Secondary School Science Teachers as the Key to a Sustainable Workforce in the Mining and Mineral Processing Industry: Changing Peoples' Attitudes

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Abstract

This paper reports on an innovative professional development program for school science teachers run collaboratively between the Centre for Sustainable Resource Processing and Murdoch University. Ultimately the initiative aims at increasing the pool of school students with strong science and mathematics backgrounds while highlighting the challenging careers available in the mineral resource sector including the gold industry. The program is unique in that it seeks to develop a network of science teachers who may participate in a series of workshops, short course and tours over a several years. The objective is to raise secondary school students' awareness of potential careers within the minerals sector by exposing teachers to a real life, hands-on look into the mining and minerals resource industry. Though the program includes the breadth of the resource processing sector, the potential value to gold processing is in developing greater pool of potential employees. The initiative allows teachers to develop a better insight into the practical applications of the theoretical sciences they are required to teach. The evolution of the program from the first trials with Western Australian teachers to introduction of the initiative to Queensland teachers are reported on. Additionally, the results of a pilot study involving 40 participating teachers are described. This study used a questionnaire and follow-up interviews to gain quantitative and qualitative feedback from teachers. There is evidence that the professional development program has resulted in teachers acquiring a new found appreciation for the application of the fundamental chemistry and physics they teach within the school curriculum. Also reported are associations between teacher participation in this professional development program and changing attitudes towards the industry in a positive way.

Overview

The problem

The Stern Review (Stern, 2006) impacted global opinion in ways not often seen for most scientific reports. Arguing that the world economy depends on the wealthiest countries dealing with climate change has received broad-based support in the community at large. *Time Magazine* (Kluger, 2006) reports that atmospheric carbon dioxide levels notched up again during 2005 to 381 parts per million, the highest level recorded since continuous records have been kept and over 100 ppm higher than at the start of the Industrial Revolution. Despite phasing out leaded petrol in recent years, the Torrens River in Adelaide, South Australia, has lead levels in its muddy bed of 0.5 % − almost high enough to mine the metal commercially (Roberts, 2006). The gold industry particularly has had its share of environmental headlines during the past several

years (Langman, 2006, Robinson, 2006, Perlez and Johnson, 2005). Are those of us in industry the ecological culprit?

But wait − there is so much more! Before one resorts to any 'Chicken Little' cries that the sky is falling, it must be acknowledged that we create a great deal of good news, too. London 'smog' has given way to smokestack scrubbers that remove sulphur and nitrogen compounds as well as many heavy metal pollutants previously dumped into the atmosphere. ReSand™ and dry processing promise to turn old waste streams into new value streams while reducing mineral processing CO_2 production (Green, 2006). In Australia platypuses are found in the upper reaches of the Yarra River for the first time in decades (Bain, 2006). Certainly a majority of western ('global') industries boast of 'sustainability programs' and take great pains in publicizing the attention they pay to environmental stewardship. Are those of us in industry the ecological cure?

One could easily argue that industry is both cause and cure − our technology-based solutions give rise to new problems which are in turn solved by our application of science and technology. With a global population of 6.5 billion people and growing, we have long since passed the point of turning back to simpler times in an effort to put technology behind us. Surely none would trade the latest Australian life expectancy levels of 80.2 years (United Nations Population Division, 2004) for a lifespan that averaged just over 50 years in 1900. The authors of this paper would argue that the very existence of our species may rest on our ability to learn and apply our knowledge to solve problems not yet dreamed of. But the reality is that 'industry' does not learn and contemplate and new knowledge. Acquisition and application of knowledge is wholly in the domain of the people who are a part of these industries. The challenge of progress can only be met if each generation produces a 'best and brightest' core of young people willing to tackle the great scientific and technical issues of the day head on. Reporting on the blight of the Great Barrier Reef being starved by warming waters, *The Weekend Australian* (Stewart, 2007) contends that only better science can cure the excesses of our technological success. The authors of this paper argue that this 'better science' will more likely than not find its roots in the applied fields of mining, extractive metallurgy and energy studies rather than in marine biology or environmental science. Of course if this is the case, a steady supply of bright school students with strong backgrounds in chemistry, physics and maths needs to be maintained in Australia, the United States and throughout the world.

The key to sustainability − bright young students interested in resource sector careers

There is ample evidence to suggest that this is not happening. The American Chemical Society statistics paint a dire scenario within the USA (Storck, 2006). In one sample of more than 35,000 people employed in some facet of chemistry or chemical engineering, the median age of the chemical cohort was 41.3 years in 1990, 44.7 years in 2000 and 47.0 years in 2005. At that rate there is much doubt that the total amount of professionals in the chemical sciences can even stay constant over the coming decades. In reference to a National Science Board paper on trends in science and engineering, Storck reports:

> *"If the trends identified in Indicators 2004 continue undeterred, three things will happen. The number of jobs in the U. S. economy that require science and engineering will continue to grow; the number of U. S. citizens prepared for those jobs will, at best, be level; and the availability of people from other countries who have science and engineering training will decline, either because of the limits*

> *imposed by U. S. security restrictions or because of intense global competition for people with those skills."* (p. 46)

One can find similar statistics across the scope of scientific disciplines, but an argument can be made that the greatest shortage of incoming talent − certainly in western countries − is within the range of physical sciences.

This need is quite apparent within the gold industry as well as across the entire mining and mineral resource sector of Australia. By far the largest wealth-creating industry for the country, nearly a third of Australia's export income is dependent upon the mining and minerals sector. But at the same time this multi-billion dollar industry has geared up to feed the insatiable demand of raw materials to China, India and the western world, the supply of young science graduates gaining the academic credentials and experiences in the Science, Technology, Engineering and Mathematics (STEM) subjects needed to maintain a qualified workforce continues to dwindle. The problem has been well documented, but no easy solution has become apparent (Churach and Nichols, 2007, Bartier, Tuckwell and Way, 2003, Churach, 2003, Nicol, 2005).

The Centre for Sustainable Resource Processing (CSRP) has viewed the issue with particular concern. Though the chief mission of the CSRP is to conduct research involving the mineral processing industry in Australia, it has become increasingly apparent that the real key to sustainability must be found in people. Operating under the assumption that there can be no research without researchers (or no employer without employees) CSRP has teamed with staff at Murdoch University Extractive Metallurgy in searching for a way to involve the mining, minerals and resource processing industry with the community at large in the hope of developing greater interest in careers within the resource sector among school students. The question arises as to the most effective method of reaching "the masses", as it were. One might be tempted to reach young people through the media, but the question remains as to how to target this audience in an efficient, cost effective manner.

Specific benefits to the gold industry

A recent report looking into the demands of each commodity in each Australian state in light of the nationwide skills shortage reinforced the notion that gold producers face the same shortfall of workers as others within the resource sector (Minerals Council of Australia, 2006). Specifically, the report forecasts annual gold production expanding from 270 tonnes in 2005 to 345 tonnes in 2015 with the 2005 gold workforce of 18,335 employees growing to 25,396 by 2015 (p 6). The largest shortages will be in non-professional occupational classifications, particularly trades people and semi-skilled help. In competing for labour within a tight market of job seekers, the gold sector will draw future employees from this group of students now finishing middle and upper secondary years across the country. Any effort that results in expanding this pool of potential employees will benefit all commodity areas.

Reaching out to school students

But how do we expand the pool? What inputs do school students use to make decisions? The Western Australian Government's *2003 Youth Survey* shows that young people turn to fairly obvious sources for information including the Internet, books, newspapers, magazines, television and radio. It should be emphasised however that sources of information and influences on

decision making are not one in the same thing. Again the WA *2003 Youth Survey* proves quite comprehensive in its survey of 7,919 young people (aged 12-25 years old) across all socio-economic backgrounds and educational circumstances. Concerning who these respondents consider to be the major influences in their lives, one could predict the high standing of parents (94% responded "a lot" or "some" influence) and friends (96%). Less predictable may be the very high regard many of our youth hold for their teachers and lecturers, with 78% of these young people saying teachers had "a lot" or "some" influence in their lives. This total is higher than the respondents in the survey reported for other relatives, sports coaches and other popular figures.

A more recent nationwide study by the Australian Government's Department of Education, Science and Training (2006) supports the contention that teachers have a strong influence on their students' subject selection. Using a sample of 1,830 high school students from all Australian states and territories, the study explored the issues affecting student selection of courses of study. In particular, year 10 students responded that the most influential people having an impact on the selection of science subjects (i.e., making them "enjoy studying sciences") were teachers (71%), ranking them even above parents (66%) and peers (57%) in influencing subject selection.

Churach (2006) points out that:

> *"…these findings support the old notion that "the best salesman 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. That parents and friends rank 1 and 2 as the most influential on opinions is easily predictable. In the same sense one can understand the high ranking of teachers as opinion influencers. For the most part, young people spend their "working days" in the company of teachers and in many cases, interact with some teachers for more hours per week than they would normally interact with a parent. If all things would be equal, the target audience to be reached would be parents and friends, though in terms of numbers, there is little leverage to be gained in attempting to reach (for example) 20,000 parents in order to influence 30,000 of their children. We can say with great confidence that the teacher-student relationship is real and that these relationships already exist (in the Western Australian instance) between several hundred WA teachers and several tens of thousands of WA school students. (p 112)*

Obviously funding is limited, so one must take into account the best cost-to-benefit ratio of any method employed to communicate with school students. In that light it appears that existing teacher-student relationships present an opportunity too good to pass by. But if a program is to be directed at teachers, should the effort be broadly based at all teaching staff or only those teaching in specific subject areas?

The Science Career Inventory (SCI): Teachers are heroes

Students have looked to their teachers for guidance as well as knowledge for as long as there have been teachers and students. No doubt Plato reflected a great deal of thought that Socrates (his teacher) shared with him. The influences of Buddha, Jesus and Confucius are notable in that they still exert an influence on many people centuries after these teachers walked the earth. An informal survey around the office water cooler would offer anecdotal support for the notion that

most remember some teacher who at some point in their lives had a significant influence on them that reached beyond the classroom and impacted on their personal development.

A recent study looking at what motivational factors affect career choice in the minerals resource and energy sector has found support for just this scenario (Churach and Rickards, 2007). The Science Career Inventory (SCI) employs a questionnaire exploring six potential career drivers using 36 questions divided into 6 scales (financial, academic, relationship, lifestyle, altruistic and personal esteem). It also includes several open-ended questions concerning influences of teachers on career decisions. The number and type of responses to these open-ended questions offers strong support concerning the value of school teachers as a valuable means of reaching secondary students with information concerning career choices. Reflecting on a sample of 244 respondents, the study reports:

> *"…school and university teachers had the greatest influence on the career choices of those included in this sample population. Of these teachers, the overwhelming majority were high school science teachers, though quite a few mathematics people were mentioned. The value of informing secondary school science teachers about the energy and mineral resources sector is heightened by their direct contact with students who may want to consider these areas as a career choice. It is also of note that school teachers are usually the primary significant other that students in high school confer with during the two or so years before completion of secondary education, when vocational and educational decisions are being reinforced by the subjects chosen for those final two years of secondary education. In short, students are somewhat locked in and out of some alternatives based on these important subject choices and teachers have an influence on these choices."* (p 9)

It seems that the target audience that could allow industry to maximise its leverage in an attempt to influence young people would be secondary science teachers. The teachers already have existing relationships built with many of their students and both teacher opinion and input is highly valued by most of these young people. Additionally, each teacher may see 150-200 students in the course of a week, so if positive experiences can be provided for secondary teachers, there is every reason to believe their students will view the industry in increasingly more positive terms. Even more, for those students most likely to be open to careers in the mining and mineral resource sector in many cases look to their science teachers as heroes.

A study on the state of science education in Australia, "*The Status and Quality of Teaching and Learning of Science in Australian Schools"*, was presented to the Department of Education, Training and Youth Affairs in Canberra in 2001. The researchers offered an in depth report on the state of science education in Australia and pointed time and again to the teachers being the key to any positive change within schools. Amongst the many recommendations made by the team was the following, underlining the value of including the wider community in producing the highest quality education:

> *Teachers working alone in their classroom can make small steps towards change. Teachers working together can make larger strides. Schools collaborating make a greater impact still. But quality science education curriculum and professional development resources are very expensive and require the very best expertise to develop. Collaborative ventures that pool the financial and human resources from a number of jurisdictions have the potential to produce the world-class materials that are required for a contemporary, relevant and engaging science education for all students (Goodrum, Hackling and Rennie 2001, p. 169).*

In a time when education budgets undergo cuts and government systems continually insist on more for less, the time is ripe for alternative ways of acquiring the resources and learning experiences that will result in greater excellence among our teaching staffs.

How does an industry reach out to teachers?

The Technical and Vocational Education Initiative (TVEI) instituted in the United Kingdom in the 1980s was an example of a government attempt to involve industry in teacher professional development). Initially many teachers were quite suspicious of potentially devious motivations and hidden agendas that industry sponsors may bring into schools. Was it possible controversial industries merely wanted to change their images? (Keith, Lakin and Callaghan, 2000) Moreover, is it possible that industry sponsors may view teachers as an over-paid and under-worked part of the public sector bureaucracy?

If industry input to teachers' professional development is to have a positive impact on teachers, it must be based on trust and mutual need between the industry sponsors and the teacher participants. That teachers (particularly on the secondary level) need "real world" experiences with which they can build upon their theoretical base is apparent. Conversely, the necessity for industry to have any input into the ever-expanding breadth of knowledge in a 21st century classroom is equally important for the simple reason that "Teachers of science will be the representatives of the science community in their classrooms" (National Research Council, 1996, p. 61).

School-Industry partnerships may offer value on an *ad hoc* basis, though the success of these arrangements may often be dependent on the energy and personalities of a few prime players on either side of the fence. Australia's Chief Scientist, Dr Jim Peacock, laments that there is a "mismatch of science as it is taught in schools and how science exists in the 'real world'" (Tytler, 2007, p. *v*). There is a need to somehow open science teachers to these 'real world' opportunities.

One Australian program may offer some help to overcome the above mentioned mismatch. The Cooperative Research Centres Programme instituted by the Australia government in 1990 attempts to change the research culture of the country. The aim can be stated simply, although the implementation of their charge is much more difficult. In brief, CRCs are meant to bring together the expertise of industry, research organisations, educational institutions and Federal and State government agencies together as core participants in each centre to address specific research priorities in a variety of commercial and public interest areas. The ultimate goal of the CRC Programme is to boost the competitiveness of Australian technology and to help ensure the country maintains and extends its science and technology base well into the 21st century (Churach, 2003).

The point has been made previously in this paper that one of the most important wealth-producing industries in the Australian economy (mining and mineral resources) has experienced a great decline in young people indicating interest in careers within the sector. Many in the industry ask if anything can be done to stem the tide and somehow develop greater interest among young people in this challenging and profitable field.

Professional development experiences for secondary science teachers

The Centre for Sustainable Resource Processing and Murdoch University Extractive Metallurgy staff have run a program offering a series of on-going professional development (PD) activities for secondary science teachers for the past several years. The point of the program is to stress "positive activities", with great emphasis placed on the plural "activities". Other programs offer

teacher professional development activities and some can be quite intensive. The Colorado Mining Association and Colorado School of Mines have offered a summer teacher program going back several decades (Witkowsky, 2004), but even this program calls for a one-time course run for a group of K-12 teachers. The CSRP-Murdoch 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 resource processing. Ideally, teachers would 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 would allow the teachers involved to develop relationships with scientists and industrialists to a point where they feel comfortable in asking questions and sharing experiences (Churach, 2004b). Over a period of time (a few years) it would seem natural for teachers to gradually integrate their new-found knowledge into the curriculum and to have positive impacts on their students' perceptions of the industry. There is support for this approach in the literature. One project carried out in Alberta, Canada, indicated more positive outcomes when career options became infused into the curriculum and not taught as separate items (Millar, 1995). This research indicated the need for a strong dose of professional development to be provided to teachers.

Certainly, teacher professional development is in the realm of various state education departments, but in the area such as mining and minerals resource processing, little in the way of real professional development can be expected from government sources. The reason for this is two-fold: First of all, education departments tend to focus more specifically on process issues (e.g., in WA during the past several years, the schools have been mandated to move to the new outcomes-based curriculum) and nearly all of the monies provided fund those type of professional development offerings. Secondly, few academics and even fewer educators have any practical industrial experiences involved with mining, minerals and resource processing. It seems that the time is right for a cooperative venture involving school teachers with both academia and industry personnel.

The original introductory short course was entitled "The Chemistry and Physics of Extractive Metallurgy" and was held in the Extractive Metallurgy laboratories at Murdoch University. This one-day workshop allowed science teachers to spend a day in laboratories exploring three key areas: mineral processing (physically separating ores), pyrometallurgy (the use of heat to extract metals) and hydrometallurgy (the use of water to extract metals). Because these teachers had voluntarily given up a day of their term breaks, the sponsoring organisations funded the cost of the staffing, the materials used for the professional development activities and the tea, lunch and a wine and cheese end to the day. Teachers went home with a bag of teaching materials including posters, CDs, and the like along with a tin ingot they poured and a chemist's spatula they gold plated.

The first PD received such positive feedback that a range of activities have subsequently been scheduled. A follow-up "Advanced Extractive Metallurgy" course was added during the second year of operation. This one-day PD has teachers begin the day with a rock sample of ore which they process into a purified metal by the end of the workshop. Murdoch teaching staff and researchers offer expert "consultancy" services throughout the day. Many of the participating teachers requested more activities and over the past several years, many more learning events have been offered. Since the program's inception, an array of professional development modules and several tours have been offered. Some of these activities offered on an on-going basis are:

- "The Chemistry and Physics of Extractive Metallurgy" (over a dozen short-courses)
- "Advanced Extractive Metallurgy" (a half dozen short courses)
- "Online Interactive Learning – Providing a Minerals Industry Context for Secondary Student Learning Workshop" (2 short courses)
- Several tours of research facilities at Murdoch University and Curtin Universities in Perth
- Several industry tours (e.g., Alcoa's bauxite mine and processing facility, AngloGold Ashanti's gold mine and processing plant)
- Remote site teacher PD visits and lectures at Geraldton, Karratha, Port Hedland, Broome
- STAWA Future Science presented by the Science Teachers Association of Western Australia – annual presentations and lab sessions
- Gladstone Area Mathematics, Science and Engineering Teachers (Queensland) PDs and lectures
- Diploma of Education Metallurgy students 90-minute Extractive Metallurgy Laboratories (student teachers)

Pilot Study Results

Quantitative outcomes of the PDs

Having offered the program for several years, the authors developed a survey for teachers using questions designed to assess a series of attitudes secondary science teachers hold about the mineral resource industry and how the professional development program may affect these attitudes. The survey was reviewed by the academic staff at Murdoch University Extractive Metallurgy and at the Science and Mathematics Education Centre at Curtin University of Technology to determine whether it covered a range of issues facing both the industry and teachers in Western Australia.

The survey consists of 16 questions each of which calls for the participant to respond twice, once based on their point of view before the first professional development they attended within the program and a second time from their point of view today. Respondents answered numerically on a 5-point Likert Scale with 1 being "Strongly Disagree" and 5 being "Strongly Agree" (see Appendix I). Though a running registration list of approximately 100 participating teachers was kept over the three years, it did not include student teachers and teachers contacted during short (50-minute) presentations at Science Teachers Association of Western Australia (STAWA) presentations. Initially 78 surveys were sent to teachers and 12 were returned because teachers had changed jobs or otherwise could not be contacted. Of this total of 66 surveys, the data reported here are based on a sample of 43 surveys returned (65%).

Results of all the surveys were tallied to find the average response for each question both before and after the respondents participated in any PDs. Though actual values of responses can not be taken as a meaningful reflection on the PD program, the shift in average response can be interpreted as a change in teacher attitude towards the industry. A positive shift in score is interpreted as a positive shift in teacher attitude towards the industry and a negative shift in score is viewed as a negative shift in teacher attitude towards the industry. Results of the survey are shown in Table 1.

A two tailed t-Test for paired samples was run on each of the 16 question sets in the survey and in every case the change was found to be statistically significant ($p<0.01$). This can be interpreted

as indicating that the changes in attitudes shown by teachers were much more likely to have been associated with the PD work they had done than with any kind of chance occurrence. Certainly the qualitative results reported below seem to support this finding.

[Table 1 here]

It is interesting to note that the two greatest shifts in response were with the teachers' overall knowledge of the industry (1.40) and teachers getting to know and network with scientists (1.28). Other notable shifts in teacher attitudes were in teacher willingness to provide career information to students (1.05) and to use mining and mineral processing examples in class (1.00). Standard deviations are also listed for each scale indicating the spread of responses. In the four attitude shifts mentioned here, the small stand deviations implies that participants showed similarly large changes in responses - exactly what would be anticipated if a strong association existed between teacher PDs and attitude changes.

[Figure 1 here]

Qualitative outcomes of the PDs

Much of the qualitative feedback received in this program supports the positive effects of these professional development offerings on teacher attitudes towards the industry. If success can be measured in enthusiasm, then the program has been a smashing hit. Studies by Shrigley (1974) and Sunal (1982) have pointed to the fact that involving science teachers in industry-related field experience development activities not only affected attitudes towards science in general, but also attitudes towards science teaching changed in a dramatic way. Interactions with and among teacher participants indicates the professional development events reported here have resulted in a similar reinforcement of teaching activities.

Additionally, teachers who became engaged in the professional development program tended to continue their involvement with two, three or more activities. Of the 43 teachers responding to the survey reported here, nearly two-thirds (26 of 43) opted to participate in several of the offerings. Though the average number of PDs the teachers participated in was 2.28, some teachers completed 4, 5 or 6 of them. In one case, a high school chemistry teacher took part in 7 different activities. It is notable to point out that in every case, these PDs occurred outside of school hours and thus the teachers were voluntarily giving up their own time.

One chemistry teacher has attended seven different activities over the several years. "*It is very generous … to provide teachers with the opportunity to see chemistry in an industrial context and to be able to understand another employment avenue for our students. For the teacher to be able to relate the course to real world situations seems to bring it alive for the kids.*" This teacher has also made use of the network developing through this initiative to communicate with academic staff at Murdoch and CSRP and has organised visits for his own students to the university.

Another science teacher reported, "*As a self-confessed lay person in this area I though it time I obtained a better understanding of the processes and issues relating to the minerals industry - a major economic driver in our state/country. [Thanks] …for providing such a well balanced discussion on this area and plenty of practical opportunities for us to experience throughout the day. I was pleasantly surprised at how many fragmented pieces of information I was able to put*

together to create a more rounded understanding of the industry and its issues. I would like to recommend this course to any secondary teachers involved in teaching in the subject area."

Still another chemistry teacher had this to say about one of the one-day PDs she completed last year: *"I thoroughly enjoyed this course ─ it was great to be able to do some new hands-on experiments. The gold plated spatula has been a real hit at school."*

One Head of Science Department at a Perth college spoke highly of her visit to the gold mine site. *"A million thanks for enabling me to have the most wonderful experience by visiting the mine last week ─ it was really the high point of my holiday. I have been enthusing my family and students with the story ever since..."*

A professor in science education at a local university also went along to the gold mine. *"I have gained long term residual value from my visit to the …mine site. Not only has it provided an on the ground authentic experience of the people and processes that are the heart and soul of a successful mining operation, but it has provided a clear picture of what a significant contribution to the economic wellbeing and community life of our country this industry offers. It is significant and yet is a quiet achiever in terms of public knowledge."*

And the enthusiasm comes from the providers of the experiences, too. The General Manager of a global gold producing company says that it is critical for the mining industry to demonstrate to the teaching profession that the Australian mining industry is the world leader in its technological, safety and environmental practices and that it provides exciting and stimulating careers in a truly global industry. *"We take pride in what we do and enjoy communicating the excitement of our industry and its benefit to the broader community,"* he says.

One of the professors at Murdoch University who has volunteered a great deal of time to organising and implementing the teachers PDs pointed out that, *"If no one takes the time to provide these kinds of experiences for the high school teachers, then we can't expect their students to realise that many opportunities exist in this exciting industry. We in Extractive Metallurgy have been delighted with the opportunity to partner the … [CSRP] in this valuable initiative. Graduate prospects have never been better than they are currently due to the continuing boom in global metal demand."*

A program manager for Australia's Commonwealth Scientific and Industrial Research Organisation (CSIRO) commented after taking a group of teachers on a tour of a mineral research facility, *"It was terrific to see the genuine enthusiasm the teachers showed for our research. This was very evident from the questions asked during and after their visit. Enthusiastic science teachers are essential for promotion of science at school and the supply of quality undergraduates to universities. CSIRO can supply great career opportunities for science graduates, but it can't happen without good science teaching in schools."*

Future studies

The use of teacher professional development as a change agent for teacher attitudes towards industry will be explored in greater detail by an on going study carried out with support from the Centre for Sustainable resource Processing (Nichols and Churach, 2007). This work aims to expand the sample of teachers in the pilot study and include teachers in another state (Queensland) and another country (the United States). Additionally, this work will assess teacher programs and lesson plans in an attempt to determine how much information gained from the professional development activities actually filters into the school classroom. Finally, there is

now anecdotal evidence that a measurable percentage of incoming first year students studying extractive metallurgy at Murdoch University have had some interactions with teachers who have participated in the program. Upcoming work will attempt to quantify this outcome.

Conclusions

The teacher program offered by CSRP-Murdoch University continues and has spread to another Australian state (Queensland) in partnership with the Gladstone Area Mathematics, Science and Engineering Teachers (GAMSET). At this point there are several conclusions that can be drawn with a reasonable degree of confidence.

Firstly, the teachers who have participated in one or more of the teacher professional development offerings have offered a great deal of verbal feedback in support of the program. As pointed out previously, many teachers opted to give up their free time during school holidays or in the evenings to do more than one activity. The network that has formed is lasting and with some teachers has endured over the entire two-and-a-half years of the project.

Secondly, the shift in teacher attitudes towards a more favourable perspective of the mineral resource sector was significant in all sixteen questions asked in the survey. This suggests a strong association between teachers participating in the professional developments and a positive shift in their attitudes towards the industry.

Thirdly, there is anecdotal evidence that, at least in the case of Murdoch University Extractive Metallurgy, first year student enrolments have risen since the inception of the teacher program. Though the numbers are too small to present statistically significant results, several students choosing to major in Extractive Metallurgy have reported they had input from teachers involved with the professional development program.

Finally, the attitude shifts represented by the last two questions (15 = *Getting a bit of an "inside view" of any Australian industry makes me a better teacher* and 16 = *PDs that offer a maximum amount of science content-oriented material make me a better classroom teacher*) seem to indicate that the teachers in this sample believe more professional development offering a better insight to "real-world" science applications (eg., industry) would result in improved teaching on their part. Though this project is sponsored by the mineral processing sector, all industries dependent upon young people studying the fields of science, technology, engineering and mathematics could benefit from sponsoring teacher professional developments as a vehicle for reaching out to young people.

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APPENDIX 1

Murdoch University Extractive Metallurgy / Centre for Sustainable Resource Processing Teacher Professional Development Program Feedback Survey

I am gathering data in an attempt to measure the effectiveness of the 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 with us and secondly from your perspective today after having participated in one or more of these PDs.

A returned envelope has been addressed and stamped for your convenience. 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.

Regards,

Dan Churach

Name _____ **School** _____
(optional)

How many CSRP / Murdoch University Professional Development activities have you participated in to date? Tick the boxes that apply.

Intro PD ☐ Advanced PD ☐ On Line Learning PD ☐ Mineralogy PD ☐

Industry Tour ☐ Community Lecture ☐

Any Other Activity sponsored by the above organisations? _____

		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…

		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. Please return form to Dan Churach,
Centre for Sustainable Resource Processing, PO Box 1130, Bentley, WA 6102

Figure 1: Graphical representation of mean response before and after teachers participated in PDs.

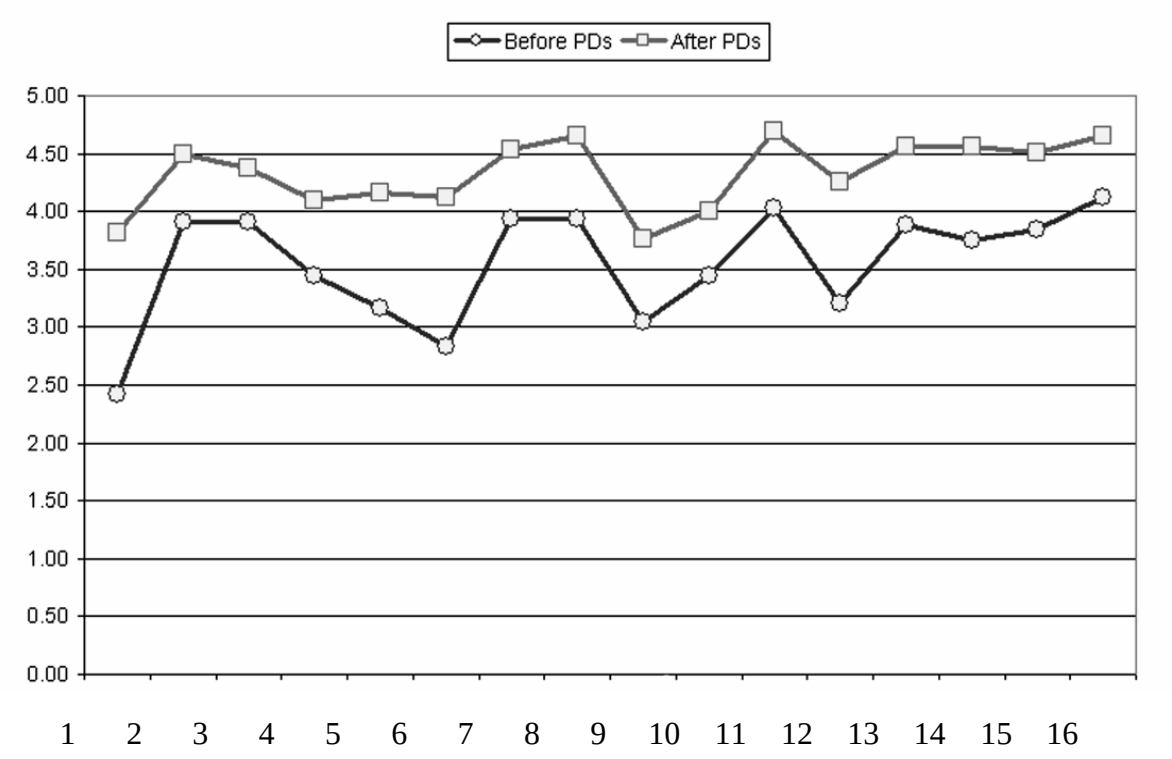

Table 1:
Mean teacher response to survey questions.

Survey Question	Mean response before any PDs	Standard deviation	Mean response today	Standard deviation	Shift in attitude score
1. My overall knowledge of the Mining and Mineral Resource industry is very extensive?	2.42	1.01	3.81	0.93	1.40
2. I believe that careers in the Mining and Mineral Resource industry are worthwhile recommending to my students.	3.91	0.87	4.49	0.74	0.58
3. I have a very positive attitude towards the Mining and Mineral Resource industry in Australia.	3.91	0.81	4.37	0.79	0.47
4. I believe an excellent way to solve environmental problems can be found through Mining and Mineral Resource research.	3.44	0.93	4.09	0.72	0.65
5. I use examples of the Mining and Mineral Resource industry in my classes frequently.	3.16	1.19	4.16	0.69	1.00
6. I know a scientist I can e-mail or phone to get information concerning a mineral processing or chemistry question.	2.84	1.25	4.12	1.00	1.28
7. I consider a Mining and Mineral Resource in Australia to be a modern, high-tech industry.	3.93	0.77	4.53	0.59	0.60
8. I think that a Mining and Mineral Resource industry offers an exciting career path for young people.	3.93	0.99	4.65	0.53	0.72
9. I talk to colleagues and friends about issues concerning the Mining and Mineral Resource industry in Australia.	3.05	1.05	3.77	1.02	0.72
10. I believed that people in the Mining and Mineral Resource industry care about the natural environment.	3.44	0.96	4.00	0.76	0.56
11. The more teachers do hands-on activities, the better they will understand the Mining and Mineral Resource industry.	4.02	0.64	4.70	0.51	0.67
12. I provide information to students concerning the possibility of a Mining and Mineral Resource major at university.	3.21	1.08	4.26	0.76	1.05
13. I have a positive view of career researchers and scientists in Mining and Mineral Resource industry.	3.88	0.85	4.56	0.50	0.67
14. Getting a bit of an “inside view” of the Mining and Mineral Resource industry makes me a better teacher.	3.74	0.85	4.56	0.50	0.81
15. Getting a bit of an “inside view” of any Australian industry makes me a better teacher.	3.84	0.90	4.51	0.55	0.67
16. PDs that offer a maximum amount of science content-oriented material make me a better classroom teacher.	4.12	1.05	4.65	0.61	0.53

n = 43