible way. However, It could be extended and used for other research studies about the mining and mineral processing industries that have different research focii. The statements could be grouped in multiple ways to develop themes for research and each statement could be investigated in greater depth in line with those themes.

5.8 FINAL COMMENTS

This research study assessed the impact of content-rich professional development events on science educators' attitudes towards the mining and mineral processing industries. The quantitative and qualitative data collected showed a positive change in attitude across all statements in the Feedback Survey (to varying extents) and the Clarification Tool gave reasons why the changes occurred. The Clarification Tool added information that would not have otherwise been available and the mixed method approach was tailored to probe the themes that were identified in more detail. This method of data collection would be recommended for this type of research study.

The teachers were willing to use examples from the mining and mineral processing industries to illustrate how science is used in the real world. They talked about careers in the mining and mineral processing industries if it complemented the unit of work that they were currently teaching. The teachers were able to write curriculum documents using the content knowledge from the professional development events and tailored this to the learning needs of their students. The teachers had not contacted the scientists after the project had finished, but indicated that they would if they required any further content knowledge.

Even though “Working Scientifically” is a requirement of the new science syllabus, teachers often find it difficult to find relevant examples to enhance their teaching. The professional development associated with this project definitely captured and motivated the teachers. They developed a resource that is being shared with other science teachers and, in doing so, this encourages other teachers to interact with

scientists in their local community. In the quest to find real life examples of scientists and their work and to use these examples in their teaching practice, the teachers in this study have made an attitudinal change towards the mining and mineral processing industries. When science teachers interact with scientists, they use the experience they gain to enhance their classroom practice.

Using both quantitative and qualitative data give science education researchers a method of measuring the change in science teachers' attitudes towards the content presented at professional development events. If teachers have support, they gain confidence to teach science using up-to-date, real-life experiences.

Finally, even though it is disappointing to note that no further interaction (that the researcher knew about) continued once the QCAT/Education Queensland professional development program finished, the teachers from the QCAT/Education Queensland cohort who were part of the writing team continued to use it when they taught their unit of work. The teaching resource was made available to the other Education Queensland teachers and was distributed by the SSO. The SSO gave a presentation at a science teachers' conference and the SSO and one other member of the writing team presented the resource to the science teachers. The resource was made available at the end of the presentation session for other science teachers to use.

CHAPTER SIX

REFERENCES

Adey, P. (2004). The Professional Development of Teachers: Practice and Theory. Dordrecht, The Netherlands, Kluwer Academic Publishers.

Ainley, J., Kos, J., & Nicholas, M. (2008). Participation in Science, Mathematics and Technology in Australian Education. Camberwell, The Australian Council for Educational Research.

Appleton, K. (1995). "Student teachers' confidence to teach science: Is more science knowledge necessary to improve self-confidence?" International Journal of Science Education **19**: 357-369.

Appleton, K. (1997). Teaching Science: Exploring the Issues. Rockhampton, Central Queensland University Press.

Appleton, K. (2003). "Science activities that work: Perceptions of primary school teachers." Research in Science Education **32**: 393-410.

Australian Curriculum, Assessment and Reporting Authority. (2010). Science (Foundation to Year 10) Information Sheet.

Australian Curriculum, Assessment and Reporting Authority. (2013). Senior Secondary Curriculum – Earth and Environmental Science, Education Services Australia.

Australian Institute for Teaching and School Leadership. (2014). Australian Professional Standards for Teachers. Australian Government.

Australian Science Teachers' Association. (2002). National Standards for Highly Accomplished Teachers of Science. Deakin West, ACT, Australian Science Teachers Association.

Australian Curriculum, Assessment and Reporting Authority. (2013). The Shape of the Australian Curriculum: Version 4. Sydney NSW, Australian Curriculum,

Assessment and Reporting Authority.

Australian Curriculum, Assessment and Reporting Authority. (2014). The Australian Curriculum v7.2 Science Foundation to Year 10. Australian Curriculum, Assessment and Reporting Authority, Education Services Australia.

Australian Teacher Performance and Development Framework (2012)

Bainer, D.L. & Wright, D. (1998). "Teacher Choices about Their Own Professional Development in Science Teaching and Learning." ERIC Clearing House, Washington DC. Paper presented at the Annual Meeting of the American Educational Research Association (San Diego, CA, April 13-17, 1998)

Bartholomeusz, S. (2012). "Does no one understand the mining industry?" Business Spectator (12 SEPT 2012).

Bartier, F., Tuckwell, K. & Way, A. (2003). "Supply of professional staff: Is there a problem?" AusIMM Bulletin: Journal of the Australian Institute of Mining and Metallurgy **Jan/Feb 2003**: 30-34.

Brewer, J. & Hunter, A. (1989). Multimethod research: A synthesis of styles. Newbury Park, CA, Sage.

Churach, D. (2004a). "Bridging the gap: Science teachers hold the key to our future." AusIMM Bulletin: Journal of the Australian Institute of Mining and Metallurgy **Jan/Feb 2004**: 28-32.

Churach, D. (2004b). "Teacher-industry Synergies: A convergence of problems offers sustainable solutions." The Journal of the Science Teachers' Association of Western Australia **40**(2): 11-17.

Churach, D. (2005). Teacher professional development as the key to a sustainable workforce in the mineral resource sector. Fourth International Conference on Science, Mathematics and Technology Education. Victoria, Canada.

Churach, D. & Fisher, D. (2001). "Science students surf the web: Effects on constructivist classroom environments." Journal of computers in mathematics and

science teaching **20**(2): 221-247.

Churach, D. & Nichols, D. (2007). Industry Supported Professional Development in the Mineral Resource Sector. Rotterdam, The Netherlands, Sense Publishers.

Churach, D. & Rickards, T. (2003). The Science Career Inventory (SCI): What motivates students to pursue higher degrees in metallurgy? Western Australian Institute for Educational Research Forum, Western Australia.

Churach, D. & Rickards, T. (2006). Motivational drivers affecting career choices in the resource sector: The science career inventory (SCI). Sustainable communities and sustainable environments: Proceedings of the Third International conference on Science, Mathematics and Technology Education, Perth, Curtin University of Technology.

Churach, D. & Welham, N. (2007). Secondary school science teachers as the key to a sustainable workforce in the mining and mineral processing industry - Changing people's attitudes. World Gold 2007. Cairns, AusIMM The Minerals Institute.

Cohen, J. (1977). Statistical Power Analysis for the Behaviour Sciences. New York, Academic Press.

Cohen, L., Manion, L. & Morrison, K. (2000). Research Methods in Education. London, Routledge Falmer.

Coleman, R. & Coleman, A (2003). "Youth Mentor Online." Youth Studies Australia **22**(4): 3-10.

Colorado School of Mines. (2007). "All about mining - A total concept of the mining industry for K-12 teachers." Retrieved 02.01.2011, from <http://www.denvergold.org/events/a-total-concept-of-the-mining-industry.html>.

Commonwealth of Australia. (2007). Meeting in the middle - assessment, pedagogy, learning and disadvantage. Literacy and Numeracy in the Middle Years of Schooling Initiative - Strand A Queensland Project Report. Barton ACT, Australian Department of Education, Employment and Workplace Relations (DEEWR).

Coolahan, J. (2002). Teacher Education and the Teaching Career in an Era of Lifelong Learning, OECD Publishing.

Creswell, J. (2005). Education Research: Planning, Conducting and Evaluating Quantitative and Qualitative Research. New Jersey, Pearson Education International.

CSIRO. (2007). "Queensland Centre for Advanced Technologies (QCAT)." Retrieved 29.06.2008, from <http://www.csiro.au/Outcomes/Energy/Energy-from-oil-and-gas/QCAT.aspx>.

Cumming, J., Wyatt-Smith, C., Ryan, J. & Doig, S. (1998). The literacy curriculum interface: The literacy demands of the curriculum in post-compulsory schooling - Final Report, Griffith University and Department of Employment, Education, Training and Youth Affairs.

Deming, W. (1986). Out of the crisis: quality, productivity, and competitive position. Cambridge, Cambridge Press.

Department of Education, Employment and Training. (2014). Role Description Teacher (Generic). Brisbane.

Department of Education, Employment and Workplace Relations. (2007). Literacy and Numeracy in the Middle Years of Schooling - Queensland Project Report: Meeting in the middle - assessment, pedagogy, learning and educational disadvantage. Department of Education, Employment and Workplace Relations. Barton ACT, Commonwealth of Australia.

Education Queensland. (2006). "Science Education Strategy 2006-2009."

Ericsson, M. (2012). "Trends in the mining and metals industry." International Council on Mining and Minerals October, 2012.

Fraser, B. & Tobin, K. (1991). Combining Qualitative and Quantitative Methods in Classroom Environment Research. Oxford, Pergamon Press.

Fraser, B. & Walberg, H. (1981). "Psychosocial learning environment in science classrooms: A review of research." Studies in Science Education **8**: 67-92.

Goodrum, D., Hackling, M. & Rennie, L. (2001). *The Status and Quality of Teaching and Learning of Science in Australian Schools: A Research Report*. Department of Education, Training and Youth Affairs. Canberra, Department of Education, Training and Youth Affairs.

Harris, K., Jensz, F. & Baldwin, G. (2005). *Who's Teaching Science? Meeting the demand for qualified science teachers in Australian secondary schools*. Australian Council of Deans of Science. Melbourne, University of Melbourne.

Harrison, A. & Nichols, D. (2002). *Enhancing science teachers' pedagogical content knowledge at Biloela State High School*. Science Works for the Smart State Conference. Brisbane, State of Queensland, Department of Education.

Hawley, W. & Valli, L. (1999). The essentials of effective professional development: A new consensus. San Francisco, Jossey-Bass Education Series.

Hoban, G. (1997). Opportunities for Knowledge Building in Professional Development Models. Wentworth Falls NSW, Social Science Press.

Hobson, D. (1993). "Re-thinking old ways: Towards a more critical approach to practical work in school science." Studies in Science Education **22**(1): 85-142.

Hofstein, A. (2006). Improving the classroom laboratory learning environment by using teachers' and students' perceptions. Singapore, World Scientific Publishing

Hofstein, A. & Lunetta, V. (2004). "The laboratory in science education: Foundations for the twenty-first century." Science Education **88**(1): 28-54.

Hughes, R., Molyneaux, K. & Dixon, P. (2012). "The Role of Scientist Mentors on Teachers' Perceptions of the Community of Science during a Summer Research Experience." Research in Science Education **42**(5): 915-941.

Lingard, R., Ladwig, J., Mills, M., Bahr, M., Chant, D. & Warry, M. (2001). *Queensland School Reform Authority Longitudinal Study*, A. Thomas (Ed) Brisbane, State of Queensland (Department of Education).

Loucks-Horsley, S. (1989). Developing and supporting teachers for elementary school science education. Washington DC, The Network, Loucks-Horsley, S., Love, N., Stiles, K., Mundry, S. & Hewson, P. (2003). Designing Professional Development for Teachers of Science and Mathematics. Thousand Oaks CA, Corwin Press.

Luke, A. (2003). Beyond the middle: A report about literacy and numeracy development of target group students in the middle years of schooling. Department of Education, Science and Training. St Lucia, Brisbane, School of Education, University of Queensland. **Vol 1**.

Lyons, T. & Quinn, F. (2010). Choosing Science: Understanding the declines in senior high school science enrolments. University of New England, National Centre of Science, ICT and Mathematics Education for Rural and Regional Australia.

MacFarland, T. (1998). "Mann-Whitney U-Test." Retrieved 09.12.2012, from http://www.nyx.net/~tmacfar/STAT_TUT/mann_whi.ssi.

Magnusson, S., Krajcik, J. & Broko, H. (1999). Nature, sources and development of pedagogical content knowledge. Dordrecht, The Netherlands, Kluwer.

Matters, G. (2006). Assessment approaches in Queensland senior science syllabuses. Queensland Studies Authority. Brisbane, Australian Council for Education Research.

Millar, G. (1995). "Helping schools with career infusion." ERIC Digests.

National Curriculum Board. (2009). Shape of the Australian Curriculum: Science. Commonwealth of Australia. Barton ACT, Commonwealth of Australia.

Nicol, M. & Woffenden, M. (2002). The future of extractive metallurgy. Parker Centre Industrial Advisory Committee. Perth, Murdoch University.

Nichols, D., Churach, D. & Fisher, D. (2007). Industry-funded, content-rich professional development: Influences on attitudes towards applied science. National Association of Researchers in Science Education (NARST) Conference. New Orleans, USA.

Nichols, D. (2009). Increasing teachers' content knowledge by developing partnerships with scientists. 40th Australasian Science Education Research Association (ASERA) Conference. Geelong, VIC.

Nichols, D., Monteath, S., Churach, D. & Fisher, D. (2009). Science teachers and scientists working together: The partnership's impact on teachers' attitudes. Association for Science Teacher Education (ASTE) International Conference. Hartford, USA.

Nichols, D. & Appleton, K (2008). Teaching literacy in the middle years using science as the host. Association for Science Teacher Education (ASTE) International Conference. St Louis, USA.

Popham, W. & Sirotnik, K. (1973). Education Statistics: Use and interpretation. Harper & Row Publishers. New York, USA.

Queensland Curriculum, Assessment and Reporting Framework. (2007). Science Essential Learnings. Department of Education, Training and the Arts. Brisbane, The State of Queensland (Queensland Studies Authority).

Queensland Department of Education. (2003). Science State, Smart State: Spotlight on Science. Education Queensland. Brisbane, Queensland Department of Education.

Queensland Department of Education. (2005). Professional Standards for Teachers: Guidelines for Professional Practice. Education Queensland. Brisbane, Queensland Department of Education.

Queensland School Curriculum Council. (1999). Years 1 to 10 Science Syllabus. The State of Queensland. (The Office of the Queensland Curriculum Council). Brisbane, Queensland Curriculum Council.

Rennie, L. (2012). Evaluation of the Scientists in Schools Project 2011-2012. Australian Government Department of Education, Employment and Workplace Relations. Dickson ACT, CSIRO Education.

Rodrigues, S. (2005). Teacher Professional Development in Science Education. New York, Nova.

Schulman (1987). "Knowledge and teaching: Foundations of the new reform." Harvard Educational Review **57**(1): 1-23.

Skamp, K. (1991). "Primary science and technology: How confident are teachers." Research in Science Education **21**: 290-299.

Smith, D. & Neale, D. (1989). "The construction of subject matter in primary science teaching." Teaching and Teacher Education **5**(1): 1-20.

Sparks, D. & Hirsh, S. (1997). A new vision of staff development Oxford OH, National Staff Development Council.

Stats Direct. (2013). "P values." Retrieved 20.11.2013, from http://www.statsdirect.com/help/Default.htm#basics/p_values.htm.

Tague, N. (2005). The Quality Toolbox, ASQ Quality Press.

Teacher Quality and Educational Leadership Taskforce. (2003). A National Framework for Professional Standards for Teaching. Department of Education, Training and Youth Affairs. Ministerial Council on Education. Carlton South VIC, Curriculum Corporation.

Tunks, L. (1997). From isolation to integration: The change process in an elementary school: The teachers' perspective. Annual Meeting of the American Education Research Association. Chicago, USA.

Tytler, R. (2007). Re-imaging science education: Engaging students in science for Australia's future. Camberwell, Victoria, Australian Council for Education Research.

Tytler, R., Osborne, J., Williams, G., Tytler, K. & Cripps Clark, J. (2008). Opening up pathways: Engagement in STEM across the Primary-Secondary school transition. Department of Education, Employment and Workplace Relations.

Venville, G., Rennie, L., Hanbury, C. & Longnecker (2013). "Scientists reflect on why they chose to study science." Research in Science Education **42**(6): 2207-2233.

Wallace, J. & Louden, W. (2002). Dilemmas of science teaching: Perspectives on

problems of practice. London UK, Routledge Falmer.

Western Australian Government. (2003). "Western Australia Youth Survey"
Retrieved 12.01.2006, from <http://www.youthsurvey.wa.gov.au/>.

Wong, S. & Hobson, D. (2009). "From the horse's mouth: What scientists say about scientific investigation and scientific knowledge." Science Education **93**(1): 109-130.

Wyatt-Smith, C. & Cummings, J. (2003). "Curriculum literacies: Expanding domains of assessment." Assessment in education: Principles, Policy and Practice **10**(1): 47-59.

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APPENDIX A

Permission Letter

Assessment of teacher professional development as a change agent for the mining and mineral processing industries.

The aim of this research project is to determine the most appropriate model for the delivery of information about science and industry to science teachers to ensure that there is a positive change in student learning. Data for this study will be collected from both science teachers and their students.

Science teachers will be asked to provide some or all of the following:

- Survey
- Descriptive answers
- Interviews
- Unit plans
- Assessment items

Students will be asked to provide some or all of the following:

- Pre- and post tests
- Assessment scripts
- Interviews

All data collected will be confidential and stored securely at the Science, Maths Education Centre (SMEC) for a period of five years. The data collected will only be used for the purpose of this survey. The researcher and her supervisors are the only persons who will have access to the data collected. Persons participating in the study will not be identified in any published material.

Participation in this study is completely voluntary and participants are at liberty to withdraw at any time without prejudice or negative consequences.

Further information about this study can be obtained from:

**Di Nichols
Biloela State High School
Locked Bag 2
Biloela 4715**

**Dan Churach
Centre for Sustainable
Resource Processing
PO Box 1130
Bentley, WA 6102**

If participants wish to make a complaint on ethical grounds about the collection of data they should contact:

Secretary of Human Research Ethics Committee – Curtin University of Technology.

This project has been approved by the Curtin University Human Research Ethics Committee.

Consent Form

Assessment of teacher professional development as a change agent for the mining and mineral processing industries.

I _____ (Name)

Have been informed of and understand the purposes of the study have been given an opportunity to ask questions. I understand that I can withdraw at any time without prejudice and that any information which might potentially identify me will not be used in published material. I therefore agree to participate in the study as outlined to me.

Signature _____ Date _____

Signature of Parent (if participant is a student) _____

APPENDIX B

The Feedback Survey

GAMSET / CSRP / Murdoch Teacher Professional Development Program Feedback Survey

We are gathering data in an attempt to measure the effectiveness of the GAMSET / CSRP / Murdoch University Teacher Professional Development activities. Please take a few minutes to complete the following series of questions concerning your attitudes towards the Mining and Mineral Resource industry and how these attitudes may have changed after your participation in our Teacher Professional Development Program.

You are asked to respond to each of the following statements twice, firstly from the perspective you had before the Mineral Processing Professional Development work you have done and secondly from your perspective today after having participated in one or more of these events.

Your feedback will help to make our professional development work more supportive of you and other teachers in the future.

Thank you in advance for your input. You can follow the on-going report of our research at the Centre for Sustainable Resource Processing website at <http://www.csrp.com.au/>.

Regards,
Di Nichols and Dan Churach

1. NAME _____ SCHOOL _____ <div style="text-align: center; margin-top: 5px;">_____ (optional)</div>	
How many GAMSET / CSRP / Murdoch Professional Development Events have you participated in to date? Tick the boxes that apply. Intro Session at QAL, July 2005 <input type="checkbox"/> Copper Lecture/Talk, November 2005 <input type="checkbox"/> Aluminium through the Looking Glass Lecture, June 2006 <input type="checkbox"/> Any GAMSET activity? _____	
	Strongly Disagree Disagree No Opinion Agree Strongly Agree
My overall knowledge of the Mining and Mineral Resource industry is very extensive?	1. Before the first PD 1 2 3 4 5 2. Today 1 2 3 4 5
I believe that careers in the Mining and Mineral Resource industry are worthwhile recommending to my students.	3. Before the first PD 1 2 3 4 5 4. Today 1 2 3 4 5
I have a very positive attitude towards the Mining and Mineral Resource industry in Australia.	5. Before the first PD 1 2 3 4 5 6. Today 1 2 3 4 5
I believe an excellent way to solve environmental problems can be found through Mining and Mineral Resource research.	7. Before the first PD 1 2 3 4 5 8. Today 1 2 3 4 5
I use examples of the Mining and Mineral Resource industry in my classes frequently.	9. Before the first PD 1 2 3 4 5 10. Today 1 2 3 4 5
I know a scientist I can e-mail or phone to get information concerning a mineral processing or chemistry question.	11. Before the first PD 1 2 3 4 5 12. Today 1 2 3 4 5

PLEASE TURN THE PAGE TO COMPLETE THE OTHER SIDE...

2.		Strongly Disagree	Disagree	No Opinion	Agree	Strongly Agree
I consider a Mining and Mineral Resource in Australia to be a modern, high-tech industry.	13. Before the first PD	1	2	3	4	5
	14. Today	1	2	3	4	5
I think that a Mining and Mineral Resource industry offers an exciting career path for young people.	15. Before the first PD	1	2	3	4	5
	16. Today	1	2	3	4	5
I talk to colleagues and friends about issues concerning the Mining and Mineral Resource industry in Australia.	17. Before the first PD	1	2	3	4	5
	18. Today	1	2	3	4	5
I believed that people in the Mining and Mineral Resource industry care about the natural environment.	19. Before the first PD	1	2	3	4	5
	20. Today	1	2	3	4	5
The more teachers do hands-on activities, the better they will understand the Mining and Mineral Resource industry.	21. Before the first PD	1	2	3	4	5
	22. Today	1	2	3	4	5
I provide information to students concerning the possibility of a Mining and Mineral Resource major at university.	23. Before the first PD	1	2	3	4	5
	24. Today	1	2	3	4	5
I have a positive view of career researchers and scientists in Mining and Mineral Resource industry.	25. Before the first PD	1	2	3	4	5
	26. Today	1	2	3	4	5
Getting a bit of an “inside view” of the Mining and Mineral Resource industry makes me a better teacher.	27. Before the first PD	1	2	3	4	5
	28. Today	1	2	3	4	5
Getting a bit of an “inside view” of any Australian industry makes me a better teacher.	29. Before the first PD	1	2	3	4	5
	30. Today	1	2	3	4	5
PDs that offer a maximum amount of science content-oriented material make me a better classroom teacher.	31. Before the first PD	1	2	3	4	5
	32. Today	1	2	3	4	5

THANK YOU FOR YOUR PARTICIPATION.

*If you would like to know more about our research, please contact Di Nichols
(dnich25@eq.edu.au)*

or

Dan Churach (dan.churach@csrp.com.au) or visit our website at <http://www.csrp.com.au/>.

APPENDIX C

Qualitative Data for Assertions

Qualitative Data for Assertions

1. Teachers' content knowledge about the mining and mineral processing industries had improved as a result of participating in the professional development events.

Science Educator (Coded)	Source	Date	Quote
MW	Follow-up questions (Phase 2, Part 1)	25.07.07	I felt more confident about teaching the Earth science unit because of the knowledge that I had gained from the workshops.
HH	Follow-up questions (Phase 2, Part 1)	25.07.07	My knowledge about mining had improved. I believe this to be a direct benefit to my students as I am able now use this knowledge in class when I am teaching the units.
AA	Follow-up questions (Phase 2, Part 1)	25.07.07	I had never heard of gasification
AA	Interview (Phase 2, Part 2)	04.04.08	I can see links with my classroom teaching. What goes on here and the things [knowledge] that I can take back and use in the classroom.
DP	Interview during the writing of the resource (Phase 2, Part 3)	01.12.08	Makes it more real not just theoretical when they see results – it is more meaningful When you first go you don't know what it was leading to when they talked about coal gasification. I felt it wasn't relevant to my primary school context. There are benefits – talking with other teachers who teach science in primary schools and when you have primary schools where many teachers don't seem to put much emphasis in science (they are not trained and so don't feel confident). They load the course with SOSE.
GH	Interview (Phase 2, Part 2)	04.04.08	Seeing different kinds of science, seeing students and what they had learnt at launch was inspirational / encouraged use of the unit. I have seen different kinds of science and learnt much about mining.
MG	Interview (Phase 2, Part 2)	04.04.08	Gave rigor and scientific validity to task.
RR	Follow-up questions	25.07.08	Gained good science teaching ideas and easy access to resources I was exposed to the new concept of 'clean coal'

	(Phase 2, Part 1)		Learnt basic greenhouse information
RH	Follow-up questions (Phase 2, Part 1)	25.07.07	Talk to scientists, different (great ideas, broaden knowledge learning, networking with teachers)

2. Teachers were willing to provide real world examples of mining and mineral processing when it suited their specific teaching needs.

Science Educator (Coded)	Source	Date	Quote
CM	Interview (Phase 2, Part 2)	04.04.08	Real life learning about mining gives enriched learning experiences for students.
AA	Follow-up questions (Phase 2, Part 1)	25.07.07	After touring the QCAT facility, I now see what scientists are doing and understand how they work.
DR	Interview (Phase 2, Part 2)	04.04.08	Teachers are able to use the information to cater for the different learning styles and learning needs in their classes. Watch and talk about (students could have scribes) Supports negotiated curriculum Catering for learning styles and bringing this to life. Also allows for students with learning disabilities to participate when they see things – others can scribe for them. Vital to have literacy activities embedded in science
DP	Interview during the writing of the resource (Phase 2, Part 3)	01.12.08	More room is required for students do the activities about mining. I try to focus on questions and essential learnings. More space for what the kids do is required.
JP	Follow-up questions (Phase 2, Part 1)	25.07.07	When I get the question ‘what’s the point of this?’ or how do we know that?’ we talk about how scientists discovered things.
ES	Interview during the writing of the resource (Phase 2, Part 3)	01.12.08	Modelling greenhouse was modified to show temperature rise and fall to show retention of heat. Set prac used with modifications in year 8 My students are engaging with concepts about mining and I find that planning hands-on activities for the student is very beneficial.
DF	Interview (Phase 2, Part 2)	04.04.08	That’s the whole point – they are in school. I’m often talking to them about academic success to make kids realize that some people do the activities, e.g. in science, for their work...point out people can pursue their

	Part 2)		passions as a career.
RH	Interview (Phase 2, Part 2)	04.04.08	Co-ordination of teachers / logistics. The accuracy of science in the resources is important and the scientists can provide that. Teachers need to convert that for their students. Teachers know their students' level of comprehension.
MW	Follow-up questions (Phase 2, Part 1)	25.07.07	I like to use real examples of what scientists are doing when it relates to my teaching topic. The interactions with these scientists has allowed me to do that.

3. Teachers were able to write curriculum documents and teaching resources using material from the professional development events.

Science Educator (Coded)	Source	Date	Quote
DP	Interview during the writing of the resource (Phase 2, Part 3)	01.12.08	Would link to things he does. Weather unit fits in.
ES	Interview during the writing of the resource (Phase 2, Part 3)	01.12.08	The components of the CD have been used to re-develop a Year 9 unit. Given the nature of the unit tasks of the unit tasks we have written, we are able to adapt assessment tasks to fit the new content about mining and the processing of minerals.
JP	Interview during the writing of the resource (Phase 2, Part 3)	01.12.08	Used in Year 9 Dynamic earth Unit We fit some of the activities into assessment (greenhouse diagram activity) and did Greenhouse experiment
MG	Interview during the writing of the resource (Phase 2, Part 3)	01.12.08	I used filters as major assessment item for the unit. It was good because it incorporated technology and science. I changed the activities for literacy rotations, depending on whether they were independent or teacher guided activities. I used different materials for experiments I feel confident in writing teacher resources about mining. I changed some old activities to suit the new content

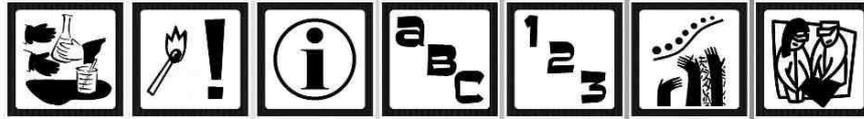
4. Teachers had not initiated any further contact with the scientists

Science Educator (Coded)	Source	Date	Quote
AA	Follow-up questions (Phase 2, Part 1)	25.07.07	I gained a fuller understanding of what QCAT does and what happens here. I can see that links can be developed between the school and QCAT.
AB	Follow-up questions (Phase 2, Part 1)	25.07.07	The scientists at QCAT are busy and I haven't had time to contact them either.
DP	Follow-up questions (Phase 2, Part 1)	25.07.07	That's the whole point – we are in school and the scientists are working at QCAT. We are both really busy.
ES	Interview during the writing of the resource (Phase 2, Part 3)	01.12.08	Opportunities for staff to work with scientists/researchers. Opens eyes of teachers/students to topical environmental science issues. Career paths are explored. Would be good to have 3 or 4 career snapshots in next release.
AC	Follow-up questions (Phase 2, Part 1)	25.07.07	I was interested in the scientist's background and how they became involved in their career. These is good direction for students.
JP	Interview during the writing of the resource (Phase 2, Part 3)	01.12.08	When I get the question 'what's the point of this' or 'how do we know that' we talk about how scientists discovered things. We also discuss cool science jobs regularly. I try to be enthusiastic and encourage the students who have inquisitive minds to pursue science.
MG	Interview (Phase 2, Part 2)	04.04.08	Time consuming topic complex for primary – teachers need lots of background support to teach. Personal networks, professional development, reputation as a leader as science educator, links with scientists/community, middle phase links with high school.

RR	Follow-up questions (Phase 2, Part 1)	25.07.07	Its handy to have access to materials eg coal if I need it. Access own scientists for support
RH	Follow-up questions (Phase 2, Part 1)	25.07.07	Access to the scientists and their knowledge is valuable and I know where to contact if I need to.

APPENDIX D

Teacher Resource



Using the Activity Icons

At the top of each activity, icons are highlighted for teachers to quickly and easily identify the nature and focus of the activity.

The icons are used to represent:



Hands-on experiment



Caution: this experiment requires close adult supervision or may be best performed as a teacher demonstration



Teacher or student background information



Literacy activity



Numeracy activity



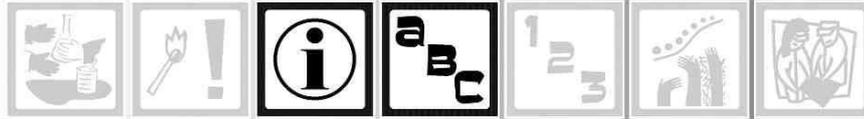
Indigenous perspectives activity



Careers in Science

POWERFUL SCIENCE: CLEANING UP OUR ENERGY UNIT OVERVIEW

Year Level/s	Middle years (4 – 9)				
Purpose	Students engage with energy and environmental concepts as they investigate the highly topical and relevant scientific research area of low emission coal technologies.				
Unit Description <i>Context for learning</i>	<p>With global warming becoming more of a concern and the current high costs of alternative energy sources, it is essential to research how we can use energy resources such as coal, in a more sustainable manner. Research on low emission coal technologies has been occurring for many years but only recently has the media attention and society's desire to solve the global warming issue made it essential for teachers and students to engage with this scientific topic.</p> <p>POWERFUL SCIENCE: CLEANING UP OUR ENERGY looks at the greenhouse effect, coal as an energy resource, current uses of coal and how to make coal use more environmentally friendly. It takes complex scientific processes involved in low emission technologies such as coal gasification and post combustion capture of hydrogen and CO₂, and draws out the fundamental scientific concepts that students can engage with on their level, in a practical manner.</p>				
Teaching and Learning Strategies <i>5 E's Model</i> <i>Incorporating Literacy and Numeracy</i>	<p>This unit is structured upon the 5 E's inquiry model of teaching which reflects a constructivist view of learning. Students' knowledge and understanding are developed through the 5 phases of learning which include:</p> <p>ENGAGE - Sets the context, raises questions, elicits student mis/preconceptions EXPLORE - Investigation work, first hand, concrete experience of the topic or phenomenon EXPLAIN - Explanations/communication of the students' understanding ELABORATE - Extension of the topic/concept, applying to new situations EVALUATE - Assess, compare, reflect</p> <p>The unit reflects strong cross-curricular priorities of literacy and numeracy, to enable students to analyse and respond to the world around them, to construct and apply their knowledge effectively and to convey their understandings to others.</p>				
Inquiry Question/s <i>The key questions which guide the sequence of the unit include:</i>	1. ENGAGE: <ul style="list-style-type: none"> • What is climate change? • What are greenhouse gases? 	2. EXPLORE: <ul style="list-style-type: none"> • How do coal-fired power stations impact on the environment? • What is coal? • Where is coal found? • How is coal formed? 	3. EXPLAIN: <ul style="list-style-type: none"> • How is coal mined? • How is coal used in electricity production? 	4. ELABORATE: <ul style="list-style-type: none"> • What are low emission coal technologies? • How do they remove unwanted by-products? • What are techniques used in separation? 	5. EVALUATE: <ul style="list-style-type: none"> • How can we design an effective filter?
Develop Assessment <i>Formal/ Informal assessment</i>	Assessment Tool	What will be assessed?		When will it be assessed?	
	Generic criteria sheet	Students ability to "work scientifically"		Throughout the unit	
	Filter Design Task	Students ability to experiment with filter materials to create an effective filter		On completion of the filter design task	
Make Judgements	A generic criteria sheet has been developed using the Science standards from the Queensland Curriculum Assessment and Reporting Framework. The criteria sheet has been designed for use with any of the hands on experiments, including the final assessment item.				



Investigating the Greenhouse Effect

Key concept:

This activity aims to investigate the Greenhouse effect through a variety of literacy strategies.

The Greenhouse Effect

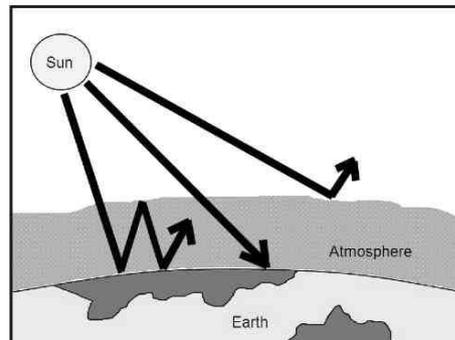
The Earth's atmosphere absorbs energy from the sun, but much of it is radiated back towards space. This atmosphere consists of a natural blanket of gases, including carbon dioxide, which traps heat energy. This natural blanket keeps the temperature on Earth constant to support life, the same way a greenhouse maintains the temperature for plants.

Burning fossil fuels releases carbon dioxide which increases the amount of heat that is trapped. Many scientists predict that this will lead to increased temperatures on Earth, which may have an impact on our planet.

Activity: Diagramming

Diagramming can be used before, during or after reading. For this activity, the reader (or readers if working in groups) reads the text allocated and reproduces the information in diagrammatical form.

Diagrams can include headings, pictures, colour, symbols, labels etc. The purpose is to make the message or information as clear to the viewer as possible. To give students more structure you may like to give students a list of words or text they must include in their diagram.



Activity: Silent Round Robin

A silent Round Robin is when students SILENTLY observe other student/s' work. Once they have looked at other people's responses, they then have the opportunity to make alterations to their own diagram to improve it.

Greenhouse Earth

You've probably heard about the 'greenhouse effect'. The greenhouse effect is a term that describes how gases in the Earth's atmosphere reduce the amount of heat escaping from the Earth. The more of these gases there are, the more the earth heats up. It is a bit like if you climb into a closed car on a sunny day, it's warmer inside because the sun's heat is trapped by the glass and metal.

The gases in the atmosphere act like a blanket around the Earth. They allow the sun's rays to warm the Earth's surface, but they also prevent much of the heat escaping. When more carbon dioxide is released into the air by the burning of fossil fuels, the 'blanket' becomes denser, trapping more heat from the sun near the surface of the Earth, making the air and oceans slightly warmer. This is what scientists call global warming. It is suggested by scientists that by making the Earth warmer, land ice melts and the sea levels rise.

The challenge we now face is that human actions - particularly the burning of fossil fuels (coal, oil and natural gas) and land clearing - are increasing the concentrations of these gases, creating the prospect of global climate change.

Activity: Cause and effect using signal words

One good way to find cause and effect relationships is to look for the SIGNAL WORDS. Ask students to highlight the signal words listed in the box and use the text around the signal words to help fill in missing sections in the table.

because	making	creating
----------------	---------------	-----------------

Cause	Signal Word/s	Effect
it's warmer inside	because	the sun's heat is trapped by the glass and metal
trapping more heat from the sun near the surface of the Earth	making	the air and oceans slightly warmer
burning of fossil fuels and land clearing are increasing the concentrations of these gases	creating	the prospect of global climate change

Many fact sheets with simple diagrams to explain the greenhouse effect and greenhouse gases are available online. For example, the Australian Government Department of Climate Change website includes general fact sheets as well as plans of action to address climate change in Australia.

<http://www.climatechange.gov.au/science/publications/pubs/fs-climatechange.pdf>

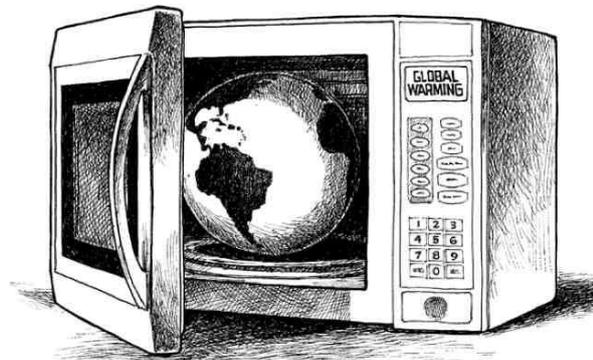
Activity: Understanding Scientific Texts

When students are reading scientific texts, they often need focussed key teaching and scaffolding to comprehend the text effectively. The following strategies could be used when using a fact sheet like the one above in your classroom. Students could:

- identify the scientific words in the text and describe them with everyday words to understand their meaning
- create a glossary of terms
- compose questions and answers from the text
- cut up sentences/paragraphs into parts, mix them up then try to put them back together so that the text makes sense
- create their own cloze activities for their peers

Activity: Interpreting Political Cartoons

Cartoons are a highly engaging literacy text to encourage higher order thinking and the development of visual literacy skills with students. Using a cartoon like the one below, students could apply their knowledge of the greenhouse effect and climate change to explain what is happening in the cartoon and why it is relevant or thought provoking.



<http://cagle.com/news/GlobalWarming07/1.asp>

Activity: Climate Zones March South (The Courier-Mail, August 7 2008)
 See Appendix 6 for full size article

This guide is appropriate to use with any text - simply modify the questions as required.



BEFORE READING THE TEXT

Activate background knowledge:

- What is climate change? What do you know about climate change?
- Why are many people worried about the idea of climate change?

Understand the conventions of the text:

- What type of genre is this?
- What is the purpose of newspaper articles?
- What are some features of newspaper articles?
- Look at the headline - what do you think the article will be about?

WHILE READING THE TEXT

- Highlight unfamiliar concepts and terms
- Ask questions

AFTER READING THE TEXT

Use a structure such as a three level guide to help guide student responses.

LEVEL 1 – Literal comprehension (the answer is right there in the text)

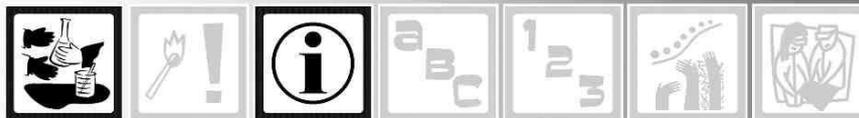
1. According to the article are sea surface temperatures rising?
2. What are the average Northeast temperatures in 1950 and 2007? How much have they increased/decreased by?
3. According to the article how far on average have climate zones shifted south in the past 60 years?

LEVEL 2 - Inferential comprehension (make your own judgement)

1. What is the key message in the article?
2. What is the author's message in the following statement? '...sceptics should dip their toes in the water off a Queensland beach if they want proof the phenomenon exists'.

LEVEL 3 - Applied comprehension (using background knowledge/finding out more)

1. What is the El Nino effect, and what is the link (if any) to climate change?
2. What are the potential effects of rising sea temperatures?



Modelling the Greenhouse Effect

Key concept:

The aim of this experiment is to demonstrate what effect increasing the gases in the atmosphere would have on the earth's temperature. The increased gases (from burning fossil fuels) are modelled by using a plastic container.

Background Information:

The greenhouse effect can be experienced by getting into a car that has been parked in the sun with the windows wound up. The air (gas particles) inside have been heated and are unable to escape. The gas particles have gained heat energy from the sun. While we rely on this effect to maintain liveable temperatures on earth, if the amount of carbon dioxide in the atmosphere increases, more heat is trapped, so the temperature on earth will increase.

Researchable Question:

What happens to *the air temperature* when we cover the thermometer with a container?

Prediction:

I think *the air temperature will be higher when the thermometer is inside the container.*

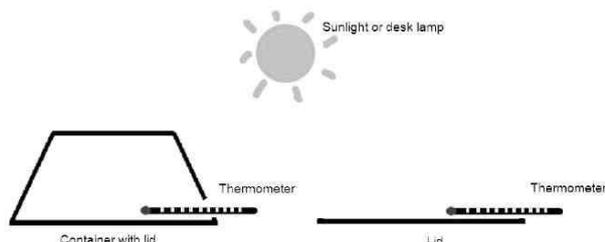
Ensuring a Fair Test:

What to Change <i>Independent Variable</i>	What to Measure <i>Dependent Variable</i>	What to Keep the Same <i>Controlled Variables</i>
<ul style="list-style-type: none"> ▪ The opportunity for heat to escape 	<ul style="list-style-type: none"> ▪ Air temperature 	<ul style="list-style-type: none"> ▪ Amount of light ▪ Time in the sun
How to make the change	How to measure it	How to control the variables
<ul style="list-style-type: none"> ▪ Plastic container to cover one thermometer 	<ul style="list-style-type: none"> ▪ Use the same type of thermometer marked in degrees 	<ul style="list-style-type: none"> ▪ Place thermometers so they get the same sunlight for the same amount of time

Materials:

- 1 plastic container
- 2 plastic container lids or sheets of cardboard
- 2 thermometers
- desk lamps (if doing the experiment on a cloudy day)

Experiment Set Up:



Procedure:

1. Set up both thermometers in a sunny position or under desk lamps sitting on the lids/cardboard sheets.
2. Record the temperatures on both thermometers initially (both thermometers should have the same initial reading), and after every minute for 8 minutes.

Results:

Time in mins	Temperature in ⁰ C									Change in Temperature (final – initial)	
	Initial	1	2	3	4	5	6	7	8		
Uncovered											
Covered											

Discussion: *Suggested teacher questions to prompt student thinking*

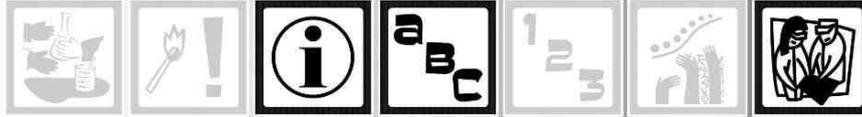
1. Were the controlled variables kept the same to ensure a fair test?
2. What happened to the temperature in each case? (This data could be graphed.)
3. Why did the temperature increase?
4. Was it the same for both? Explain why/why not?

Conclusion: *Suggested teacher question to prompt student thinking*

1. Did the results support your prediction? Explain why.

Applying what we have learnt: *Suggested teacher questions to prompt student thinking*

1. How does this experiment model the greenhouse effect?
2. What does the container represent?
3. What might happen if the blanket of gases around the earth got thicker?
4. Could we design a new experiment to investigate this concept further?



SCOPE Video Activities

Key concept:

Students will use an online video resource from popular Science TV show SCOPE to investigate and discuss key concepts related to climate change.

Climate 101

Activity: Word Wall

- View the Climate 101 clip <http://www.csiro.au/scope/clips/e70c02.htm>
- Brainstorm the key words related to climate change
- Record on a "Word Wall"

Climate Change Word Wall			
climate	change	greenhouse	gases
solar	atmosphere	nitrogen	oxygen
carbon dioxide	methane	effect	warming

Activity: Using the transcript for literacy activities

(<http://www.csiro.au/scope/transcripts/e70c02transcript.htm>)

Use the transcript from the clip to highlight key words. Add any words you might have missed to the word wall.

Climate Change: What can you do?

View the resource at: <http://www.csiro.au/scope/clips/e70c01.htm>

Activity: Use the clip as the basis for engagement and discussion

1. What is climate change all about? What are the key issues?
2. How will being "Power Wise" reduce the effects of climate change?
3. List all the appliances in the classroom/household that use electricity?
4. What images are used to emotively suggest that climate change is an important issue?
5. Make a "top ten ways to combat climate change" list.

Activity: Artists Message

Use magazines to find pictures related to climate change. Choose one strong image as the centre piece for a poster. Create a slogan or message about climate change to share with others. For example, an image of a light bulb with the message *Switch off – Make a Change.*



Get Graphing! Teacher Information

Key concept:

This activity aims to develop numeracy skills which underpin the ability to work scientifically.

Background information:

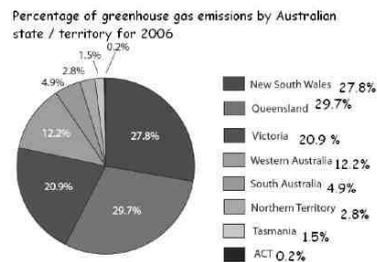
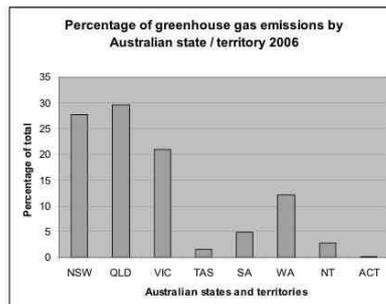
Australia's national greenhouse gas (mainly carbon dioxide, CO₂) emissions in 2006 totaled 576.0 million tonnes. One tonne (t) equals 1000 kilograms (kg). This greenhouse emission total comprised 27.8% from New South Wales, 29.7% from Queensland, 2.9% from Victoria, 12.2% from Western Australia, 4.9% from South Australia, 2.8% from the Northern Territory, 1.5% from Tasmania, 0.2% from the Australian Capital Territory.

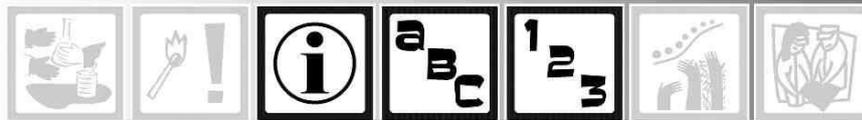
Activity: Create a table from the information above

State or Territory	% of total greenhouse gas emissions
NSW	27.8
QLD	29.7
VIC	20.9
TAS	1.5
SA	4.9
WA	12.2
NT	2.8
ACT	0.2

<http://www.climatechange.gov.au/inventory/stateinv/pubs/states2006.pdf>

Activity: Graph it!





Get Graphing! Student Activity

Background information:

Australia's national greenhouse gas (mainly carbon dioxide, CO₂) emissions in 2006 totaled 576.0 million tonnes. One tonne (t) equals 1000 kilograms (kg). This greenhouse emission total comprised 27.8% from New South Wales, 29.7% from Queensland, 2.9% from Victoria, 12.2% from Western Australia, 4.9% from South Australia, 2.8% from the Northern Territory, 1.5% from Tasmania, 0.2% from the Australian Capital Territory.

Activity: Create a table from the information above

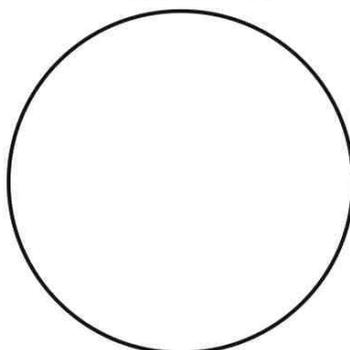
State or Territory	% of total greenhouse gas emissions
NSW	
QLD	
VIC	
TAS	
SA	
WA	
NT	
ACT	

Activity: Graph it!

Use this information to represent the % **greenhouse gas emissions** in a pie graph. A pie graph is a circle graph that is divided into sectors representing the size of a piece of data. If the percentage for each area is known it is easy to construct a pie graph. Every 1% is equal to 3.6 degrees. Using a protractor and the percentages from your table, construct a pie graph.

Title _____

Key



Try using the same data to create a bar graph using grid paper or Excel. Compare the graphs. Which graph is the easiest to interpret?



What is Coal?

Key concept:

This activity aims to investigate coal and its properties.

Resources:

- Hand lens
- Black and brown coal samples

POWERFUL SCIENCE: CLEANING UP OUR ENERGY CD:

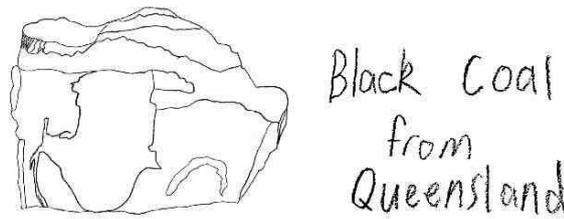
- *Science Rocks*, chapter 2: "Exploring Rocks and Minerals"
- Coal PowerPoint
- *ITAM Coal in a Sustainable Future* information booklet

Activity:

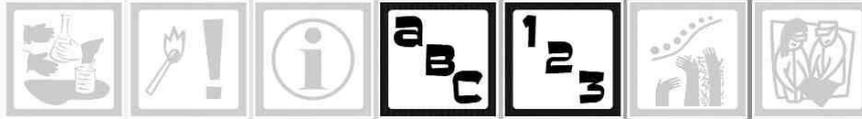
1. Using the hand lens, carefully observe the coal. What words would you use to describe it?
2. Draw a detailed diagram of the coal sample.
3. Using a rock identification key/chart, like the one found in *Science Rocks*, use your observations to classify the coal sample.
4. Using the information about coal from the **POWERFUL SCIENCE: CLEANING UP OUR ENERGY CD**, create a concept map to summarize what you have learnt about coal from this activity.

The following is a list of potential issues associated with this activity:

- Always wash your hands after handling coal
- Mining companies or your local high school science department may be able to provide coal samples.



Student diagram, Year 4, Kenmore South State School



Coal Formation Flip Book

Key concept:

This activity aims to investigate how coal is formed. Students view an animation or text that explains the formation of coal. Students then create a flip book to demonstrate their understanding of the process.

Materials:

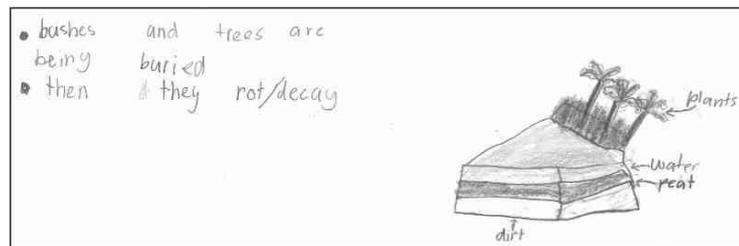
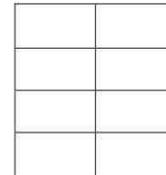
- A4 paper (1 per student)
- Stapler
- Coloured pens etc
- Information on coal formation from **POWERFUL SCIENCE: CLEANING UP OUR ENERGY CD ROM: ITAM Coal in a Sustainable Future**

Online Resources:

- The following website provides an excellent animation of the coal formation process:
http://www.classzone.com/books/earth_science/terc/content/visualizations/es0701/es0701page01.cfm?chapter_no=visualization

Activity:

1. Research how coal is formed using the suggested resources.
2. Divide the page into 8 sections as shown.
3. Staple the sections together to create a flip book.
4. Provide key phrases to write at the bottom of each section. This will guide students so that they correctly draw each stage of the formation process.



Student example, Year 4, Kenmore South State School



Sedimentary Layers in a Jar

Key concept:

The aim of this investigation is to demonstrate how soil and other particles would settle into layers of sediment over time. This links to how vegetation and other natural materials are transformed into coal over millions of years.

Background information:

This experiment very simply models how layers of rock may be formed. It shows that larger (heavier) particles settle first. This process of materials settling and forming layers is repeated over time. Layer upon layer is built up causing pressure on the lower layers. Trapped vegetation is squeezed and slowly changes into coal.

Materials:

- Large sealable clear wide neck plastic bottle (2 litres or more)
- Variety of soil types (including rocks/pebbles, clay, sand, dirt, vegetation) in quantity that would fill the bottle to about 1/3
- Water to fill bottle

Procedure:

1. Use a clean bottle.
2. Fill to about 1/3 of bottle depth with a mixture of dirt and earth materials.
3. Screw lid on and shake vigorously.
4. Top up the bottle with water.
5. Replace cap and shake vigorously for a further two minutes.
6. Place bottle onto level surface and let stand until all material has settled.

Teacher preparation: 2 weeks ahead of time

An example could be prepared by the teacher two weeks earlier so that sediment has time to settle and act as a model for the students.

The following is a list of potential issues associated with this experiment:

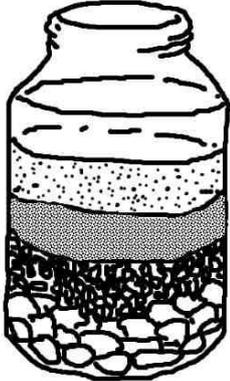
- Contents should not include insects/animals due to decomposition.
- The bottle should be stored on a shelf where it is not subject to daily bumping or vibrations as much as possible. The more frequently it is agitated the longer it takes for the contents to settle.

Variations:

1. A number of bottles each containing different materials. Measuring different rates of settling.
2. Have bottle(s) photographed every hour and converted to a Photostory so that time lapse can be tracked.

Results:

Results could be provided through regular observations of the jar and a detailed diagram drawn at the conclusion of the experiment like the example provided below.

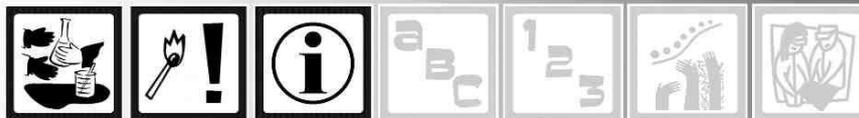
My observations	
At the beginning of the experiment	
After 1 day	
After 3 days	
After 7 days	

Discussion: *Suggested teacher questions to prompt student thinking*

1. What kind of materials tend to settle first?
2. What kind of materials tend to settle last?
3. What do you think would happen if we left the jar for a longer period of time?
4. What do you think would happen if we shook the jar up again?

Conclusion: *Suggested teacher questions to prompt student thinking*

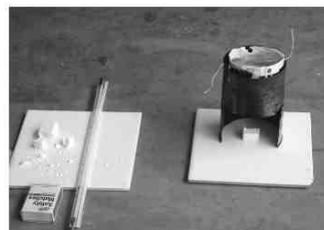
1. How does this model the formation of coal?
2. What are the differences between this and the formation of coal?
3. What did we learn from this investigation?
4. What generalisations can we make?



Burning Fuel for Energy

Key concept:

This experiment aims to demonstrate how chemical energy from a fuel source (like coal) can be transformed into heat energy by burning. The heat energy can be transferred to water and this increases the temperature. In a coal-fired power station, coal is burnt to heat water in order to produce steam which turns a turbine to generate electricity.



Researchable Question:

What happens to the *water temperature* when we *heat it using a firelighter*?

Prediction:

I think *the temperature will rise about ten degrees* because *the heat from the burning fuel will be transferred into the water*.

Ensuring a Fair Test:

What to Change <i>Independent Variable</i>	What to Measure <i>Dependent Variable</i>	What to Keep the Same <i>Controlled Variables</i>
<ul style="list-style-type: none"> ▪ Time (Stop Watch) 	<ul style="list-style-type: none"> ▪ Temperature in degrees 	<ul style="list-style-type: none"> ▪ Environmental conditions ▪ Amount of water/fuel
How to make the change	How to measure it	How to control the variables
<ul style="list-style-type: none"> ▪ Identify time intervals 	<ul style="list-style-type: none"> ▪ Thermometer ▪ Avoid letting the thermometer touch the bottom of the can 	<ul style="list-style-type: none"> ▪ Fans/wind ▪ Measure water ▪ Measure firelighter

Materials per group:

- 1 baked bean can or similar
- 1 soft drink can
- Masking tape to secure edges of the tins
- 1 firelighter cut into MAB ones block size (1cm³)
- Chopstick or wire
- Thermometer
- Measuring jug to measure the volume of water
- 2 x Heatproof ceramic tiles (Ask at your local tile shop for cut offs or seconds)

- Hole punch
- Matches/ BBQ lighter/ Long taper candle

Procedure: Please read the safety information provided (p20).

1. Construct what is commonly known as a calorimeter (see diagram and safety instructions for more detail)
2. Place the firelighter on the tile.
3. Measure the volume of water (100mL) and pour into the soft drink can.
4. Measure the initial temperature of the water before lighting the firelighter. Record in the data table.
5. Light the firelighter and place the large tin over the top of it.
6. Measure the temperature of the water in the soft drink tin every 30 seconds until the firelighter has extinguished.

Results:

Water Temperature in $^{\circ}\text{C}$						
Time in mins	0.0 (Initial)	0.5	1.0	1.5	2.0	Overall temp change $[\Delta t]$ (Highest – initial temperature)
Temp						

Represent this information graphically.

Discussion: Suggested teacher questions to prompt student thinking.

1. Were the controlled variables kept the same to ensure a fair test compared to other groups in your class? Why was this important?
2. Use the graph to describe your results.
3. Did the results support your prediction? Explain.
4. What was the main energy transformation (change) that took place?
5. Can you apply the following formula to calculate the amount of energy released by the firelighter?

Use the formula $Q = vK\Delta t$ where:

$Q = \text{Energy in joules}$ $v = \text{volume of water in mL}$
 $K = 4.18 \text{ J/mL}^{\circ}\text{C}$ (which is a constant) $\Delta t = \text{Change in temperature } ^{\circ}\text{C}$

Conclusion: Suggested teacher questions to prompt student thinking

1. Which part of the process in a coal-fired power station does this experiment model?

Safety Considerations:

Because you are burning firelighters, please consider the age and ability of your students and the environment in which you perform the experiment. You may wish to complete the experiment as a demonstration with students monitoring or recording the temperature.

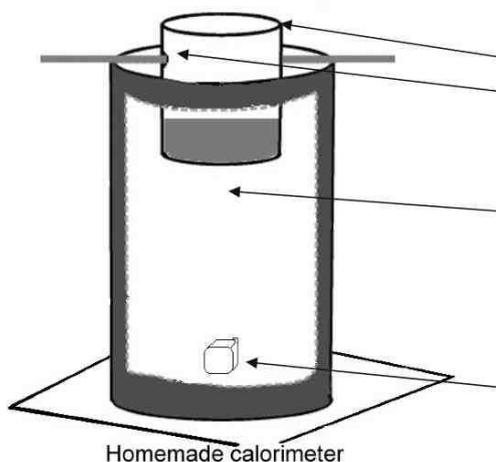
Ventilation - When burning any material please ensure that you do so in a well ventilated area. Ideally outside in an open concrete area.

Fire Hazards - It is a good idea to brief students on the dangers of fire and to have relevant fire safety equipment available. Additionally you may wish to provide students with safety goggles and ask students to ensure that their hair is tied back.

Heat - The tin and water will be hot after the experiment. Please leave the equipment to cool before packing up. It is a good idea to brief students on handling hot materials and what to do if they do come into contact with any hot surfaces.



Guidelines for construction:



Carefully cut soft drink can with scissors. (approx 7cm in height)

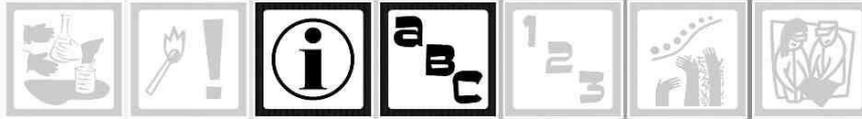
Masking tape edges for safety.

Use a hole punch to create holes on the side of the can, to thread through the chopstick or wire.

CAUTION: This area of the can heats up quickly during the experiment. Let it cool before moving the equipment.

Use a can opener to remove the top and bottom of the can. Tape if sharp.

Use MAB ones block size pieces of firelighter (1cm³) for a safe amount of heat generated. Typically, you will experience about a 10 degree temperature change. The larger the firelighter piece, the greater the energy transferred.



Coal Mining Questions

Key concept:

Use the Question Matrix to develop questions about coal mining and then ask students to research the answers.

Activity: The Question Matrix

The Question Matrix is a versatile tool that utilises 12 simple words to involve students in the learning process. The Question Matrix (see below) may be used in the classroom to help write and incorporate higher level questions, promote higher level thinking, encourage students to be more active thinkers, generate interest in a topic, introduce or review a unit and even help students write a project.

The Question Matrix may be used in a number of ways. Some suggestions include:

1. Ask students to write 6 questions about the topic that they want answered. Use these to help you plan what aspects of the unit you will teach or which activities you will cover.
2. Place students in groups and ask each to generate questions about the topic using specific sentence starters (Question Matrix strips) eg the six 'Why' questions. You may try to give the more difficult sentence starters to the better students in the class.
3. Place all of the first words (what/where/which/who/what/how) words on one dice and the second words (is/did/can/would/will/might) on a second dice. Have students play in groups - each person has a turn rolling the dice and then attempting to form a question using this sentence starter.

	What	Where/ When	Which	Who	Why	How
is	<i>What is...?</i>					
did		<i>Where did..?</i>				
can				<i>Who can..?</i>		
would			<i>Which would..?</i>			
will						<i>How will..?</i>
might					<i>Why might..?</i>	



To Mine or not to Mine?

Key concept:

This activity aims to develop numeracy skills which underpin the ability to work scientifically. In this activity, students use ratio to determine whether coal would be mined by open cut or underground methods.

Scenario:

You work for a mining company and it is your job to recommend whether the mine should be open cut or underground.

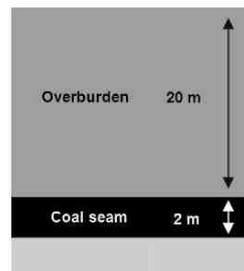
Background information:

Coal forms in layers which are called seams. The dirt and rocks (worthless material) found above the coal seam are called overburden. Removing the overburden and collecting the coal results in "open cut" mining. Digging tunnels through the overburden and removing the coal is "underground" mining.

The deepest open cut mine in Australia is approximately 150 m. An open cut mine of this depth would indicate that the coal seam was very thick and that the overburden was not difficult to remove. Underground mines in Australia can be as deep as 500 m but mines in other countries can reach 1000 m in depth.

Coal seams up to 150 m in depth would be considered for open cut mining. Core samples would be taken from the proposed mine site to establish the thickness of the overburden and the seam. The measurements of the overburden and the seam are used to determine the "stripping ratio". Generally the stripping ratio must be 15:1 or less for the coal to be mined in an open cut method.

Stripping ratio = Thickness of the overburden: (compared to) thickness of the seam.



Example:

Here the overburden thickness is 20 metres and the coal seam is 2 metres.

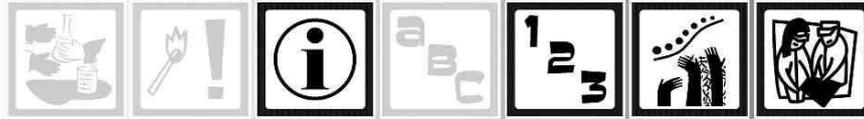
This means the stripping ratio is 10:1 which is viable to mine.

Because the coal is at the depth of 22 metres you would suggest that the coal would be mined by open cut method.

Activity: For each core sample calculate the stripping ratio and state whether it should be mined in an open cut or underground method.

Core sample 1	Core sample 2	Core sample 3
		
Stripping ratio:	Stripping ratio:	Stripping ratio:
At what depth is the coal seam?	At what depth is the coal seam?	At what depth is the coal seam?
Your recommendation:	Your recommendation:	Your recommendation:

★ Would the decision to mine an area be determined by the stripping ratio of one core sample? Why/why not?



Cultural Heritage Surveys

Key Concept:

Students apply numeracy skills in a relevant coal mining context.

Background information:

Cultural Heritage surveys are conducted before exploration and mining activities take place. The survey identifies anything of cultural importance. It can include historical buildings or areas of land that have cultural artefacts, or sites of cultural significance, on them.

Usually, cultural group representatives conduct the surveys and the purpose of a cultural heritage survey is to document and record items of importance. A common outcome of these surveys is a map showing the locations of cultural items. The information is also used to develop a cultural heritage management plan. This plan outlines what measures are required to deal with the items or areas of cultural significance in an appropriate manner.

Items of cultural importance can include:

- Buildings
- Parks
- Monuments (eg ANZAC)
- Cemeteries
- Aboriginal artefacts and sites
- Trees

Items can be dealt with in a number of ways including; being removed and relocated, removed and stored to be returned after the mining is complete or destroyed with the consent of the relevant cultural group.

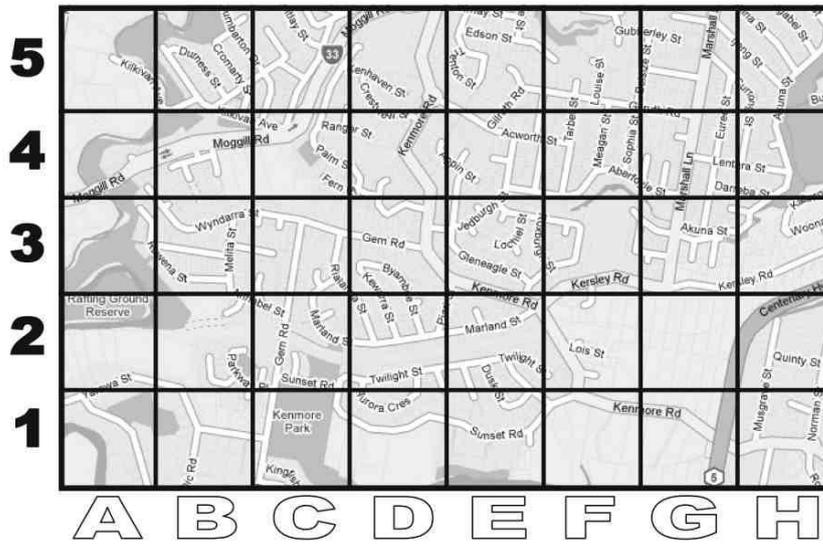
Activity: Create a cultural survey map

Before considering whether you can mine an area or not, cultural heritage surveys are conducted by community group representatives and scientists.

- Step 1: Read the information about what items were found.
- Step 2: Create a key for different types of culturally important items.
- Step 3: Use your key to mark on the map what was found.
- Step 4: Make a recommendation about whether you think the area should be mined.

Survey information:

- Aboriginal artefacts found at A2, A3, C1 and H4
- Parks were located at C1, C2, B5, H4 and H5
- A memorial site was located at C4
- Trees of significance were found at G2, D5 and A5
- A cemetery was located at the corner of Gem Road and Kenmore Road
- A school was located at F3



Key:

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Recommendation:



Interview with a Geologist

Dianne is a teacher who was teaching her students about the energy that comes from rocks. She wanted to talk to someone who works in the industry so that she could find what that would be like so that she could tell her students. She arranged to meet Danique, a qualified geologist working at a coal mine, to ask her some questions about her career. The interview took place before dinner while they were both sitting on Dianne's verandah.

Dianne: So Danique, what made you decide to be a geologist?

Danique: Well I was actually studying geography at Uni when someone who I knew and admired in the mining industry recommended that I do geology. I was able to organise my subjects so that I could major in geology. As soon as I made the change I knew I had made the right decision as I wanted an interesting career.

What subjects did you do at school that helped you with your job?

In middle school it was Science and SOSE and in senior, geography and chemistry. I found geography very interesting. In chemistry we did scientific investigations just the same way that scientists do. I was able to investigate a problem by writing a question and then planning and carrying out a practical investigation to answer the question. Doing the experiments was a lot of fun.

Did this prepare you for work as a geologist?

Yes most definitely. In geography we learnt to use PowerPoint to give oral presentations about our group project work. I now have to present reports to various groups of people. In chemistry I learnt to look at scientific results and interpret them. I do this all the time at work as this helps me make the decisions about where to mine the coal.



Can you outline the progress of your career?

While I was at Uni, I did work experience at a coal mine near Ipswich. This gave me the opportunity to see the rock structures that I was learning about. I graduated and did an honours project at a mine in Central Queensland. I then was offered full time work back where I did my work experience.

"Every day is different. I have a wide variety of tasks which can be indoors or outside. I really have the best of both worlds."

What types of things do you do at work each day?

Every day is different. I have a wide variety of tasks which can be indoors or outside. I really have the best of both worlds. One day I can be down in the pit looking at the structure of the coal and making decisions about how it will be mined, then the next I can be in the office doing geological models of the rocks under the ground. Some days I go out on a drill rig, supervise the drilling and core the coal. I work with a team of geologists and we all get on well. So, it's very hard to outline a typical day.

What direction can you see your career taking in the future?

I enjoy computer modelling. That's when you take the information from under the ground and put it on the computer. You can then generate a picture of what is under the ground. This is one way of finding coal. This information is used make decisions about where mining will be done next. I would like to do more computer modelling in the future and that's where I can see my career going.

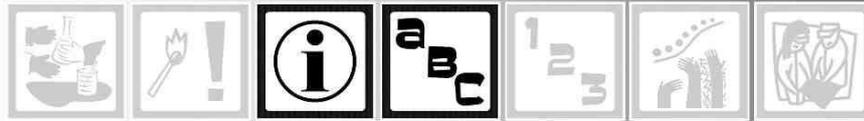
What about leisure time? What do you do when you take a break?

I work eighteen days on and then have nine days off. When I am working it's very busy and I usually work a twelve hour shift. But...on the nine days off, well it's great! I can go away if I want or spend time with my friends. I love water skiing and on my break I have plenty of time to do that. I'm going to get my speed boat license. I also enjoy watching DVDs, listening to music and going shopping.



Literacy questions

1. What is the main reason for the interview?
2. How is it made clear in the text who is asking the questions and who is answering them?
3. Where else have you seen this interview technique?
4. Is the interview casual or formal? How do you know?
5. Does Danique enjoy her job? How can you tell?
6. If you had the opportunity to interview a scientist, what questions would you ask?
7. What is the difference between geography and geology? How are these subjects similar?
8. At school, Danique was able to "work scientifically" in chemistry. What are the steps that she describes?



Low Emission Coal Technology

Key concept:

Students complete a cloze activity about low emission coal technologies and the reduction of harmful emissions. This cloze may be used as an introductory activity to investigate low emission coal technologies or used following research and discussion as a way for students to demonstrate their knowledge.

Activity: Cloze

scientists	coal	hydrogen	steam	underground
impact	gas	pumped	dioxide	water
low	electricity	rocks	drilled	furnace

_____ is burnt in power stations to make steam. This _____ is used to turn large turbines which create _____. Power stations emit greenhouse gases such as H₂O (_____), CO₂ (carbon dioxide) and CO (carbon monoxide).

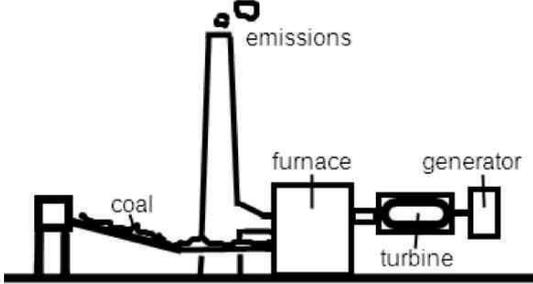
_____ emission coal technologies improve the performance of coal and reduce the _____ on the environment. _____ are researching different ways to do this. Coal is burnt in a special _____ (a really hot oven). A gas is produced. This _____ is separated and converted to hydrogen and carbon monoxide. The _____ runs the power plant.

The carbon monoxide is converted to carbon _____. Instead of releasing the CO₂ it is stored. It is put under a sea bed in an _____ cave with no exit. A hole is _____ deep into the ground and the CO₂ is _____ in. The CO₂ changes and deposits as a mineral in the _____.

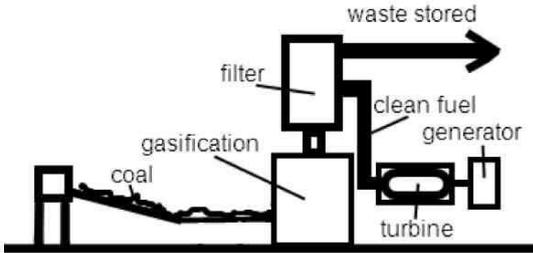
Activity: Diagramming

As students have a variety of learning styles, creating diagrams is an excellent way for visual learners to express their understanding of a concept or to assist with the literacy component of a task. *Example diagrams shown below.*

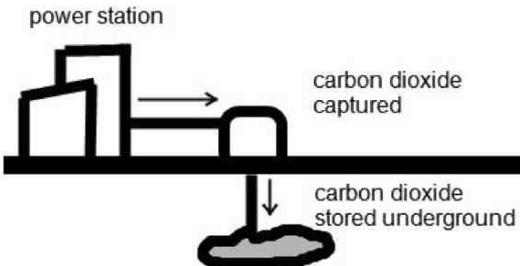
**Conventional Coal Burning Power Station –
Draw a power station and the gases it emits**



**Low Emission Power Station –
Draw a power station with low emission coal technology**



**Where does the CO₂ go? –
Draw a diagram that shows the storage of CO₂**





Gas Filter Model

Key concept:

The aim of this hands-on activity is to provide a physical model of a gas filter that is used to separate gas molecules of different sizes in low emission coal technology processes.

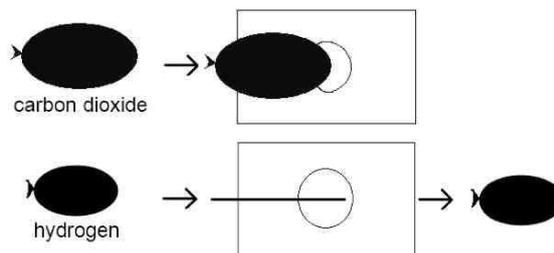
Background Information:

In some low emission coal technologies, the coal undergoes a gasification process which eventually produces hydrogen and carbon dioxide. With metal filters, scientists are able to separate these two gases. The hydrogen is used as a 'cleaner' fuel to produce electricity and the carbon dioxide is stored rather than released into the atmosphere, reducing impact on the environment.

Materials:

- Balloons
- Large sheets of cardboard
- Scissors

Activity:



1. Blow balloons up to large and small sizes to model carbon dioxide (large) and hydrogen (small) molecules.
2. Ask students to pass the balloons through the holes in the cardboard sheets to demonstrate the filtration process.
3. Link the visual demonstration to the process of separating hydrogen and carbon dioxide.

Follow up activities:

1. Students could brainstorm other ways to model a gas filter. They could use sports balls and cardboard tubes or people and hoops.
2. On a diagram of a coal-fired power station, students could identify where in the process the gas filters would be used.



Investigating the Separation Process

Key concept:

The aim of this activity is to investigate the separation process using a simple model of a water filter. Separation is an important concept in understanding how low emission coal technologies work.

Researchable Question:

What happens to *dirty water* when we use *different materials* to filter it?

Prediction:

I think *the cotton balls will work best* because *they are thick and will trap the dirt*.



Ensuring a Fair Test:

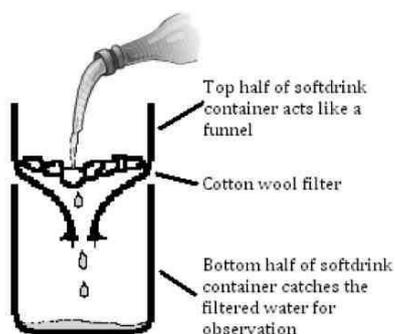
What to Change <i>Independent Variable</i>	What to Measure <i>Dependent Variable</i>	What to Keep the Same <i>Controlled Variables</i>
<ul style="list-style-type: none"> Filtering materials 	<ul style="list-style-type: none"> Water quality by observation (cleanest water) 	<ul style="list-style-type: none"> Amount of water to filter Quality of water being filtered
How to make the change	How to measure it	How to control the variables
<ul style="list-style-type: none"> Use a different material in each test 	<ul style="list-style-type: none"> Observe how clean the water becomes 	<ul style="list-style-type: none"> Measure the water Use the same dirty water for each test

Materials:

- 2 litre soft drink bottle per group
- Scissors to cut the bottle in half
- Different filtering materials for each group to compare: eg cotton wool, coffee filter, stockings, shade cloth (or other materials available to you)
- Measuring cups
- Container/jug for each group to hold the dirty water to filter
- Dirty water (mix soil/rocks/sand with water and shake it up so that the larger particles have not settled)

Procedure:

1. Cut the 2 litre soft drink bottle in half to create a funnel and a container.
2. Create a filter by placing a layer of the material inside the funnel.
3. Shake up the "Dirty Water" and measure out 1 cup (250mL).
4. Pour the dirty water into the funnel.
5. Observe the water after it has been filtered.
6. Repeat for different filter materials to compare the results.



Results:

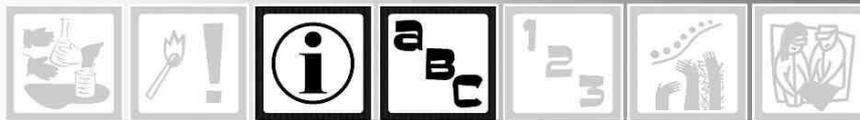
Type of Filter	Observation How clear is the water? What is left behind in the filter?
Cotton wool	
Coffee filter	
Shade cloth	
Stockings	

Discussion: *Suggested teacher questions to prompt student thinking*

1. Were the controlled variables kept the same to create a fair test? How?
2. Which material was the most effective filter? Why?

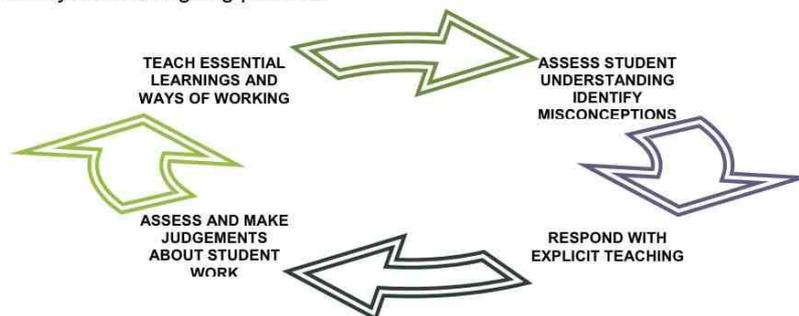
Conclusion: *Suggested teacher questions to prompt student thinking*

1. What generalisations can we make about filters? What did we learn?
2. How do you think this experiment relates to the work scientists are doing in low emission coal technologies?
3. Which part of low emission coal technology process uses a filter?
4. Why would making a gas filter be difficult?



Assessment

Assessment is an integral component of effective teaching and learning. A model of teaching and learning (shown below) demonstrates how assessment is a cyclic and ongoing process.



Scientific reports:

Scientific reports are a common way for teachers to assess students in Science (see Appendix 2 and 3). It is important to note that a scientific report requires a high level of explicit teaching to develop the curriculum literacies that underpin the scientific report genre. An effective approach is to focus on one aspect during an experiment, such as drawing diagrams or to use a strategy such as a POE (Predict, Observe, Explain) to gradually scaffold students' understanding, building up to writing a full report.

Other assessment ideas:

Assessment does not always have to be in the form of a scientific report. Students can demonstrate their learning in a variety of ways including oral presentations, giving demonstrations, building models, creating role plays and designing scientific posters and displays.

Criteria sheets:

Included in the resource is a generic criteria sheet (see Appendix 1) developed from the QCAR Framework that could be used for any experiment from this unit. This criteria sheet could also be used as an ongoing assessment tool, focussing on different aspects of the criteria in different activities.

Assessing reflection:

A PMI chart (Plus, Minus, Interesting) is a common and effective way to assess students ability to reflect upon their learning. Questions posed in scientific experiments in the discussion and conclusion sections should also prompt students to engage in reflective thinking.

TASK DESCRIPTION:	Student: _____
	Overall Grade A B C D E N

	ASSESSABLE ELEMENTS	TASK SPECIFIC DESCRIPTORS				
		A	B	C	D	E
DIMENSIONS - KNOWING AND UNDERSTANDING, WAYS OF WORKING	TITLE and RESEARCHABLE QUESTION	Accurate, precise and relevant title Researchable question accurately defines what will be measured and changed	Effective title Researchable question is relevant to the experiment and has correct structure	Adequate title Researchable question is relevant to the experiment but lacks correct structure	Title and researchable question somewhat relevant	Title and researchable question attempted
	PREDICTION	Prediction highly developed and well justified drawing on accurate prior knowledge	Prediction well developed and justified drawing on accurate prior knowledge	Prediction developed and justified	No justification given for prediction	Prediction not relevant to the task
	FAIR TEST	A fair test thoughtfully designed and all variables involved in the experiment have been identified	A fair test designed and variables involved in the experiment have been identified	A fair test designed and some variables involved in the experiment have been identified	A test has been designed and one variable involved in the experiment identified	One variable involved in the experiment has been identified
	PROCEDURE	Investigation thoroughly planned considering all safety issues, and experiments completed	Investigation thoroughly planned considering some safety issues and experiments completed	Investigation has been planned and the experiment completed	Investigation partially planned and an experiment completed	Experiment partially completed
	RESULTS	Clear and accurate communication using illustrations, representations and terminology	Coherent and accurate communication using illustrations, representations and terminology	Sound communication using illustrations, representations and terminology	Disjointed communication using some illustrations, representations and terminology	Unclear communication using some illustrations, representations and terminology
	DISCUSSION and CONCLUSION	Discerning analysis and evaluation to draw well-reason conclusions	Logical analysis and evaluation to draw well-reason conclusions	Relevant analysis and evaluation to draw credible conclusions	Narrow analysis and evaluation to propose obvious conclusions	Cursory analysis and evaluation to propose conclusions
		Perceptive reflection of the experiment	Informed reflection of the experiment	Relevant reflection of the experiment	Superficial reflection of the experiment	Cursory reflection of the experiment
PARTICIPATION IN INVESTIGATION	Insightful application of science procedures to plan and conduct investigations	Effective application of science procedures to plan and conduct investigations	Competent application of science procedures to plan and conduct investigations	Variable application of science procedures to plan and conduct investigations	Minimal application of science procedures to plan and conduct investigations	
OVERALL	USING THE SCIENCE STANDARDS	Comprehensive knowledge and understanding of concepts, facts and procedures	Thorough knowledge and understanding of concepts, facts and procedures	Satisfactory knowledge and understanding of concepts, facts and procedures	Variable knowledge and understanding of concepts, facts and procedures	Rudimentary knowledge and understanding of concepts, facts and procedures

Comments:

SCAFFOLDING A SCIENTIFIC REPORT		Rating A B C D E N
Years 4-7		
NAME: _____	Class: _____	Date: _____

TITLE: _____
(What are we investigating?)

RESEARCHABLE QUESTION: What happens to _____
*(dependent variable
 What are we measuring or observing?)*

when we change _____ ?
(independent variable)

PREDICTION: _____
(What do you think is going to happen?)

because _____
(conjunction) (knowing/experiencing to justify your thinking)

ENSURING A FAIR TEST:	Change	Measure	Keep the same
	<i>(independent variable)</i>	<i>What and How? (dependent variable)</i>	<i>(controlled variable)</i>
<ul style="list-style-type: none"> Use Cows Moo Softly to help you! 			

PROCEDURE: List the materials _____

Experiment Steps

- What are the materials we need and the steps we follow to complete the experiment? _____ 1.
- _____ 2.
- _____ 3.
- Each step begins with a process/doing word _____ 4.
- _____ 5.

Diagrams

- 2D
- horizontal labels
- simple lines or symbols

Draw a diagram to show how to set up the experiment.

Writing a Scientific Report

Recommended for students in Years 8-9

Title:

The full title of the experiment should be an indication of the task set. For example, Burning Fuel Practical

Experimental Details:

Group member names and date on which the experiment was completed.

Abstract:

An abstract is similar to a summary. It should be brief and give the reader an idea of:

- what was studied
- why it was studied

In general, it should be no longer than 3 or 4 sentences.

Introduction:

This should provide the reader with some background theory or information relating to the area that you are investigating. This section may include some definitions.

Aim:

A brief statement about the purpose of the investigation. Why are you doing the experiment? This sentence should start with 'To investigate...'

Hypothesis:

A statement that can be tested. This is an *educated* expectation of what your results might be. Your investigation should centre around this hypothesis.

Materials:

A list of the apparatus and substances used. This is to be presented in bullet point form. You must be specific as the experiment should be able to be reproduced from your materials and method descriptions.

For example,

- 100 mL beaker
- 25 mL measuring cylinder

Procedure:

The procedure describes how the experiment or investigation was performed. The steps should be organised in a numbered list. The procedure should include specific information about safety.

Results:

First produce a table of results which might include observations as well as numerical data you have collected. This should then be presented in appropriate forms, for example, graphs and figures. Any graph must be produced using graph paper or a computer program such as Excel.

Discussion:

Here you discuss what you have discovered, this should be linked directly with what you aimed to achieve and should refer to any relevant literature. You should link your results with the theory related to the topic by way of explanation of what happened. The discussion section should also answer any questions raised in the investigation. This section is to be written in complete sentences that explain any results and observations. Furthermore any possible errors in the experiment or the experimental design should be identified. Possible solutions or improvements must also be proposed.

Conclusion:

This is a short statement which should refer directly to your aim and hypothesis and restate your final results. You should also identify 'what's next' in terms of further research that could be conducted.

References:

This is similar to a standard bibliography of any work you have used or referred to in completing the laboratory report.

Other Important Information:

- Diagrams are another important part of a laboratory report. If hand drawn they should be simple in design, in pencil and neatly labelled. For computer generated images or photos you must also include labels as necessary.
- A ruler must be used for drawings or graphs involving straight lines.
- All figures, diagrams and tables are to be numbered and labelled. For example, Figure 1 – Diagram of equipment set up for burning fuel experiment.

Science Essential Learnings by the end of Year 5	Addressed within the unit
Ways of Working <i>Students are able to:</i>	
• pose and refine simple questions, and make predictions to be tested	✓
• plan activities and investigations, identifying and using elements of a fair test	✓
• collect and organise data, information and evidence	✓
• evaluate information and evidence to support data gathered from activities and investigations	✓
• select and use tools, technologies and materials suited to the activities and investigations	✓
• draw conclusions that are supported by evidence, reproducible data and established scientific concepts	✓
• communicate scientific ideas, data and findings, using scientific terminology and formats appropriate to context and purpose	✓
• identify and apply safe practices	✓
• reflect on and identify different points of view and consider other people's values relating to science	✓
• reflect on learning to identify new understandings and future applications.	✓
Science as a human endeavour <i>Science relates to students' own experiences and activities in the community.</i>	
• Scientific ideas can be used to explain the development and workings of everyday items, e.g. scientific notions of energy can help explain how a bicycle moves.	✓
• Ethics is a significant part of scientific endeavour, e.g. an ethical consideration is whether or not it is appropriate to test products on animals.	✓
• Science can help to make natural, social and built environments sustainable and may influence personal human activities, e.g. implementing "green" strategies may help to minimise a person's "ecological footprint".	✓
• Science can contribute to people's work and leisure, e.g. the development of new technologies has contributed to increased efficiency in the workplace; people can have a healthier lifestyle if they understand how their physical development benefits from physical activity and healthy food choices.	✓
• Cultures from around the world, including those of Aboriginal people and Torres Strait Islander people, have contributed to scientific understanding e.g. Aboriginal people extract dyes from natural materials; Galileo, an Italian scientist, described motion of objects in the solar system.	
Earth and beyond <i>Changes and patterns in different environments and space have scientific explanations.</i>	
• The earth, solar system and universe are dynamic systems, e.g. the idea that planets orbit the sun and moons orbit planets can be used to explain day and night and the phases of the moon.	
• Changes to the surface of the earth or the atmosphere have identifiable causes, including human and natural activity, e.g. weathering and erosion; air pollution.	✓
Energy and change <i>Actions of forces, and forms and uses of energy, are evident in the everyday world.</i>	
• The greater the force on an object, the greater the change in shape or motion, e.g. pressing harder on a plasticine ball makes it flatter; the harder a ball is thrown the further it travels.	
• Forces may act at a distance or may need to be in contact with an object to affect it, e.g. magnetic and gravitational forces attract objects from a distance; hitting a ball requires contact with a bat.	
• Energy can be transferred from one object to another, e.g. a heater transfers warmth to a nearby human body.	✓
• Different forms of energy used within a community have different sources, e.g. electricity can be generated from a range of sources, including coal and solar energy.	✓
Life and living <i>Living things have features that determine their interactions with the environment.</i>	
• Living things can be grouped according to their observable characteristics, e.g. insects have six legs; marsupials have pouches; fish have gills and fins.	
• Structures of living things have particular functions, e.g. roots bring water and minerals to plants; skeletons give bodies shape and protect vital organs.	
• Reproductive processes and life cycles vary in different types of living things, e.g. plants reproduce by seeds, bulbs and cuttings; animals may lay eggs or produce live young.	
• Living things have relationships with other living things and their environment, e.g. the relationship between clown fish and an anemone on a coral reef is mutually beneficial.	
Natural and processed materials <i>Properties, changes and uses of materials are related.</i>	
• Materials are composed of smaller parts, some of which may be visible to the naked eye, while others are too small to be seen, e.g. cloth can be made up of interwoven fibres; rocks may be composed of visible crystals.	✓
• Materials are used for a particular purpose because of their specific properties, e.g. lunch boxes and water bottles are made of plastic, because plastic is durable and water resistant.	
• The properties of an object can differ from the properties of its component parts, e.g. concrete differs from the cement, water and sand from which it is made.	
• Properties of materials are affected by processes of change, e.g. sugar dissolves in water; ingredients interact when a cake is baked.	✓

Science Essential Learnings by the end of Year 7	Addressed within the unit
Ways of Working	
<i>Students are able to:</i>	
• identify problems and issues, and formulate testable scientific questions	✓
• plan investigations, including identifying conditions for a fair comparison, variables to be changed and variables to be measured	✓
• collect and analyse first- and second-hand data, information and evidence	✓
• evaluate information and evidence and identify and analyse errors in data	✓
• select and use scientific tools and technologies suited to the investigation	✓
• draw conclusions that summarise and explain patterns in data and are supported by experimental evidence and scientific concepts	✓
• communicate scientific ideas, data and evidence, using scientific terminology suited to the context and purpose	✓
• identify, apply and justify safe practices	✓
• reflect on different points of view and recognise and clarify people's values relating to the applications and impacts of science	✓
• reflect on learning, apply new understandings and identify future applications.	✓
Science as a human endeavour	
<i>Science impacts on people, their environment and their communities.</i>	
• Scientific knowledge has been accumulated and refined over time, and can be used to change the way people live, e.g. use of and changes to technology, including mobile phones and computers; improved medical procedures.	✓
• Ethical considerations are involved in decisions made about applications of science, e.g. preservation of wilderness environments to help protect endangered species.	✓
• Scientific knowledge can help to make natural, social and built environments sustainable, at a scale ranging from local to global, e.g. recycling to reduce resource use.	✓
• Different cultures, including those of Aboriginal people and Torres Strait Islander people, have contributed to science and scientific practice, e.g. Indigenous knowledge of flora and fauna makes contributions to scientific knowledge and the development of pharmaceutical products; traditional Chinese medicine recognises relationships between the human body and the environment; English scientist, Sir Isaac Newton, described gravity.	
Earth and beyond	
<i>Interactions and changes in physical systems and environments can be explained and predicted.</i>	
• Gravitational attraction between objects in the solar system holds them in fixed orbits, and has predictable effects on the earth, e.g. changing tides are a result of gravitational attraction between the earth, the moon and the sun.	
• Changes to the earth occur over varying time periods and can be interpreted using geological evidence, e.g. changes that are part of the water cycle occur over a shorter time scale than does rock formation; change over time can be identified through fossils and rock layers.	✓
Energy and change	
<i>Forces and energy can be identified and analysed to provide explanations that benefit community lifestyles and decision making.</i>	
• The motion of an object changes as a result of the application of opposing or supporting forces, e.g. a surfer makes use of a number of forces, including gravity, buoyancy and the motion of the water, to ride a wave.	
• Renewable and non-renewable energy sources can be identified and used for different purposes, e.g. wind or coal is used to generate electricity; wind can also be used to pump water.	✓
• Energy can be transferred and transformed, e.g. recharging a car battery transforms electrical energy into chemical energy that is stored in the battery; plants transform light energy from the sun into chemical energy that is stored.	✓
Life and living	
<i>Living things have structures that enable them to survive and reproduce.</i>	
• Cells are the basic unit of all living things and perform functions that are needed to sustain and reproduce life, e.g. some organisms are single-celled; complex organisms such as humans are collections of specialised cells.	
• Systems of scientific classification can be applied to living things, e.g. dichotomous keys can be designed for groups of organisms.	
• Survival of organisms is dependent on their adaptation to their environment, e.g. animals use camouflage to protect themselves; plants in very dry areas may store water in modified structures.	
• Different feeding relationships exist within an ecosystem, e.g. producer, consumer, herbivore, carnivore relationships form a food web.	
Natural and processed materials	
<i>Properties, changes and uses of substances and mixtures are related to their particular composition.</i>	
• Properties of a material will vary according to the type and quantity of components that make up its structure, e.g. the colour of a paint depends on the proportion of different colours in the mixture; durability of Aboriginal arts works is dependent on paint ingredients; different alloys of iron produce different amounts of rust.	✓
• Chemical change produces new substances that have properties different from those of the original substances, e.g. burning paper produces ash	✓
• Physical change produces no new substances, e.g. changing a solid to a liquid and back to a solid.	

Science Essential Learnings by the end of Year 9

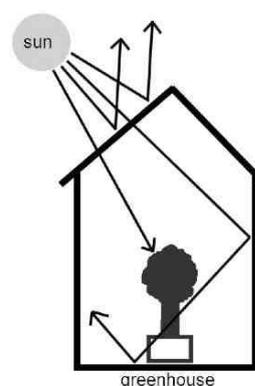
Addressed
within the unit

Ways of Working <i>Students are able to:</i>	
• identify problems and issues, formulate scientific questions and design investigations	✓
• plan investigations guided by scientific concepts and design and carry out fair tests	✓
• research and analyse data, information and evidence	✓
• evaluate data, information and evidence to identify connections, construct arguments and link results to theory	✓
• select and use scientific equipment and technologies to enhance the reliability and accuracy of data collected in investigations	✓
• conduct and apply safety audits and identify and manage risks	✓
• draw conclusions that summarise and explain patterns, and that are consistent with the data and respond to the question	✓
• communicate scientific ideas, explanations, conclusions, decisions and data, using scientific argument and terminology, in appropriate formats	✓
• reflect on different perspectives and evaluate the influence of people's values and culture on the applications of science	✓
• reflect on learning, apply new understandings and justify future applications	✓
Science as a human endeavour <i>Responsible and informed decisions about real-world issues are influenced by the application of scientific knowledge.</i>	
• Immediate and long-term consequences of human activity can be predicted by considering past and present events e.g. <i>consequences of unsustainable use of fossil fuels can be seen in environmental impacts.</i>	✓
• Responsible, ethical and informed decisions about social priorities often require the application of scientific understanding e.g. <i>use of alternative forms of energy; use of recycled water; development of influenza and cervical cancer vaccines.</i>	✓
• People from different cultures contribute to and shape the development of science e.g. <i>Australian Indigenous knowledge can be applied to land and water management, food production and waste management.</i>	
Earth and beyond <i>Events on earth and in space are explained using scientific theories and ideas, including the geological and environmental history of the earth and the universe.</i>	
• Scientific ideas and theories offer explanations about the earth that extend to the origins of the universe e.g. <i>ideas about the expanding universe.</i>	
• Global patterns of change on earth and in its atmosphere can be predicted and modelled e.g. <i>the effects of rising temperatures on natural environments</i>	✓
• Geological evidence can be interpreted to provide information about past and present events e.g. <i>the earth's surface is shaped by volcanoes and earthquakes, which can be understood in terms of the theory of plate tectonics.</i>	✓
Energy and change <i>Forces and energy are identified and analysed to help understand and develop technologies, and to make predictions about events in the world.</i>	
• An unbalanced force acting on a body results in a change in motion e.g. <i>a car is slowed by friction from braking.</i>	
• Objects remain stationary or in constant motion under the influence of balanced forces e.g. <i>a book resting on a table; a vehicle travelling at constant speed.</i>	
• Energy can be transferred from one medium to another e.g. <i>the stove transfers heat to the pot of water.</i>	✓
• Transfer of energy can vary according to the medium in which it travels e.g. <i>some materials are good conductors of heat; light is refracted when it moves from air to water — the pencil appears to bend in a glass of water.</i>	
• Energy is conserved when it is transferred or transformed e.g. <i>a light bulb converts electrical energy into light energy and also produces heat.</i>	✓
Life and living <i>Organisms interact with their environment in order to survive and reproduce.</i>	
• The diversity of plants and animals can be explained using the theory of evolution through natural selection e.g. <i>Australian marsupials would have had a common pouched ancestor.</i>	
• In ecosystems, organisms interact with each other and their surroundings e.g. <i>the scavenger role of the crab in the mangroves means that it has a plentiful supply of food and it contributes by cleaning its surroundings</i>	
• Complex organisms depend on interacting body systems to meet their needs internally and with respect to their environment e.g. <i>the digestive system processes food and the circulatory system distributes it throughout the body.</i>	
• All the information required for life is a result of genetic information being passed from parent to offspring e.g. <i>hereditary information is contained in the genes located on chromosomes.</i>	
• Changes in ecosystems have causes and consequences that may be predicted e.g. <i>bushfires destroy natural bushland, which temporarily changes the ecosystem; birds return to dried-up waterholes after rain.</i>	
Natural and processed materials <i>The properties of materials are determined by their structure and their interaction with other materials.</i>	
• Changes in physical properties of substances can be explained using the particle model e.g. <i>use of the particle model to describe states of matter.</i>	
• Matter can be classified according to its structure e.g. <i>elements and compounds, or molecules and atoms.</i>	
• Chemical reactions can be described using word and balanced equations e.g. <i>hydrogen plus oxygen gives water or $2\text{H}_2 + \text{O}_2 = 2\text{H}_2\text{O}$.</i>	✓
• Reaction rate is affected by various factors, including temperature, concentration and surface area e.g. <i>milk goes sour more quickly when left at room temperature; a soluble tablet will dissolve faster when it is crushed.</i>	

Coal and Low Emission Technologies

The gas, carbon dioxide (CO₂) occurs naturally in the earth's atmosphere. Together with other gases (including water vapour, methane, nitrous oxide, and ozone) carbon dioxide helps to maintain a reasonably constant temperature on earth. The gases absorb some of the radiation from the sun. This process leads to the heat energy from the sun staying close to the earth instead of mainly being reflected as happens on planets without an atmosphere.

These gases are referred to as "Greenhouse gases" as they have the same effect as the glass or plastic which covers buildings called Greenhouses that are used to grow plants in cold environments.



This greenhouse (pictured) in Queenstown, New Zealand reduces the chance of the plants freezing in winter. Heat energy is absorbed by the air inside the building (as shown in the diagram above), helping to keep the temperature warmer than outside.

When coal is burnt to produce electricity carbon dioxide is produced. Over the last 300 years the amount of coal and other fossil fuels (including petrol) that has been burnt has increased. Consequently the amount of carbon dioxide in the atmosphere has increased.

According to the United Nations Intergovernmental Panel on Climate Change (IPCC), "The amount of carbon dioxide in the atmosphere in 2005 (379 ppm) exceeds by far the natural range of the last 650,000 years (180 to 300 ppm)". Parts per million (ppm) is the way the concentration for gases is expressed. A measurement for carbon dioxide of 300 ppm in air would mean that for every 1 000 000 particles in air 300 would be carbon dioxide particles.

The effect of extra carbon dioxide in the atmosphere means that more heat energy is retained leading to an increase in the average temperature of the earth sometimes referred to as global warming.

The International Energy Agency (IEA) consists of 28 member countries including Australia. This organization was founded during the oil crisis in 1973 with the intention of coordinating energy supplies in emergencies. The organization gathers statistics about supplies, generation and use of energy. IEA statistics reveal that currently coal is used to generate nearly 40 % of the total electricity in the world. In Australia, in 2009, coal is used to generate more than 80% of the electricity.

The **CSIRO Queensland Centre for Advanced Technologies (QCAT)** and other research organisations are investigating ways to reduce the amount of carbon dioxide that is released into the atmosphere. The methods or strategies devised to reduce the amount of carbon dioxide going into the atmosphere are collectively called "Low emission technologies".



Teachers visiting QCAT facilities..

Low emission technologies can be categorised or grouped as:

- ✓ Managing wastes from coal
- ✓ Capture & separation of CO₂
- ✓ Storage & sequestration of CO₂
- ✓ Gasification processes

Managing wastes from coal

When coal is burnt there may be impurities in the coal which contribute to unwanted gases being released. Coal that contains sulfur can form sulfur dioxide which may mix with water vapor forming acid rain. Nitrogen in the air may react with oxygen in the air because of the high temperatures present in coal burning power stations. The result of this reaction is nitrous oxide – another greenhouse gas. Scientists are developing technologies to clean the coal and reduce the harmful impurities in coal. They are also developing filters which trap the harmful emissions.

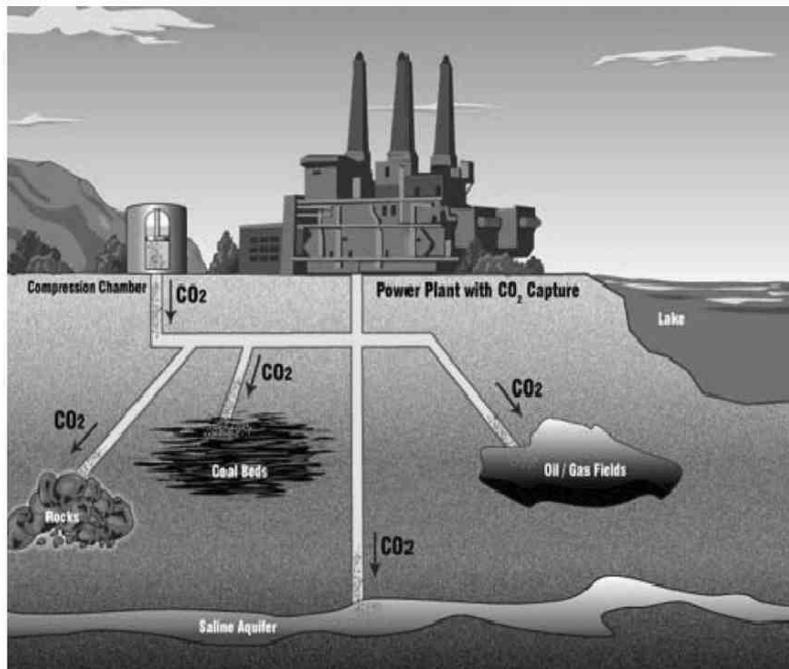
Capture & separation of CO₂

Scientists have already developed technology to capture the carbon dioxide as it is released via chimneys in the power station. This may be done by bubbling the gas through a solution where the gas reacts with a chemical so that it stays in the liquid. Special membranes have also been developed to trap the carbon dioxide. Unfortunately these methods use energy and cost a lot of money. Scientists are working to improve efficiency and use low cost materials to improve the capacity to apply this technology at an industrial level.

Storage & sequestration of CO₂

In the future, power plants will be designed so that the carbon dioxide will be captured and then stored instead of being released to the atmosphere. Storing the gas in suitable underground places is sometimes called geosequestration but may also be referred to as carbon capture and storage.

Storing the gas underground depends on a number of factors. Geologists must identify suitable rock structures for storage and engineers must work to design processes for transporting the gas to the storage areas. The technology is currently being trialled in the Otway Project. A video clip which shows an animation of the process is available on the CRC (Cooperative Research Centre) - Greenhouse Gas Technologies website: <http://www.co2crc.com.au/> Another excellent video resource can be found on the NewGenCoal website: <http://www.newgencoal.com.au/randdtv.aspx>

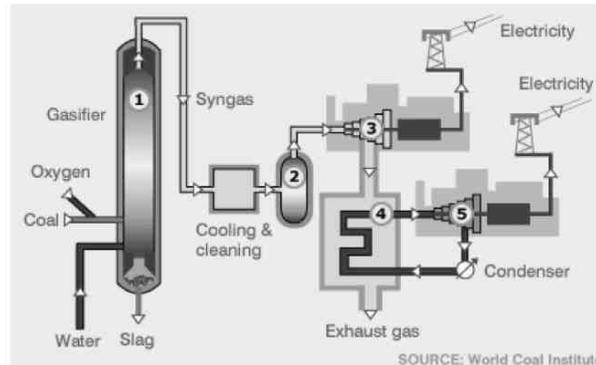


<http://mkcommunists.files.wordpress.com/2009/02/carbon-capture-recovery.jpg>
(accessed 23 April 2009)

Norway's Sleipner gas field in the North Sea was the world's first industrial-scale CO₂ storage. The CO₂ is injected into a deep reservoir (saline aquifer) about a kilometre below the sea bed and remains safely in place. The Utsira sandstone formation is said to be capable of storing 600 billion tonnes of CO₂.

Gasification processes

The process of coal gasification involves placing the coal in a high temperature and exposed to steam and a low concentration of oxygen. The resulting products are mainly hydrogen gas (H_2) and carbon monoxide gas (CO) with a small amount of CO_2 . The H_2 and CO mixture is known as syngas. The carbon monoxide is converted to carbon dioxide and separated from the hydrogen using a special filter. The hydrogen can then be burnt in high temperature gas turbines used to directly turn generators for electricity production.



1. Coal burnt to produce syngas
2. Syngas burnt in combustor
3. Hot gas drives gas turbines
4. Cooling gas heats water
5. Steam drives steam turbines

<http://news.bbc.co.uk/1/hi/sci/tech/4468076.stm> (accessed 23 April 2009)

The hydrogen gas produced in this process may also be used in fuel cells which can be used in cars. This is an attractive prospect as it provides a way of reducing the carbon dioxide emitted by petrol fuelled cars.

In summary

New technologies for reducing emissions of carbon dioxide and other greenhouse gases are being developed and trialled continuously. The technologies are based on many of the basic science concepts being developed in school. Students are encouraged to investigate the properties and use of materials in the same way scientists work. Some students may continue in this career path to assist in developing technologies which will solve problems such as greenhouse gas emissions.

Climate zones march south

Graham Readfearn

TAKING a dip in the ocean at Redcliffe these days is like swimming in Maryborough in 1950, new research shows.

Scientists say global warming sceptics should dip their toes in the water off a Queensland beach if they want proof the phenomenon exists.

They claim climate zones have moved south by more than 200km in the past 60 years, so Brisbane's climate has moved to Byron Bay to make way for more balmy weather.

Australian Institute of Marine Science researcher Janice Lough revealed the findings in a paper published by the American Geophysical Union.

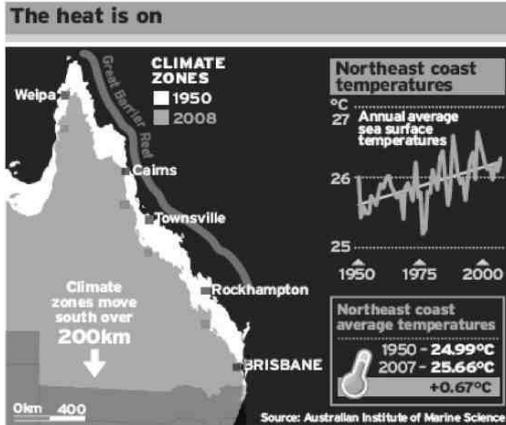
She said she was in no doubt the changes were due to global warming caused by increased greenhouse gas emissions from human activity.

"Sea surface temperatures are significantly warming along the northwest and northeast coasts of Australia — regions containing well-protected and internationally significant tropical marine ecosystems," she says in the research paper.

Dr Lough looked at sea surface temperatures recorded by ships and from satellite technology from 1950 to 2007. She analysed results from measurements taken as far north as Thursday Island in the Torres Strait and south to Coffs Harbour.

She also analysed temperatures off the northwest coast of Australia.

She found sea surface temperatures had been rising by as much as 0.12C a decade, which, with no further increase in greenhouse gas emissions, would make waters off southeast Queensland 2C warmer within the next 100 years.



"Average climate zones have also shifted more than 200km south along the northeast coast and about half that distance along the northwest coast," she said in her paper.

She said yesterday that a lot of the climate change literature was about the future. "This paper was to show that this is happening now — and has already happened," she said.

"This is down to global warming, due to human activities.

"A rise of 0.1C every 10 years might not seem like a lot, but in scientific terms it is significant. Over 50 or 100 years, you are completely changing the climate region."

She said while she believed the Great Barrier Reef would always be there, her findings showed there

would be more coral bleaching and further disruption to marine ecology.

Professor Peter Grace, research director at the QUT Institute for Sustainable Resources, said the research showed the urgent need for investment in strategies for adapting to climate change.

Dr John McBride, principal research scientist at the Australian Bureau of Meteorology, said in theory rising sea surface temperatures could see cyclones travelling further south.

But he said other factors, in particular the El Nino effect, had far more bearing on cyclone activity.

"The big factor is the impact of El Nino on tropical cyclones and what that will do under climate change," he said.

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Courtesy: *The Courier-Mail*, Thursday, August 7, 2008