Section 1

IMPC Mineral Processing Education Roadmap

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Today's mineral processing graduates are tomorrow's mining industry leaders. They need to be properly equipped if they are to effectively manage the demands and the opportunities of a changing industry in a changing world.

This document provides a list of recommendations for good practice in mineral processing education that can be used:

- by education providers, to review and evaluate their programs
- by employers to assist with selection of personnel
- by employers to develop continuing development programs for their young professionals
- by young professionals to manage their career progression

Education in this context includes formal programs delivered by universities and other academic institutions and the many forms of continuing education graduates engage with throughout their careers.

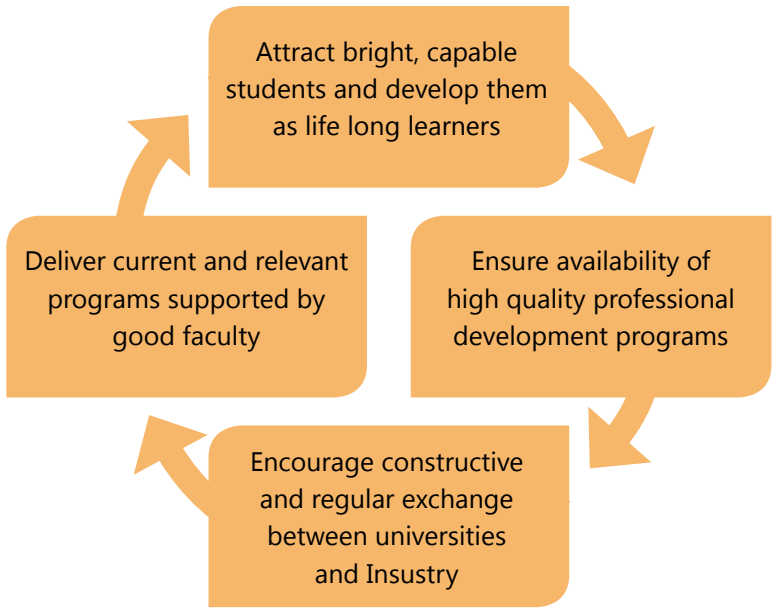
Benefits of good education

- An effective and efficient body of professionals will make sound technical decisions based on current best practice
- Graduates who are challenged and rewarded are more likely to stay in the industry
- Sound fundamental knowledge and skills will ensure professionals develop as effective leaders
- Innovation is more likely when industry is closely involved in academic research and development.

The cost of poor education

- Good prospective students will not be attracted to courses, leading to a deteriorating talent pool
- Education programs will not deliver the content needed for effective performance in the workplace
- Operational practice will not effectively adapt to new technology and work practices
- Knowledge and skills will decline as the baby-boomer generation retires.

Targets



Mineral Processing Competencies

Recommended Graduate Competencies

These competencies should be delivered by undergraduate programs. Bridging courses are recommended where graduates have not covered these topics.

General	Mineral Processing	Personal & Professional Skills
• Basic science, mathematics and statistics • Heat and mass balances • Computer applications	• Comminution • Flotation • Physical separation • Mineralogy and liberation • Sampling theory and practice • Extractive metallurgy basics (hydro/pyro)	• Problem solving, critical thinking • Research skills • Oral and written communication • Team-work

Competencies to develop during first 5 years

Early career competency development is primarily the responsibility of employers. Many of these topics are provided by academic institutions as professional development offerings.

General	Mineral Processing	Personal & Professional Skills
• Risk management • Social/ Environmental sustainability • Mineral economics, Project finance • OHS responsibility	• Metallurgical accounting and statistical methods • Sampling practice • Process control • Materials handling • Extractive metallurgy	• Global mining industry experience • Technical communication • Management and leadership

Actions

See Appendix 1 for more detailed recommended actions

Academics and industry have a joint responsibility to ensure that young professionals receive good quality education in mineral processing.

Attract and develop students

- Support programs that attract students to minerals engineering programs
- Ensure a solid foundation in basic science, engineering and mathematics
- Include mineral processing priority content:
  - Mineralogy and liberation
  - Unit processes – Comminution, Flotation, Physical Separation
  - Sampling theory and practice
  - (*some*) Extractive metallurgy and metal production
- Teach application of statistical, analytical and modelling tools
- Encourage innovative and independent thought
- Develop oral and written communication skills
- Provide opportunities for students to visit or work on site
- Provide opportunities for laboratory work
- Familiarise students with the full mine-to-metal value chain, social and environmental issues
- Aim high – challenge students

Deliver good programs

- Regularly review course content to ensure it is current and relevant
- Don't try to teach everything – employer needs are diverse and constantly changing
- Give academics experience and support their skills development
- Bring in experts from different fields to supplement teaching
- Stay abreast of best teaching practice, regularly evaluate and benchmark
- Use best available delivery technology
- Provide material assistance and training to lecturers in developing countries
- Maximise utilisation of data and resources by collaborating across institutions
- Regularly disseminate information about industry news and current practice
- Communicate with stakeholders including employers, feeder schools and others via steering committees and technical panels
- Devise strategies that ensure programs survive the fluctuation in student numbers that inevitably occurs with the mining cycle

University /Industry exchange

- Organise University/ Industry workshops and forums to exchange ideas and knowledge
- Demonstrate benefits of applied research to minerals industry decision-makers
- Ensure that education programs address economic models and industry priorities
- Consider collaborative R&D for industry using recent graduates or academic staff
- Strengthen links between academic institutions, IMPC and professional institutions such as the AusIMM, CIM, SAIMM, focussing on strategies to collaborate on delivery of education

Professional development

- Treat professional development as a non-discretionary activity
- Ensure graduates are given opportunities to fill gaps in their knowledge and skills
- Encourage in-house mentoring for graduates based on the technical competencies they need
- Ensure CPD programs are properly resourced and regularly reviewed.
- Emulate existing models of good graduate development
- Manage graduate career pathways; or provide support to enable individuals to self-manage
- Predict potential future workforce needs based on changing technology and demographics
- Limit as far as possible the hiring/ firing cycles that amplify the cycles of University enrolments

Appendices

Appendix 1: Detailed Action List

Attract and develop students

Target: *attract bright, capable students into programs, and develop them into high-performing graduates with sound knowledge of basic maths and science, and good grasp of mineral processing basics. Equip them with an analytical tool-kit that enables them to apply their knowledge in practice and ensure they are up to date with knowledge of best operating practice. They need the skills and behaviours to continue learning throughout their careers and adapt to changing technology and process requirements.*

Attract good students

- Provide support and resources for professional societies and others who provide programs designed to attract the best available students to minerals engineering programs.
- Collaborate across institutions and share information about activities that create interest and excitement about mineral processing.

Provide the right program content

- Regularly review course content and ensure it is current and relevant.
- Ensure undergraduate programs contain a good solid foundation in basic science, engineering and mathematics.
- Include as much as possible core mineral processing content on the priority topics as recommended by the IMPC Education Commission Industry Survey, 2014 – 2015 (Drinkwater 2015, *Mineral Engineering Knowledge and Skills for Today's Industry).*
- Introduce students to non-core topics and emerging technologies such as geometallurgy and sensor-based sorting.

- Ensure students learn to use modelling packages that can deal with particulate solid materials in process streams.
- Introduce undergraduates to use of tools and technologies using problem-based activities, for example:
  - Metallurgical problem-solving using mineralogical tools
  - Use of simulation to predict impact of process changes
  - Metallurgical accounting and mass balancing.
- Expose students to sustainability topics including water and energy conservation, environmental consequences of chemical and heavy metal contamination, emissions control measures.
- Identify and teach mineral processing aspects of importance locally – eg: precious metals processing and refining in Nevada, coal processing in eastern Australia, iron and steel production in India.

Develop the complete professional

- Encourage application of knowledge to practice by ensuring students understand the full value chain – mine to metal production. Teach integrated facets of all aspects of running a mining and minerals processing operation
- Develop problem solving skills using problem-based learning. Use real case studies with emphasis on *what worked? Why did it work? what didn't work?* and some thoughts on *why* ?
- Encourage innovative and independent thought using specifically designed learning activities and exercises. Teach people to find information for themselves. The role of universities is to teach people to innovate not necessarily to train them for specific tasks.
- Develop communication skills, including ability to explain and justify concepts to a non-technical audience. Include oral and written communication – presentations and report-writing.
- Give students site experience, and support co-op programs, where students spend a semester or more on site. Assist students to find vacation work.
- Provide opportunities for lab work.
- Identify undergraduate and postgraduate thesis topics that address real problems leaving room for the student to exercise some independent

thinking. Have a handbook of industry problems for application of tools and methodologies
- Communicate the need for graduates to be lifelong learners to meet industry and their personal career needs. Run student mentoring schemes to support this.
- Set up exchange programs with Industry partners for students. For example, in Iran it is common that PhDs spend a year on plant.
- Aim high – challenge students.

Deliver good programs

Target: *ensure programs are current and relevant, featuring good educational design and delivered by dedicated, competent, full time faculty. Create a learning environment that is attractive and challenging for students and includes a solid practical component. Provide exposure to industrial processing plants and a knowledge of best Industry practice, including environmental and social practice.*

Design good programs

- Regularly review course content to ensure it is current and relevant.
- Regularly disseminate information about industry news and current practice.
- Stay abreast of best teaching practice, regularly evaluate and benchmark programs with other programs around the world.
- Bring in experts from different fields to supplement teaching.
- Use best available delivery technology. Computational methods have changed education delivery in the developed world and not so much in developing world, so set up support networks and exchanges to encourage universal take-up.
- Ensure moderation is carried out for each course. This may require an external examination policy.
- Ensure minimum criteria for quality is adhered to where national bodies such as Engineering Councils are responsible.
- Ensure education programs provide alternative educational pathways for those wishing to remain in academia and those wishing to move into industry.

Support and develop staff

- Give academics industry experience. Most of the lecturers come straight from PhD or MSc studies and have no access to industry mentorship.
- Use existing experienced staff to transfer skills to new staff. Average of academics in mineral processing is >50 so there is serious risk of losing skills if they are not transferred.
- Provide networking opportunities for staff with other professionals in the industry.
- Support staff to develop their skills. Offer online courses, professional development programs and sabbatical programs.
- Run educational programs for teaching and support academic staff on the importance of good educational design and delivery of technology-assisted learning. Use technology to support these programs – videoconferencing and online content.
- Provide material assistance and training to lecturers in developing countries where minerals processing is taught and the economy of those countries rely on Mining.
- Develop programs that encourage academic staff to regularly attend conferences and workshops.
- Ensure that networking and collaboration is attractive to staff and University management, and doesn't add to the workload of individual academics.

Strengthen program viability

- Communicate with stakeholders including employers, feeder schools and others via steering committees and technical panels about courses and programs.
- Remain mindful of the fact that universities cannot take a short term focus – they must step back and focus on the long term knowledge and skills needs.
- Reduce the pressure on University departments during downturns. Set up long-term strategies that address the fluctuation in student numbers that inevitably occurs with the mining cycle.

Facilitate University/Industry exchange

Target: *encourage constructive and regular exchange between Universities and Industry that enriches teaching and research and supports best practice in industry.*

Communicate

- Ensure meaningful collaboration between industry and academia via steering committees or industry advisory bodies
- Encourage industry/academic staff exchanges
- Actively communicate to ensure senior minerals industry personnel appreciate the professional expertise of academics and researchers
- Demonstrate benefits of applied research to minerals industry decision-makers
- Identify opportunities to access board rooms and corporate head offices to discuss education and professional development for mineral processors
- Strengthen links between academic institutions and IMPC and local institutions such as the AusIMM, CIM, SAIMM, etc, focussing on strategies to collaborate on delivery of education and ongoing reshaping of the curriculum.

Provide real industry data and case studies for education programs

- Incorporate current industry data into case studies and problem examples
- Use specialists to turn industry problems into academic challenges
- Organise University/Industry workshops and forums to exchange ideas and knowledge
- Investigate opportunities for universities to engage in collaborative industry R&D using recent graduates or academic staff
- Ensure that technical conferences and seminars have a strong educational focus as well as a commercial one

Set up effective work processes

- Ensure that education programs and steering committees understand one another's budgets and priorities

Professional development

Target: *ensure availability of high quality continuing professional development. This is best achieved via structured programs that address the diverse needs of young professionals, including 'bridging' courses for graduates with limited undergraduate mineral processing (for example chemical engineering graduates). Senior technical role models are important, as are mentors who can assist with transition to senior management and corporate roles*

Ensure availability of continuing professional development (CPD)

- Undergraduate degrees are necessarily too general to provide job-ready graduates. There will always be a need to provide continuing professional development in technical topics as well as softer skills such as leadership and management.
- Ensure CPD programs are properly resourced and regularly reviewed.
- Ensure CPD programs encourage critical thinking and innovation.
- Limit as far as possible the hiring/firing cycles that amplify the cycles of University enrolments and lead to loss of skills from the sector.

Ensure viability of CPD programs

- Treat professional development as a non-discretionary activity that directly impacts shareholder value.
- Ensure that human resource departments are aware of the importance of specific mineral processing knowledge and skills so that they can ensure graduates have an opportunity to develop the required skills. This is particularly important where chemical and materials engineers are employed as mineral processors.
- Evidence shows that CPD was an excellent way of retaining people, so use this to justify the expenditure required.
- Look ahead to identify potential problems with workforce shortages in the future due to changing technology and demographics change such as the aging population of industry operators.

Utilise good delivery models

- Many mining companies have well developed continuing professional development programs. Look to models of good graduate development such as AngloAmerican Platinum's AGDP.
- Consider funding employees to do PhDs or to take sabbaticals.
- Ensure CPD programs address the need to train engineers to be more innovative and dynamic, for example in adopting new technologies.
- Encourage in-house program of mentoring for graduates, based on the technical competencies they need to develop.
- Manage graduate career pathways; or provide for individuals to manage their own career development.

Appendix 2: Mineral processing education – the current context

The challenges

Many of the submissions to this study were prefaced by statements about context. Minerals industry education is provided against the backdrop of economic, social and technological issues, and these all have an influence on outcomes.

There is also a concern about declining skills in areas where undergraduate education is incomplete and there is poor access to continuing professional development, resulting in what one survey respondent described as "an endless cycle of knowledge loss and rediscovery characterised by repeats of past mistakes and a rehash of old research as new".

The conflicting needs of stakeholders

The groups defined as "Academia" and "Industry" have different goals and objectives, and a classic conflict often arises regarding curriculum. Universities teach fundamental mathematics, science and engineering that may not have any direct bearing on the job requirements for minerals processing, leading to occasional criticism from industry that graduates are not spending enough time developing practical skills that would make them more job-ready. Universities maintain that it will never be possible to deliver job-ready graduates because of the diversity of industry roles and constantly changing technology and work practices. It is important for universities to maintain their focus on delivering solid fundamentals that enable graduates to manage their own technical skill development.

The IMPC Commission on Education acknowledges that this roadmap will not put an end to this conflict, that the discussion is healthy, and that the right balance will be achieved when there is good communication between all parties.

Barriers to delivery of quality education

The many contributing factors identified by the advisory group have been organised under five headings.

The influence of the mining cycle - on industry:

- Reduced workforce participation produces a net skills and knowledge drain which affects all aspects of the industry
- Industry generally runs in-house professional development of their graduates, though again, the mining cycles impact on staffing levels for graduate training.
- Professional development and training is one of the first things cut in tough times. Graduate training programs are easy to cut out of a budget, as they are not directly related to productivity.
- Low staffing levels often mean that nobody is allocated to look after graduate training in professional areas, despite the fact that there is always a focus on training courses on safety and management
- The high point in the cycle can be just as difficult for implementation of good training – during those times companies focus on short-term production goals

..and on universities:

- Student numbers fluctuate with the mining cycle, putting departments under pressure because of small class sizes in downturns. Undergraduate programs in Australia, Africa, Canada and the USA are currently under great strain as funding levels are directly related to student numbers
- University-based professional development programs face similar pressures
- Regions where student numbers are maintained face a glut of graduates – eg: South America

The nature of academic programs

- Education providers generally have a good understanding of what is required to deliver high quality minerals education. The major challenge is meeting the resourcing requirements.

- Universities are businesses and many governments do not support investment in mining industry education because of low student demand. Funding needs to come from elsewhere, and many university programs are directly supported by large mining companies. The level of support is highly dependent on the commodity price cycle.
- It is not possible to include really specific job-related content in education programs at Universities because of the huge diversity of industry roles and constantly changing technology and work practices.
- Collaboration between industry and universities does not necessarily assist with overall financial viability of departments. There is no financial incentive and often an increased workload on individual academics, so it is hard to make it happen
- Experienced staff are retiring from universities and there are fewer replacements than in previous times
- Many new lecturers come straight from PhD or MSc studies with no industry experience

Employment practices in mineral processing

- In some regions, a large proportion of graduates are chemical engineers and have very little specialist knowledge of mineral processing or the mining industry.
- Knowledge and skills will decline as the baby-boomer generation retires, The way professional development is delivered in industry
- Ongoing professional development can be provided in-house or externally, and programs are offered by groups including universities who also provide undergraduate education, commercial organisations, research institutions and consulting companies
- Programs need to be managed for best outcomes. Often this is done by employers but individuals (graduates) can also manage their own career development by means of pathways and guidelines – often provided by professional societies or other industry bodies.
- Training was described by one contributor as being “important but not urgent”. There is an assumption that “If we need it we can always bring in an expert”. The danger of this is that at some point the experts die out or move to a different industry.

- All of industry runs on budgets and priorities, so major programs need support of upper levels of management including those who manage budgets.
- There is also a tendency for cost-cuts to technical education first, while safety and management training programs remains.
- Many companies only do on the job training, which is often ad-hoc and limiting for graduates. A structured program of graduate development is important.
- Although there are many examples of high quality, properly resourced graduate development programs within the minerals industry, there are many others which are ad-hoc at best and non-existent at worst, leaving graduates on their own to sink or swim in their professional roles.

Appendix 3: Roadmap Contributors

Recommendations were provided to the IMPC Commission on Education in several ways:

1. Observations from a panel of leading experts and from the floor at the XXXVIII IMPC Education Symposium in Quebec City (see Appendix 3 for a list of panellists and attendees)
2. A 2015 Survey of leading members of industry and academia (see Drinkwater, 2016)
3. Individual submissions to the Commission

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