MINING ENGINEERING EDUCATION AND RESEARCH FOR SUSTAINABLE MINING: CANADIAN AND AUSTRALIAN PERSPECTIVES.

Malcolm J. Scoble[1, 3] and David C. Laurence[2]
[1]The University of British Columbia, Canada
[2]The University of New South Wales, Australia
[3] malcolms@mining.ubc.ca

Abstract: This paper characterizes the nature of mining and its mining engineering support. It then reviews the concept of sustainable mining that is emerging within the mining industry, referring to some milestones and case studies. The educational and research implications of the quest for sustainable mining are then analyzed from the perspective of mining engineering academics from Canadian and Australian Universities. A review is presented of some of the education and research initiatives by mining schools that are responding to the context of sustainable development within mining. The paper concludes by considering the implications of globalization and the need for contributions from established mining schools to build capacity within education and research institutions in the developing world.

1 MINING AND MINING SCHOOLS

The practice of mining can be traced back over centuries. The first textbook on mining engineering is well recognized as being *De Re Metallica* (Agricola 1556): translated by Herbert Hoover (a mining engineer, later to be U.S. President from 1929 to 1933). Santa Barbara is just one of many traditional patron saints dedicated to protecting the health and safety of early generations of underground miners at risk in hazardous underground working environments. (Gregory 2006). Mining is essentially the extraction of mineral resources from the earth's crust, likely in the future to be migrating into oceanic and lunar environments. The traditional life cycle of a mine is the sequence of the following phases: mineral exploration, development of mine infrastructure, and mine production, then followed by mine closure after the exhaustion of ore reserves. The mining engineer has historically been characterised as a "*Jack of All Trades and Master of None"* needing to be skilled in a diverse range of skillsets. (*Cousin Jack* was a term used to describe the Cornish miner who developed early technologies such as the steam engine in mines and who migrated to diverse mining areas in the development of global mining.) Mines can only be situated where geological processes have emplaced the economic mineral resources. Mining engineers therefore face the prospects of a career history that involves significant relocation. The contemporary reliance on long distance commuting has tended to replace the traditional mining town with the advent of a fly-in-fly-out working routine.

Mining companies have little control over traded commodity prices. Their survival through adverse economic cycles may rely on a cost cutting strategy with limited opportunity to avoid workforce reduction. Such cycles can be problematic for Universities in maintaining student recruitment into mining schools, which tend to be smaller and more focused departments. (This does not necessarily apply to geoscience and other engineering disciplines that are also important in supporting the mining industry.)

Mining engineering has traditionally emphasised occupational health and safety (OHS) in the design and planning of mining operations. Research and development in communications and automation

technology, business management and regulatory frameworks has frequently been driven by the need to maintain high OHS standards. The awareness of additional responsibilities to design and plan to avoid adverse environmental and social impacts, however, has grown significantly in the last 25 years to assume a broader set of objectives within the emerging context of sustainable development (SD). Impact assessment of new mining projects now encompasses environmental and social dimensions as well as OHS. Technical and economic corporate feasibility studies of projects now pay significant attention to environmental and social factors. New projects commonly are based on corporate engagement with the mines associated communities and the resolution of an Impact and Benefits Agreement (IBA), particularly in the case of Aboriginal communities. Industry's early engagement with communities is now commonly associated with the objective of gaining a Social Licence to Operate (SLO). Industry now prominently displays its commitment to Corporate Social Responsibility and sharing value with its communities. Incentives to build and maintain Reputational Capital is well recognized in the Board Room. Mining engineering schools have been adapting their education and research to this transformation in the nature of mining that implies reliance on a more diverse set of values, skill sets and processes. The future of mining is bright. The next generation of mining engineers will not only need to understand and be committed to SD but they also will need to be proficient in leadership, communications, ethics and social intelligence. New technologies and interdisciplinary collaboration will implicitly be fundamental to building and operating sustainable mines in the likely environments that will evolve with global warming.

2 MINING SUSTAINABLY

Controversy over new mine project development is not uncommon globally. Over the last two decades the mining industry and its educational and research institutions have grown to recognise the significance of the philosophy of SD. The emergence of the Non-Governmental Organization (NGO), also known as civil society, has changed the landscape of the mining development process. The need to prioritize the consideration of mining communities and to integrate into the process of Environmental Impact Assessment the additional dimensions of Social and Health Impact Assessment is becoming more widely accepted. In the last decade the concepts of Corporate Social Responsibility have impacted widely on industry leadership and mining school education and research. The concepts of mining community health and wellbeing are increasingly receiving significant attention in prioritizing the quality of community engagement and sharing mine project value.

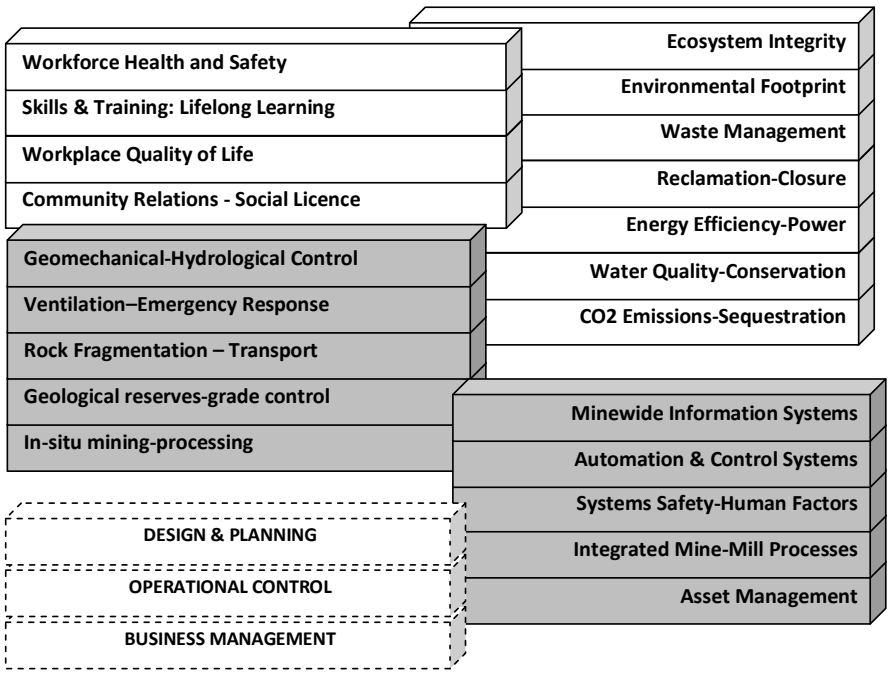

Figure 1: A classification of mining engineering responsibilities (Scoble and Laurence 2008)

Inco Ltd's proposed Voisey's Bay mine-mill project in Labrador was regarded as a ground breaking example of environmental assessment in 1997 "because it introduced *contribution to sustainability* as the basic test of acceptability". (Gibson et al 2005) The assessment Panel's interpretation of progress towards SD was that it required the following: preservation of ecosystem integrity, including the capability of natural systems to maintain their structure and functions and to support biological diversity; respect for the right of future generations to the sustainable use of renewable resources; and the attainment of durable and equitable social and economic benefits.

Sustainable mining is not only relevant to project proposal acceptability but also to subsequent operational management within the mine life cycle. In 2014 at the Mt Polley mine in Canada a significant surface mine waste (tailings) dam failure prompted widespread negative public reaction and demonstrated the growing technological and political power of the modern media. (Review Panel 2015) In addition to the technical aspects of engineering for mine waste management, it also underlined the significance of crisis management, as a key component within sustainable mine management. In mining schools a philosophy is emerging that takes responsibility for developing graduates who understand the many dimensions of sustainable mining and who will assume competent leadership for its immersion into best practice. The mine of the future should be managed as well as designed and planned by professional engineers who assume responsibility for SD in the full context of economic, social and environmental performance for future generations.

3 INDUSTRY INITIATIVES TOWARDS SUSTAINABLE MINING

The emergence of the environmental movement in the 1970s prompted the mining industry to re-examine its design, operation and reclamation processes to minimize impacts and risk to the environment and the mines' associated communities. During the 1990s occupational safety had emerged as one of the highest priorities following a series of serious mine accidents. Most mining operations adapted procedures and culture that have since led to dramatic safety improvements. More recently industry has begun to embrace corporate social responsibility (CSR) and the importance of earning a social licence to operate (SLO).

An early model of sustainable mining leadership emerged within the Vancouver-based mining company Placer Dome Ltd as it rose to prominence in Canada and abroad 25 years ago: "In many countries and regions, the concept of sustainability has captured the imagination of governments, communities, non-governmental organizations and other institutions. They influence the ability to access land for exploration and to permit, develop and operate mines. We will be judged by performance, by how we operate mines and by what remains after mines close. We need to demonstrate that while mines are temporary and ore bodies are eventually depleted, mining can make contributions to sustainable economic and social development, while returning sites to a state compatible with a healthy environment. Our vision of mining and sustainability reflects the values of Placer Dome's employees and will contribute to our business success in many ways." (Placer Dome 1998)

In 1992 at the Canadian Mines Minister's Conference in Whitehorse, Yukon, the Mining Association of Canada (MAC) proposed to bring a diverse community of interests together in order to develop a new vision for the mineral industry. "Many potential and existing mines are the subject of conflicting demands from a variety of interests related to the timing of development, the level and type of infrastructure to be built, plans for sharing benefits and distributing the costs, and approaches to the prevention or remediation of long term degradation of human and ecosystem health. Escalating land use disputes contribute to uncertainty both in terms of the investment climate and with respect to public perspectives about the role that mining should play in the 21st century. It is increasingly clear that there is a need for a policy framework to co-ordinate the various interests affected by mineral development." The MAC hoped that this new vision would foster a broader level of support for the Canadian mining industry. The approach was to become known as the Whitehorse Mining Initiative (WMI), and would provide important insights into the utility and effectiveness of multi-stakeholder initiatives. (McAllister and Alexander 1997)

In more recent years several Canadian mining and exploration associations have demonstrated federal and provincial leadership to influence the mining and exploration industry in their commitment to responsible mining, for example, the MAC through its Towards Sustainable Mining (TSM) initiative. (MAC 2015) The set of TSM tools and indicators aims to drive performance and ensure that key mining risks are managed responsibly at MAC members' facilities. "Adhering to the principles of TSM, our members demonstrate leadership by: engaging with communities; driving world-leading environmental practices; committing to the safety and health of employees and surrounding communities." The program was established in 2004 and its main objective is to enable mining companies to meet society's needs for minerals, metals and energy products in the most socially, economically and environmentally responsible way.

On the global scale, the International Council on Mining and Metals (ICMM) was established in 2001 to improve sustainable development performance in the international mining and metals industry. Today, it brings together 21 mining and metals companies as well as 33 national and regional mining associations and global commodity associations. The organization emerged out of a multi-stakeholder research initiative – the Mining, Minerals and Sustainable Development (MMSD) project, which examined the role of mining in a sustainable future. Its findings recognized the industry's potential contribution, identified core challenges and set out an agenda for change that would form the backbone of ICMM's mandate. One early MMSD contribution was the development of the Seven Questions for Sustainability Assessment Framework (an attempt to apply sustainability concepts in a practical way on the ground), see Figure 2.

Figure 2 Seven Questions for Assessing Sustainability (IISD 2004)

One of the more significant industry and government SD initiatives in Australia was the production of the "Leading Practice Sustainable Development in Mining" series, consisting of 14 handbooks covering a range of issues including acid mine drainage; air quality; cyanide stewardship; biodiversity and others. (Department of Industry and Science 2006) It was followed by a "Guide to Leading Practice" in 2011 that aimed to demonstrate that local, regional and national communities can enjoy the benefits of mining without associated adverse health and safety, environmental, economic and social impacts. The intended

audience is a broad church of mine management, government regulators, community representatives, mining students and all those with an interest in the mining industry. The Guide is written in plain English and includes around 75 case studies of leading practice throughout the mining cycle in Australia, South East Asia, the Pacific, Africa, and North and South America.

4 UNIVERSITY INITIATIVES TOWARDS SUSTAINABLE MINING

4.1 Education

The extent of collaboration between mining schools in Canada and with industry is limited, particularly in comparison with Australia. A recent UBC mining engineering study (Myoshi 2015) concluded that "industry leadership needs to become proactively involved in collaboration with schools to sustain Canada's mining education health and quality. Its leadership needs to be more aware of the critical state of the Canadian mining engineering education system. Industry needs to influence mining schools to pool resources and expertise and to work collaboratively together rather than in isolation. Companies need to accelerate the development of future leaders through offering consistent summer student and co-op hiring. Lastly, it is recommended that industry needs to prioritize mentorship and facilitate the timely transfer of knowledge from senior engineers to junior engineers." The latter point refers to dealing with the widely forecast, future global shortage of mining engineering talent.

Sustainable mining education in Australia can be traced back to 1998 and the landmark "Back from the Brink" paper, where it was recognised that "graduates …… tend to be unaware of the importance of communication and 'people skills'; how business decisions are made; occupational health and safety; the demands of life in (often remote) operational settings; and other significant issues facing industry". (Minerals Council of Australia, 1998) One of the direct impacts on UNSW Mining Engineering was the recruitment of new academic staff including those with experience in these 'significant issues'. Furthermore, in 1999, the curriculum was totally rewritten and new courses including mine management, mining law and environmental management were added. Importantly, with the cooperation of the newly created Mining Industry Safety and Health Centre in Queensland, risk and safety management was integrated into every specialist mining course. At the same time, the postgraduate programs were reviewed and similar courses were included. The success of these diploma and masters by coursework programs can be measured by the increase in student numbers from around 30 in 2000 to over 350 in 2012. The PhD programs also saw students pursuing non-traditional areas in sustainable development from 1999 onwards and since that time there has been a significant number of graduates. A significant measure of undergraduate interest in sustainability is the number of students who choose this topic for their thesis. Anecdotally this estimate is between ten and twenty per cent each year.

Back from the Brink also concluded that the delivery of education in Australia's universities had to change if the industry was to maintain and grow its international competitiveness. A course of action was recommended to ensure the supply and quality of technical professionals.The most significant outcome was the formation of the Minerals Tertiary Education Council (MTEC), aimed to to build a world-class tertiary learning environment for the education of professionals. UNSW academics became leaders in developing common shared courses for the four mining schools that were linked across Australia in a new collaborative network, Mining Education Australia. The shared curriculum included new courses that dealt with: Socio-environmental Aspects of the Mining Industry; Mine Management (mining law, safety and risk management, project management and operations management); Mining in a Global Environment (providing: tools to meet the challenges of working in an international and/or remote Australian setting; focusing on developing countries by comparing Australian and international contexts.) Case studies were also developed to provide an international perspective of mining; governance and regulatory frameworks; financing; mining companies as agents of change; cross-cultural management; gender; small-scale mining; indigenous communities; health and safety issues; and the influence of China and India. Collaboration between UNSW and Curtin West Australian School of Mines has developed a large-screen immersive visualization system to demonstrate the principles of sustainable mining practices. (Stothard and Laurence 2010) This form of technology development offers significant benefits to education and research by bringing the remote mine location into the design and planning office. Students benefit from the reality of case study exercises that can relate mining engineering design to sustainability issues.

At UBC a concern existed in 1998 over low undergraduate recruitment that had also prompted “Back from the Brink”. The UBC mining engineering department became committed to the implementation of a co-operative undergraduate degree, formalizing industry experience periods into the degree. This undoubtedly enhanced significantly the learning experience for undergraduate students. Also, faculty members saw a significant interest grow in research related to sustainable mining. New courses in Mining and the Environment, and Mining and Society drew an increasing interest of students from outside the mining engineering department. A community of interdisciplinary research students grew significantly, many of whom were women. The culture of the UBC mining school changed significantly for the better. Research projects began to evolve into remote field locations, particularly motivated by community-based research pioneered by initiatives related to global artisanal mining. Undergraduate mining students began to be involved with real world research projects overseas. Professors started to transition into a new world of qualitative research, ethical review and inter-disciplinary collaboration.

In Canada and Australia the mining industry is a major employer of Aboriginal people. Mining engineering education needs to include a full understanding of such concepts as accommodation, rights and title in the context of Aboriginal peoples. At UBC this led to the development of a First Nations and Mining outreach initiative. The recruitment of a scholar with a PhD in First Nations Law and Anthropology was facilitated with the support of industry and various Canadian First Nations groups. Education and research have benefited significantly through collaboration but disappointingly it is still the case that very few Aboriginal students at undergraduate or postgraduate levels have been recruited into the UBC mining engineering programs. There has also traditionally been a gender imbalance in the undergraduate student population in UBC mining engineering. In the postgraduate student body however women represent roughly half of the student body. Recent UBC research into Highly Qualified women in mining concluded that a “gender imbalance in the Canadian mining industry is considerable and persistent. Despite a substantial forecasted labour shortage, women represent only 14% of the national mining workforce.” (Hughes 2012)

4.2 Research

Collaboration within and between research groups on campus or between universities is critical to build adequate capacity and establish competitiveness in generating research funding from government or industry. Generating industry financial support is not necessarily assured. In 1998 UBC Mining Engineering submitted an application to the Canadian government’s new Networks of Centres of Excellence program for a grant to develop a research program formed within a proposed Canadian Network for Sustainable Mining (CaSM). This planned for collaborative research involving six primary Canadian universities with twenty industry corporations and Federal and Provincial government departments. The mission of this multidisciplinary initiative was “to foster a technical, socio-economic and political environment that integrates the planning, design and operation of mining into one complete system. This approach encompasses not only the performance of the mining operation itself, but also its harmonization with the ecological, socio-economic and political dimensions of the host environment. CaSM aims to collaborate with industry to develop technology to reduce costs, waste and environmental impact. CaSM will also work with a variety of other stakeholders including governments, Aboriginal peoples and other groups in society.” The proposal was shortlisted but sadly it was not fully funded, despite a subsequent application the next year (a reminder that Universities and their diverse disciplines compete with each other for Government funding).

Some fifteen years later UBC was successful in gaining federal support for the formation of a collaborative network: (the Canadian International Institute for Extractive Industries and Development, CIIEID). This involves UBC Mining Engineering, Simon Frazer University’s Business School and Ecole Polytechnique de Montreal Mining Engineering in collaboration with industry, NGOs and indigenous peoples. Four program areas comprise a suite of collaborative projects: Sustainable Development and Governance of the Extractive Sector; Transformation of Artisanal and Small-scale Mining; Multi-stakeholder Integration of Resource Development and Planning; Economic Diversification and Local Supply Chains.

A current BC example of interdisciplinary collaboration for sustainable mining relates to the research by complementary teams from UBC Mining Engineering and the University of Victoria's Department of Geography. One project is investigating health issues and impacts associated with mining in three Aboriginal communities and Northern municipalities in BC through a merged SD/social determinants of health lens. This community-based participatory health research project focuses on mitigating health impacts in the communities related to mining. One objective of such work is resolving how to integrate Social Impact Assessment and Health Impact Assessment into the conventional Environmental Impact Assessment process for new mining projects. Mining engineering needs to develop the collaborative support of specialists from diverse fields of expertise to fully accommodate sustainable mining capacity. An implication for research is that mining engineering professors need to be willing to develop new skill sets, not necessarily high technology-based, that enable them, for example, to deal with qualitative research methods and ethical approval. The mining curriculum needs to be adapted to provide mining students with an understanding of ethics and social responsibilities. It also seems logical that the criteria and process for the professional engineering accreditation of mining engineering programs will need to be considered in the future as the definition of sustainable mining evolves.

5 GLOBALIZATION AND COLLABORATIVE CAPACITY BUILDING

At UNSW the most significant event in the development of education and research in sustainability was the creation in 2009 of an industry Chair in Sustainable Mining Practices. The Chair was and continues to be funded by Mitsubishi Development Limited and was followed in 2011 by the establishment of the Australian Centre for Sustainable Mining Practices (ACSMP). This is an independent, research and educational body engaged in providing practical solutions for sustainability issues affecting minerals and society. It is multidisciplinary in its approach and employs the skills of mining engineers, geotechnical engineers, geologists, hydro-geologists, hydrologists, environmental scientists, chemists, lawyers and social scientists, computer scientists and even graphic artists in its projects. ACSMP is particularly active in the areas of leading practice in SD (with the Australian government and industry), water in mining, mine closure and rehabilitation, remote sensing, virtual reality applications, and capacity building in developing countries.

In 2009, under the Public Sector Linkage Program funded by AusAID, the ACSMP conceived and delivered a project which aimed to integrate SD into minerals education in the Philippines. It aimed to build capacity in its mining schools based on the principles of sustainable mining practices. It involved working with academics from the main mining schools in the Philippines, particularly the University of the Philippines to build SD into its curricula. It aimed to help the mining schools to develop the skills necessary to educate the future leaders of the Philippines minerals industry in meeting the challenges of mining in politically, socially and environmentally sensitive locations in the future. (Laurence 2011) From 2009 to 2010 the Australian Thailand Institute (ATI) funded a capacity-building project led by ACSMP to: increase awareness about sustainable mining practices; and to integrate them into in Thai mining school curricula. In Cambodia the ACSMP was tasked by the UNDP to forecast the demand for minerals professionals in 2015 and beyond, and analyse the ability of the country to supply that demand. This involved the collection of data primarily from meetings and interviews with key persons involved in all aspects of the extractives industry, including exploration companies, educational and training institutions, government departments, community representatives including NGOs and other stakeholders. ACSMP also worked in Laos in 2011 in a World Bank funded project to develop a strategic plan to enable Laos to supply its mining industry with its own mining professionals in the future. ACSMP recently collaborated with the Centre for Sustainable Mining and Industry in South Africa. Very few institutions have programs or departments teaching the sustainability or non-technical aspects of mining, including mining law, community engagement, mine safety and health, contracts, taxation etc. South African institutions stand out as incorporating these topics into its undergraduate curriculum as well as research. (Laurence and Hermanus 2013)

6 CONCLUSION

The mining industry and its schools are rapidly transitioning towards a global community. A process is well underway with the prospects of forming a new movement of corporate responsibility dedicated to the principles of sustainable mining. The traditional commitment by all parties to occupational health and safety is now being extended into the broader dimensions of sustainable mining. Collaborative, interdisciplinary education and research initiatives need to continue to develop national and international capacity to adopt global leading practices for sustainable mining. This will require the collaboration of industry, governments, civil society and mining schools. Industry can do more to foster the development and security of its educational and research institutions. Priorities for collaborative research relate particularly to: mining community health and wellbeing; Indigenous peoples; impact and sustainability assessment; and workforce diversity. More commitment to research on the part of industry and government will be important for technology development (particularly mining, environmental, communications, and educational technologies). Globalization will increasingly prompt the need for collaboration between international mining schools.

Acknowledgements

This paper reflects the personal experiences and views of the authors who wish to acknowledge those dedicated to the ongoing cause of sustainable mining in industry and government as well as academia.

References

Agricola, G. 1556. De Re Metallica. Available at http://en.wikipedia.org/wiki/De_re_metallica

Gregory, C.E. 2006. The legend of Saint Barbara, Patron Saint of Mines. TechnoMine. Available at http://technology.infomine.com/articles/1/136/barbara.saint.mines/the.legend.of.aspx

Scoble, M.J. and Laurence, D.C. 2008. *Future Mining Engineers-Educational Developments*. 1st Conf. on Future Mining, Australian Inst. of Mining and Metallurgy, Sydney, Australia, ISBN 978 1 920806 91 0.

Gibson, R.B., Hassan S., Holz, S., Tansey, J. and Whitelaw, G. 2005. Sustainability Assessment: Criteria and Processes, Earthscan, London. ISBN 1-84407-050-6.

Review Panel 2015. Report on the Mount Polley Tailings Storage Facility Breach. January 30, 2015. Available at https://www.mountpolleyreviewpanel.ca/final-report

Placer Dome Inc., 1998. Sustainability Policy, https://www.iisd.org/business/viewcasestudy.aspx?id=112

McAllister, M.L. and Alexander, C. J. 1997. A Stake in the Future: Redefining the Canadian Mineral Industry, (Vancouver: UBC Press).

Mining Association of Canada, 2015. *Towards Sustainable Mining*. Mining Association of Canada, Ottawa. Available at http://mining.ca/towards-sustainable-mining

IISD 2004. *Out of Respect: Tahltan, Mining, and the Seven Questions to Sustainability*. International Institute for Sustainable Development. ISBN 1-895536-80-4. Available at http://www.tahltan.org/out-respect-tahltan-mining-and-seven-questions-sustainability

Myoshi, M., 2015. University and industry collaboration in Canadian mining education. MASc Thesis, University of British Columbia. Available at http://circle.ubc.ca/handle/2429/51973

Department of Industry and Science 2006. *Leading Practice Sustainable Development Program for the Mining Industry*, Australian Government. Available at http://www.industry.gov.au/resource/Programs/LPSD

Minerals Council of Australia 1998. *Back from the Brink: Reshaping Minerals Tertiary Education.* Discussion Paper. National Tertiary Education Taskforce. Available at http://www.minerals.org.au/focus/mtec

Stothard P.M. and Laurence D.C. 2010. *Development and Implementation of an Enhanced Knowledge Management System for Sustainable Mining*. SIMTECT 2010 Conference: Simulation Improving Capability and Reducing the Cost of Ownership, Brisbane, Australia.

Hughes, C. M., 2012. A Study on the Career Advancement and Retention of Highly Qualified Women in the Canadian Mining Industry. MASc Thesis, UBC. Available at http://circle.ubc.ca/handle/2429/42276

Laurence, D.C. and Hebblewhite, B.K. 2011. *Sustainable minerals education – we care but do you?* 11th Underground Operators Conf, Australian Inst. of Mining & Metallurgy, Canberra ISBN 97819215224006.

Laurence, D.C. 2011. *Sustaining Minerals Education in Developing Countries – Lessons from South East Asia.* Proc. 2nd Conf. on Future Mining, Australian Institute of Mining and Metallurgy, Sydney.

Laurence, D.C. and Hermanus, M. 2013. *Building Minerals Education Capacity in Africa - the First Steps*, 6th International Conference on Sustainable Development in the Minerals Industry, Milos, Greece.