Title: Science teachers and scientists working together: The partnership's impact on teachers' attitudes

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Abstract

To enhance teacher content knowledge of the mining and minerals processing industries, a program of professional development for science teachers was developed. This program engaged scientists and teachers from suburban schools in Queensland, Australia to facilitate professional, long term partnerships between the teachers and the scientists working in the mining and mineral processing industries. In the process, it was hoped that teachers would improve their content knowledge about the mining and mineral processing industries and that this would be evident in teachers' curriculum documents. This would allow teachers to provide for their students a realistic view of the mining and mineral processing industries and the associated careers that these industries provide.

This study documents the learning journey of a group of seventeen elementary and secondary science teachers wishing to incorporate working scientifically into their science classes and to adapt the science being conducted by scientists into their classroom practice. During the study both qualitative and quantitative data were collected.

The Queensland Centre for Advanced Technology (QCAT) was in close proximity to the schools and the scientists working at the centre were willing to form professional partnerships with the teachers. The QCAT centre was set up to support research in the mining and mineral processing industries and is the Commonwealth Science and Industrial Research Organisation's (CSIRO) largest research and development precinct in Australia (http://www.qcat.csiro.au/). 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.

Significance of the study

Currently, there is a "people shortage" within the mining and mineral processing industries in Australia and at a time when fewer students choose to study physical sciences at the secondary level, the Australian mining and mineral processing industries have an increasing demand for bright, qualified young people seeking research and leadership careers with in the industry. 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).

The Australian mining and minerals processing industries have expanded at an increasing rate over the last few years and this trend is expected to continue due to the growing international demand for Australian raw materials. Simultaneously, the supply of young

science graduates gaining the academic credentials and in science, technology, engineering and mathematics needed to maintain a qualified workforce, continues to dwindle. This problem has been well documented, but no easy solution has become apparent (Nicol & Woffenden, 2002, Bartier, Tuckwell & Way, 2003, Churach, 2005).

At the same time, there is a need for science teachers to confidently teach applied science and its links to industry. Science taught by making 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 the correct industry knowledge themselves. As science teachers 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, this will allow teachers to build their confidence.

Theoretical Background

The research program investigated how content knowledge about the mining and mineral processing industries could be delivered to science teachers in the most appropriate professional development model. New content knowledge helps teachers to identify ways to translate their learnings into the classroom and improves their teaching practice (Loucks-Horsley et al., 1998). Adey (2004) has modelled factors that influence the effectiveness of professional development programs for teachers and has shown that a number of factors must be set in a positive condition to be effective and to cause a change in student learning.

Science education in Australia has experienced major changes in recent years. Outcome-based syllabuses have been implemented to give students opportunities to demonstrate their learnings, with an emphasis on "Working Scientifically". This is to give students opportunities to learn to work the way real scientists work by investigating, understanding and communicating in real life contexts (Queensland School Curriculum Council, 1999). The new syllabuses provide a vehicle for teachers to include industry practices, and the associated science content knowledge, into their curriculum.

Tytler (2007), in a report on the future of science education, recommends that the professional development of science teachers needs to encompass both resource development and a significant professional learning approach that allows local control and contextual variation. As a consequence, this attends to teacher beliefs and is supported in local areas through networks and consultants. This project addresses these elements and helps to support the science teachers in their attempt to implement changes in their teaching practice.

Results from a previous study with secondary science teachers in Central Queensland, Australia, showed that, if they see that the 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. The *locus of control* needs to rest with the teachers to enable them to choose the best in-service for their own needs (Harrison & Nichols, 2002). Also, when science teachers are involved in joint planning and teaching, it leads them to reflect on and evaluate their planning, teaching and assessing practices. It also increases the use of the science syllabus and facilitates more explicit teaching as teachers gain a deeper understanding of scientific concepts (Nichols & Appleton, 2008).

Professional development has been offered to teachers at various support levels throughout Australia to enable them to teach the new syllabuses. Some schools were able to access grant funding to plan and organise professional development events (Quality Teacher Program, 2003). Because the new syllabuses were based on the constructivist approach to teaching science, much of the professional development was focussed on this constructivist approach. However, to successfully implement the new syllabuses, teachers needed to increase their pedagogical content knowledge (PCK). PCK was proposed by Shulman (1987) as one component of an effective teacher's professional knowledge. When sustained, long term professional development is provided, it gives teachers the freedom to choose areas that align with their perceived needs. Consequently, teachers will gain confidence to use this in their teaching practice (Harrison & Nichols, 2002).

The concept of teaching authentic industry applications in their science classes may be new to some teachers and they may 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 (Churach, 2004).

A series of recommendations was proposed by the Queensland Government to ensure that students have 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. Benefits for both science educators and researchers could occur if a mentoring relationship was developed.

To continue this commitment, the Queensland Government reviewed Spotlight on Science and developed the Science Education Strategy 2006-2009 (http://education.qld.gov.au/curriculum/area/science/strategy.html). As a direct outcome of this strategy, Senior Science Officers (SSO) are now employed to liaise with industry and research organisations to provide real life science experiences for students and teachers.

The SSO planned a professional development program with these 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 program was made flexible enough so that, if teachers wished to contribute or tailor the program to their own individual learning needs, it could be changed. The project places the emphasis on the on-going nature of the program and is 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 the mining and mineral

processing industries. Teachers would gain benefit from being exposed to a variety of academic and industrial experiences over a period of time. This would allow the teachers to develop relationships with scientists to a point where they feel comfortable in asking questions and sharing experiences (Churach, 2004).

Teachers are well positioned to positively influence their students' attitudes towards science and encourage them to consider careers in science and industry (Churach, 2006). 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. A similar Canadian (Alberta) project indicated increased positive outcomes when career options became infused into the curriculum and not taught as separate items and recommended professional development to be provided for teachers to accommodate this approach (Millar, 1995).

Research Method

The research identified areas of change in teacher's attitudes towards the mining and mineral processing industries. Teachers' content knowledge about the mining and mineral processing industries was documented and their curriculum documents were critiqued. Also, the research evaluated the project in terms of its efficacy in establishing professional learning partnerships between the teachers and the scientists. Both qualitative and quantitative data were collected to determine teachers' attitudinal change towards the mining and mineral processing industries.

Funds were accessed from the Queensland Government's Science Education Strategy 2006-2009. This enabled the teachers to attend professional development events held at QCAT. It also gave them time to write units of work incorporating their new content knowledge about the mining and mineral processing industries and provide opportunities to reflect on their practice.

Quantitative Data

Data was collected from the participating teachers during the life of the project. After the professional development events held at QCAT, the participating teachers were asked to fill in a survey. The survey called an "Attitude Inventory", developed by Churach (2005) and reviewed by academic staff at Murdoch University Extractive Metallurgy and the Science and Mathematics Education Centre at Curtin University of Technology, was used to determine attitudinal change after teachers had been involved in a professional development event.

Respondents answered numerically on a 5-point Likert Scale with 1 being "Strongly Disagree" and 5 being "Strongly Agree". Participants were asked to respond to each of the 16 items from their point of view before their first professional development event and then again from their point of view after undergoing the professional development events they completed within the program.

The 16 statements on the survey were:

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

The teacher responses to the survey questions were tabulated and then graphed to show the change in attitude before and after the professional development event.

Qualitative data

Qualitative data was collected using written questions and interviews. Follow-up questions were used to clarify the teachers' responses to the "Attitude Inventory". When the data from the "Attitude Inventory" was graphed, it was evident that there was a greater shift in some items in the survey than others. As these statements stood out, they required further investigation. This formed the basis for the interview questions which were used to gain a greater insight into the actual changes that the teachers were experiencing and to draw out the reasons for these shifts.

The 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 the identified themes which refined and substantiated their validity (Cohen, Manion & Morrison, 2000).

Research findings

Quantitative Data

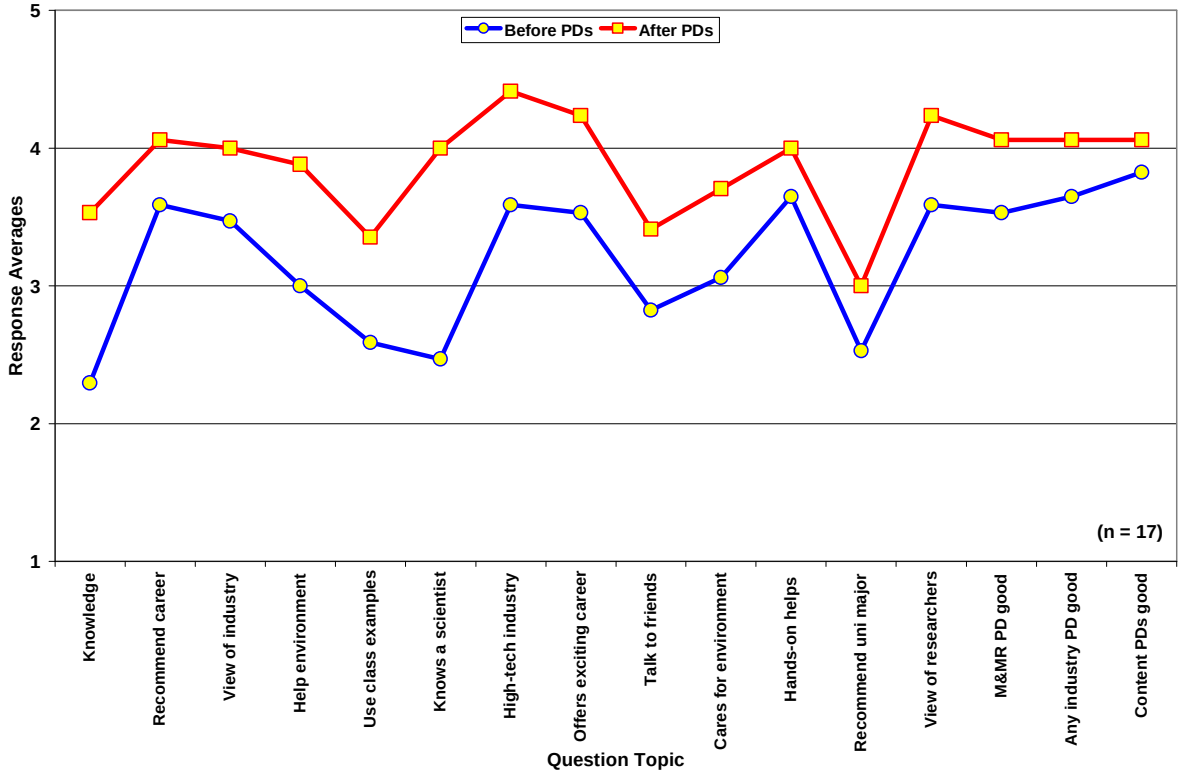
The results of all the surveys were tallied to find the average response for each question, both before and after the respondents participated in the professional development events. Although actual values of responses cannot be taken as a meaningful reflection on the professional development program, 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 mining and mineral processing industries, while a negative shift in score is viewed as a negative shift in teacher attitude towards the industry. A two tailed t-Test for paired samples was run on each of the 16 statement sets in the survey.

The data has been tabulated to show the topic of each individual statement, the "before" and "after" response and the shift for each.

Table 1: Questionnaire results (averages) for QCAT professional development events

Question No.	Question Topic	Before PDs	After PDs	Shift
1	Knowledge	2.29	3.53	1.24
2	Recommend career	3.59	4.06	0.47
3	View of industry	3.47	4.00	0.53
4	Help environment	3.00	3.88	0.88
5	Use class examples	2.59	3.35	0.76
6	Knows a scientist	2.47	4.00	1.53
7	High-tech industry	3.59	4.41	0.82
8	Offers exciting career	3.53	4.24	0.71
9	Talk to friends	2.82	3.41	0.59
10	Cares for environment	3.06	3.71	0.65
11	Hands-on helps	3.65	4.00	0.35
12	Recommend uni major	2.53	3.00	0.47
13	View of researchers	3.59	4.24	0.65
14	M&MR PD good	3.53	4.06	0.53
15	Any industry PD good	3.65	4.06	0.41
16	Content PDs good	3.82	4.06	0.24

Graph 1: Teacher attitudes towards mining & mineral resource industry before and after professional development (QCAT event on 07/11/2007)



When the data is graphed, the shift in the teacher's attitudes becomes obvious. While each topic showed a positive shift for this set of teachers, the shift was not the by the same amount. The two greatest shifts in response were "Teachers getting to know and networking with scientists" (Likert shift = 1.53) and the teachers' "Overall knowledge of the mining and mineral processing industry" (1.24). Other notable shifts are in "Teachers using examples of the mining and mineral processing industries frequently in their classes" (0.76), while "Teachers recommending a university major in the mining and mineral processing industries" had a low initial score and only a shift small shift (0.47) after the professional development events.

Qualitative Data

The results from the "Attitude Inventory" informed the direction of the questions and interviews that comprised the qualitative data and from this data four assertions were able to be made.

The assertions were:

1. Teachers' content knowledge about the mining and mineral processing industries had improved as a result of participating in the professional development events.
2. Teachers 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. Teachers were able to write curriculum documents and teaching resources using material from the professional development events.
4. Teachers had not initiated any further contact with the scientists after the professional development events, even though they believed that it would be beneficial.

Teachers' 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 teachers in the project were learning about these advances for the first time. The teachers realised that after the professional development events, their content knowledge had increased. When the teachers 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

Teachers 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

Teachers 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, teachers were able to identify how scientists "Work Scientifically". Teachers 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 teachers 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, eg in science, for their work… to point out people can pursue their passions as a career." DF

However, the teachers did not lose sight of their teaching role to cater for the learning needs of their students. The teachers 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

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

After the professional development events a group of teachers 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 teachers in this endeavour. The resource has been distributed to the teachers involved in the project and now other teachers, 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

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

By participating in the project the participating teachers were granted time away from their classes. This enabled them to interact with the scientists, however, when the professional development events were finished, the teachers returned to their busy routine. So, the aspiration for there to be an ongoing professional relationship between the teachers and the scientists did not eventuate, even though the teachers thought that such a relationship would be beneficial.

"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

Teachers 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

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

"Its handy to have access to materials, eg 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 teachers that wrote the resource did have further contact with the scientists. They interacted with the scientists during the writing phase and used them to check the content knowledge about the mining and mineral processing industries for accuracy before it was published in the resource.

Conclusion

Using qualitative data in the form of the "Attitude Inventory" did effectively measure the change in attitude of the teachers surveyed. More importantly, when these results were used in conjunction with the qualitative data, a clear indication emerged about why their attitudes changed.

When teachers 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. They were also able to identify how scientists "Work Scientifically". The teachers were willing to use examples from the mining and mineral processing industries to illustrate how science is used in the real world and would talk 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 tailor 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 have developed a resource that is being shared with other science teachers and, in doing so, 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 use these examples in their teaching practice, the teachers in this study have made an attitudinal change to 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 gives 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.

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