Mineral Engineering Knowledge and Skills for Today's Industry

IMPC Education Commission, Industry Survey, 2014–2015

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Introduction

The Mineral Industry continues to develop new products and technologies to handle increasingly complex processing challenges. Undergraduate education and ongoing professional development need to develop and maintain the competencies required to support these technologies, and yet there is growing evidence that the overall skill and competency level of mineral engineering graduates around the world is declining (McCaffery et al 2014, Munro 2016).

Education providers must understand technological trends and changing practices across different commodity sectors and geographical regions if they are to build the appropriate workforce capacity for today's minerals industry.

The IMPC Commission on Education conducted a survey of leading industry figures to establish their views about the skills and competencies they expected of graduates entering the industry as metallurgists or mineral processing engineers. This survey was conducted over 6 months in 2014/15, via an internet-based questionnaire. This survey was not intended to provide a complete and definitive account of industry needs, but to identify perceptions and expectations within different sectors of the industry, regions and types of organisations.

Summary of Findings

1. There is strong agreement about the fundamental topics needed in minerals engineering programs

The traditional fundamentals of Minerals Engineering programs emerge as the top five topics that graduates need to know about: Mineralogy, Comminution, Flotation, Physical Separation and Sampling. The same top five were specified by industry practitioners and academics alike.

Employers who employ graduates from materials, chemical and process engineering programs need to ensure that graduates can develop the knowledge and skills they need in these areas, either on the job or through professional development.

2. Universities are doing a fairly good job, but...

Universities are doing an adequate job of preparing graduates for industry but few are prepared to describe them as excellent. Their programs deliver a solid base in process theory and fundamentals but could do better at preparing students to work effectively with professionals from other disciplines. Some areas where they can improve include staying abreast of current technology, use of new tools and technologies and more use of real industry data and case studies.

One criticism of Universities is that they do not provide sufficient industry experience. Effective industry exchange programs are heavily dependent on the goodwill of industry partners, so Universities will not be able to solve their problems in isolation.

Ongoing Professional Skills Development is Ad-Hoc

Although there are examples of large companies with structured Mineral Engineering skills development programs for graduates, many employers approach technical competency development in an ad-hoc way, exacerbated by limited funds and lack of urgency. One survey respondent commented that there is *"nobody allocated to look after graduate training*

in professional areas, although there are plenty of training courses on safety and management". There may be opportunities for Universities and other quality education and training providers to meet this need via quality professional development programs.

University/Industry Partnerships are Important

Education outcomes improve when students have exposure to authentic case study data and process plant issues. Partnerships between Universities and Industry can play a vital role in providing opportunities for exchange. They can also ensure that curriculum stays current and relevant. The benefits go beyond graduate outcomes, as academics and researchers also benefit from regular interaction with industry.

There are many examples of beneficial University/Industry partnerships in the form of guest lectures, shared projects and involvement of industry representatives on steering committees and advisory boards.

Declining Skills – It Really Matters!

There is evidence of a skills decline, and skills can be linked to substandard operational performance. This work strongly supports the need for good education and skills development in the Mineral Processing discipline.

Methodology

A questionnaire was sent to selected minerals industry leaders asking them to provide feedback on:

1. The knowledge, skills and behaviours they believed were important for minerals engineers to have on graduation
2. Their views about the quality of available undergraduate and continuing education.

A total of 92 people from around the world responded to the survey, a mixture of education providers and graduate employers. All have a significant stake in the industry and its outcomes. About half (47 out of 92) were academics or researchers. Nearly all have regular contact with

young professionals. More than 65% interactions with young professionals at least weekly, and 45% interact with them daily, meaning that they are in touch with their educational level and performance.

Results

The survey consisted of six questions about the 92 respondents and their backgrounds, and a further nine questions about their views on mineral processing education and training.

The nine education and training questions concentrated on three themes:

1. specific knowledge, skills and competency requirements for mineral processing professionals
2. how well universities are meeting industry needs
3. how organisations fill graduate competency gaps using ongoing training and professional development

Knowledge, Skills and Competencies - What Graduates ought to know

Specific mineral processing competencies

Survey respondents were asked to rate the importance of specific skills or competencies, divided into two main groups. The first group related to specific mineral processing topics and the second to more general engineering and professional competencies.

Mineral Processing Competencies

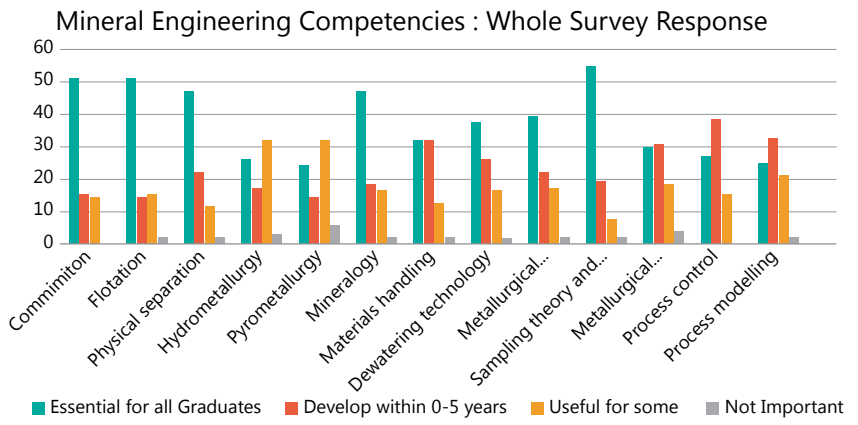
- Comminution
- Flotation
- Physical separation
- Hydrometallurgy
- Pyrometallurgy
- Mineralogy
- Materials handling
- Dewatering technology
- Metallurgical laboratory procedures
- Sampling theory and practice
- Metallurgical Accounting
- Process Control
- Process Modelling

General Competencies

- Basic science and mathematics
- Heat and mass balances
- Materials science
- Professional skills (teamwork, report writing, seminars)
- Problem solving, critical thinking
- Knowledge of minerals economics
- Project finance, NPV, Capex and Opex
- Knowledge of mining life cycle
- Sustainability in the minerals industry
- Process design
- Computer applications
- Research skills
- Industry experience

They were also asked to indicate which skills and areas of knowledge need to be included in undergraduate curriculum, and which could be picked up one the job or in other ways after graduation.

Figure 1: What do Minerals Engineering graduates need to know?



The top five of the 13 topics submitted to survey respondents for undergrads were fundamental mineral processing topics:

- Comminution
- Flotation
- Physical Separation

- Mineralogy
- Sampling Theory and Practice

The top three that could be learned on the job (i.e. not needed in the undergraduate curriculum), were:

- Metallurgical Accounting,
- Process Control
- Materials Handling

Because the survey group consisted of roughly half academics and half industry practitioners, it was considered important to see whether the ratings changed when the academics were removed from the sample. Results from filtered sub-sample were reviewed to check this. Figure 4 shows the two data sets – the full survey sample and the filtered sub-sample.

Figure 2: (a) Full sample and (b)filtered sub-sample

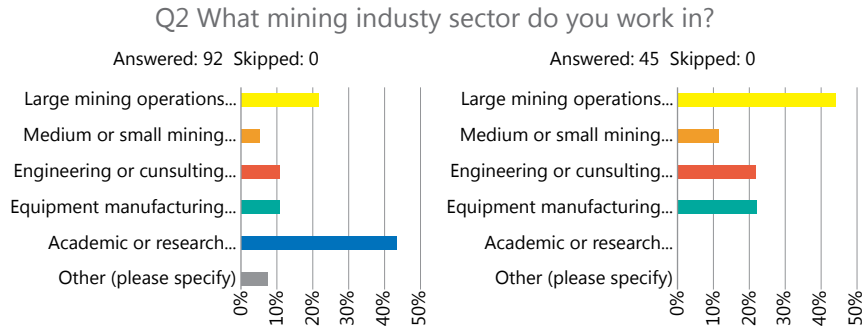
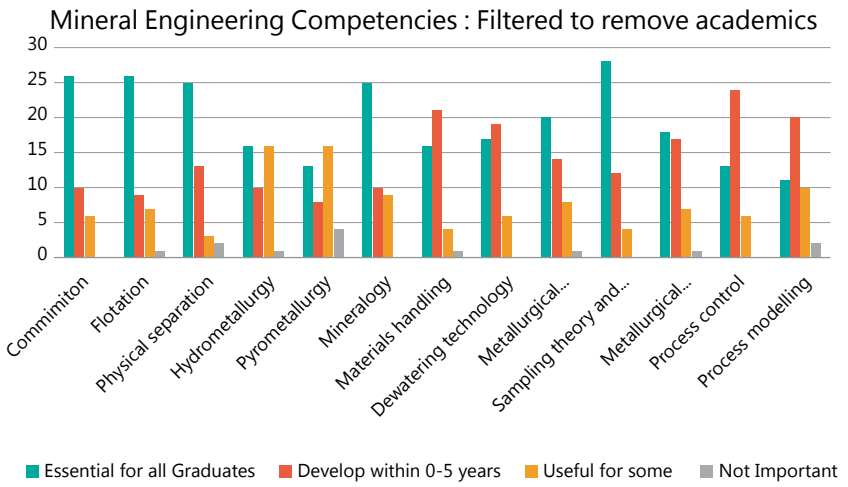


Figure 6 shows the response to the same question, this time restricted to the non-acedemics in the group.

Figure 3: What do mineral processors need to know?



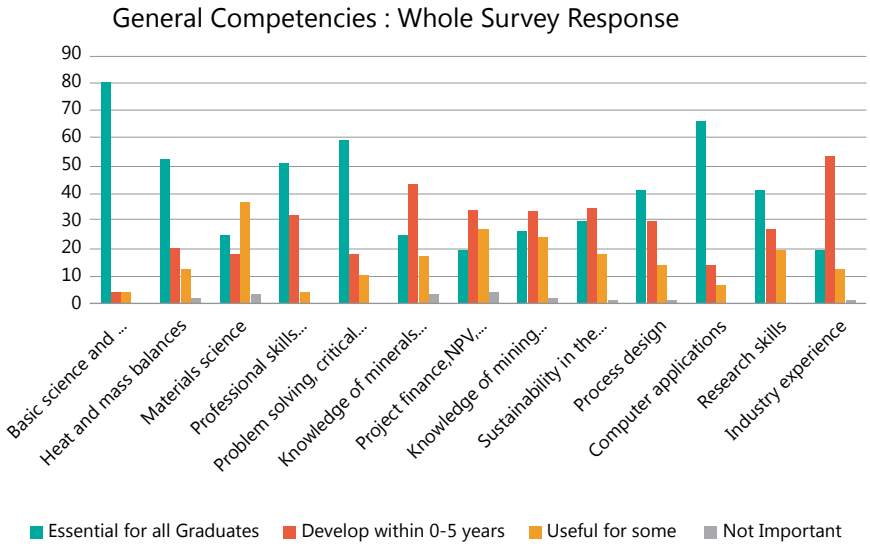
The two groups are largely in agreement, with just a couple of significant differences. The most significant relates to the importance of topics like dewatering and materials handling. They also give a higher rating to lab procedures.

Respondents were invited to comment on this question, and the following are examples of what was said:

- We have re-baselined our expectations to reflect the fact few mineral processing engineers are being produced by the universities.
- Pyrometallurgy needs to be introductory only.
- It looks like a long list of essentials, but really it is just saying a minerals engineering graduates should have some knowledge of all the branches of minerals engineering, underpinned by a knowledge of mineralogy and I would add geology and enough mining engineering to provide context and understanding of the source of feed
- We need graduate competencies, otherwise we have to train in our EIT Program

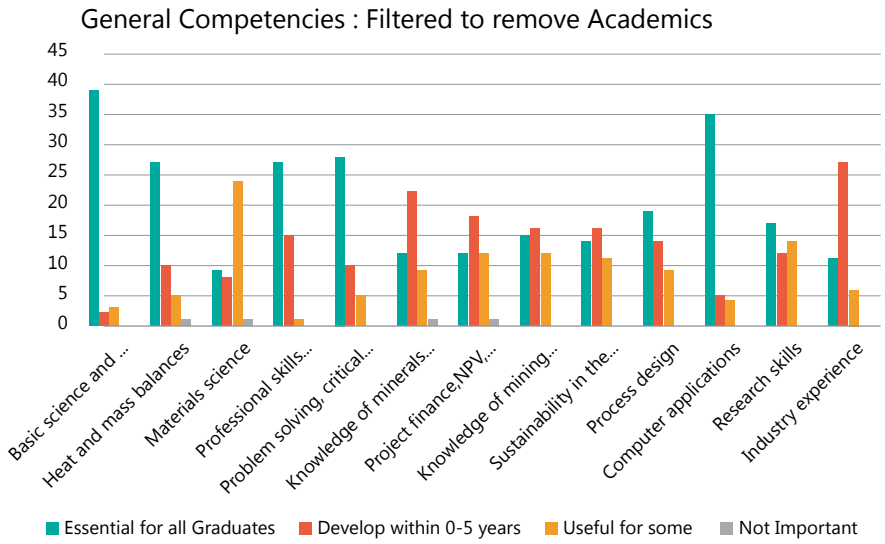
More General Competencies

Figure 4: Responses to question about general competencies required by minerals engineers



Figures 7 and 8 summarise the responses to the question about the importance of the more general engineering competencies.

Figure 5: Responses to question about general competencies required by minerals engineers



The top four topics considered essential for new graduates are the same for:

- Basic science and mathematics
- Heat and mass balances
- Problem solving, critical thinking
- Computer applications

This time, however, there is a difference when the academics are removed from the group. The 5th most important topics are:

- Research skills (whole of survey group)
- Professional skills (with academics removed)

Comments received on this question included the following:

- Graduates need to know about Mineral conservation and laws related to it

- They should have complete knowledge of Mineralogy to understand Mineral Engineering
- Teachers should have continuous interaction with industry
- For minerals engineering mass rather than heat balances are important

The list matches most stated general competencies for engineering programs. Any program that meets international engineering accreditation standards should meet the requirements specified by our survey respondents.

How well are Universities Delivering?

How well are the fundamentals being taught?

The survey asked respondents to rate how well Universities met industry's training needs in the specific mineral processing topic areas listed previously.

Overall, there is general satisfaction with education providers, but few assertions of exceptional performance. The fundamental topics of Comminution, Flotation and Physical separation were rated as best taught, while the worst were Materials handling, Dewatering technology, Metallurgical laboratory procedures, Sampling theory and practice, Metallurgical Accounting and Process Control.

When the full group is compared with the non-academics and non-academics, there is a slight difference in the overall rating, but there is sufficiently good agreement to indicate that academia is in touch with industry expectations.

Figure 6:

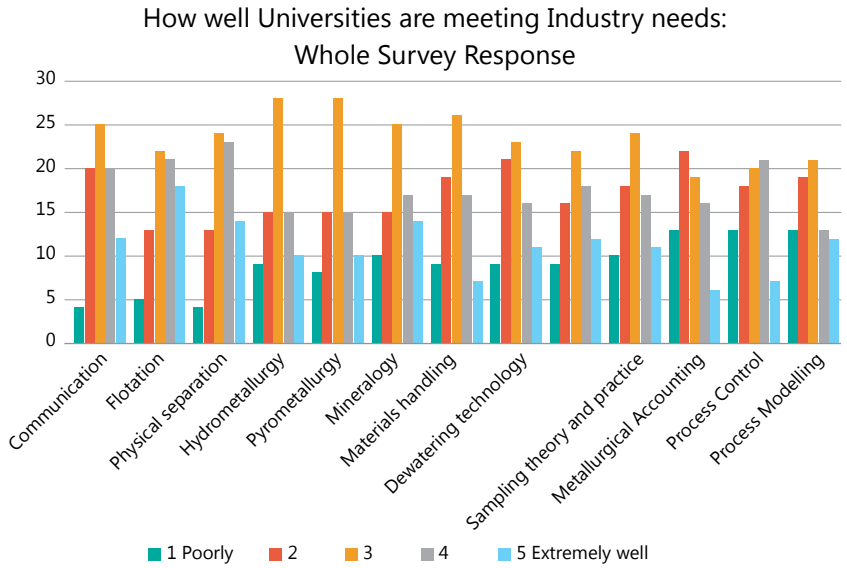
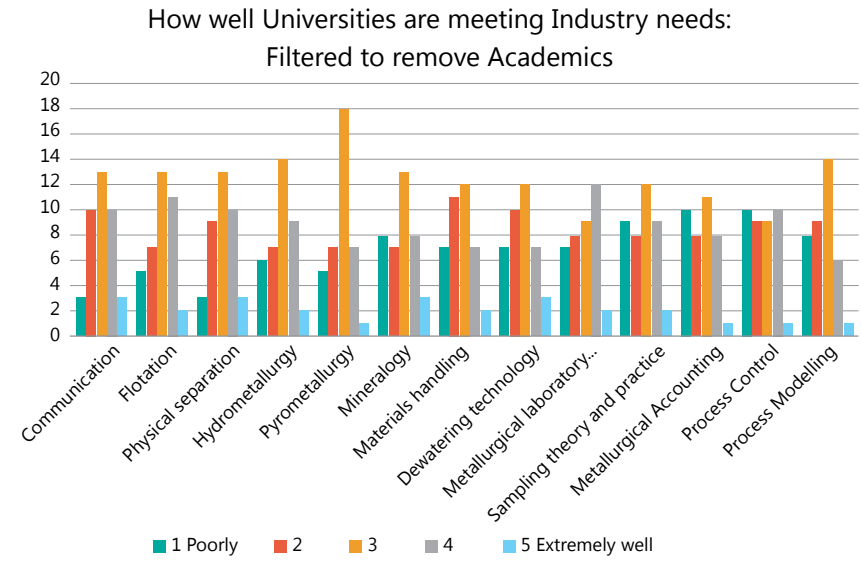


Figure 7:



Overall Performance of Universities

A more open question was asked, requesting comment on specific areas where Universities performed particularly well or badly. There was a wide range of responses, but they fell into a few key categories, which are summarised below.

Universities teach the following topics well:

- Basic theory and fundamentals
- Unit processes
- Mineral processing specialty topics, for example comminution, flotation, mineralogy
- Modelling
- Examples of world-class research
- Nurturing young talent

Universities do not do so well at:

- Keeping abreast of current technology, use of new tools and technologies
- Teaching about environmental impacts and other sustainability issues
- Arranging practical experience for students *(this was not universal – one respondent from Chile stated that arranging practical experiences was done particularly well there)*
- While they do well in educating highly specialised minerals engineers for the large companies, but not so well for the SMEs, which needs engineers with a wider scope

Below are some specific suggestions and comments provided:

- Do well in teaching theory, poor in practical classes. Curriculum is also old. Application training is also poor. New teaching techniques required. Updated industry news and practice's to be taught. Technology use is curriculum to be increased.
- Strong in general process engineering but poor knowledge of mineral processing (metallurgical) flowsheets/types of equipment/unit operations

- Integrated study of ALL facets of running a mining and minerals processing facility is not commonly taught.
- We need Teachers with strong mineral engineering knowledge and practice
- Bring in experts from different fields to deliver lectures.

University/Industry Partnerships

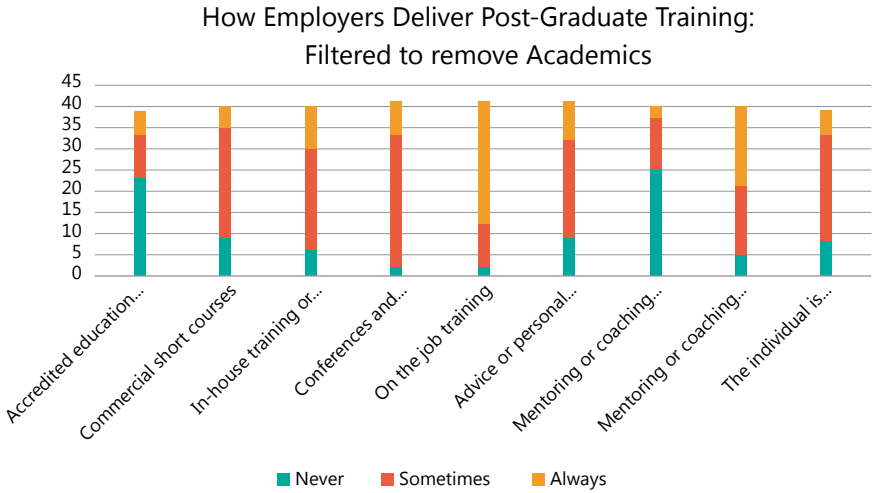
There is evidence of good industry engagement with academic institutions. Respondents were asked to indicate whether they or others from their organisation regularly engaged with education and training at Universities. Of the 45 who are not from academia or research institutions, 15 are personally involved in teaching or engaging with institutions, another 10 are aware of industry engagement and only 13 (34%) are unaware of any industry engagement with Universities. This means that nearly two thirds of the survey's non-academic respondents are engaged with education providers. Given the importance of academic -industry partnerships, this is an excellent result.

Ongoing Training and Professional Development

Graduates will never start work as fully formed Minerals Engineers no matter how good a job universities are doing. There will always be a need for ongoing professional development, but especially so in an environment where undergraduate degrees vary in content and quality, and a significant imbalance exists between graduate supply and demand. The survey included some questions about how companies addressed this important issue.

The first question asked about the mechanisms by which organisations deliver minerals engineering professional development and training. Answers indicated that most organisations use a bit of everything. However, on the job training is by far the most prevalent, and next comes mentoring and coaching. Formal training courses are much less common, and where they exist they are frequently in-house (Figure 11).

Figure 8: Delivery of Professional development



There are some quite sophisticated approaches. One respondent who works for a large multi-national mining company said:

We have developed mineral processing qualifications matrix. One dimension is position (Met I to Chief Met). Alternative paths are provided to learn and practice in each of these areas.

Barriers to professional development

Respondents were also asked what barriers they could identify to ongoing professional development. 40% said that there were no significant barriers to professional development in minerals engineering. Of those who did, 17% cited time (the most significant single barrier) followed by the cost of training or professional development (14%) and lack of corporate support for training (14%). Only 11 respondents (13% of those who answered the question) cited lack of availability of suitable programs.

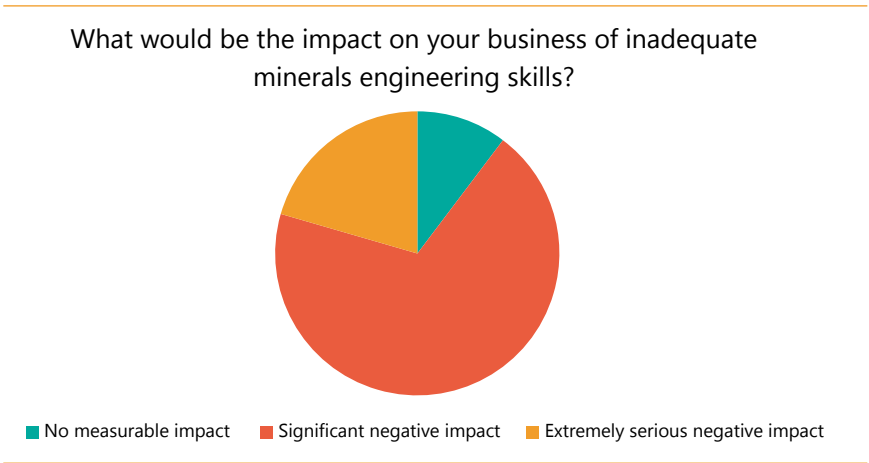
Some individual comments included:

- The largest barrier is getting past the important / not urgent mindset.
- Time shortage due to other activities (bureaucracy)
- We are a very small company
- Conference attendance is currently on hold for budget reasons
- We have very low staffing levels and nobody allocated to look after graduate training in professional areas, although there are plenty of training courses on safety and management
- Declining internal support for EIT (engineer in training) programs & training

How Much does it Matter?

It is always important to find out how much employers actually care about specific mineral processing competencies, so respondents were asked about the impact on their business of inadequate minerals engineering skills. Thankfully, good mineral processing skills and competency development is clearly important to most of the survey respondents (Figure 12).

Figure 9: Responses to question about the importance of good skills – with Academics removed from the data set



Comments provided with the answer include:

- The contribution of Metallurgy graduates to the Australian minerals industry is significant and essential to our future prosperity.
- Lack of true mining industry knowledge has a negative impact
- Our customers expect proficiency in mineral processing
- Without good education, we need to invest more time getting graduates up to speed

The need for Mineral Processing Education Guidelines

This and other work by the IMPC Commission on Education clearly indicates that there is a continuing need for quality undergraduate education in mineral engineering. Mineral processing is a challenging field that is increasing in complexity and undergraduate needs to deliver the competencies required to support the evolving technology.

New models may be required for delivery of this education, and new kinds of learning outcomes that address broader topics including financial, environmental and elements of risk related to political and social issues. It is important for educators that they develop their programs to meet these new requirements.

The IMPC is developing guidelines for mineral engineering education, due for publication in mid 2017, and based on information collected in the study reported and other reviews, including a panel discussion session held in 2016 at the XXXVIII IMPC Conference in Quebec City.

The guidelines will be disseminated internationally to encourage adoption of best practice by educational institutions. This may involve engaging with accrediting bodies such as ABET, CEAB, the Washington Accord and professional societies such as SME, CIM and AusIMM.

Conclusions

IMPC is uniquely placed to be the international authority on Mineral Processing curriculum.

The Education Commission is currently conducting several studies into the status of the education sector, and how well the programs available match industry needs. The survey and review presented here represent an important part of this body of work. The results will assist regulators, professional societies and other accrediting bodies by providing education guidelines based on current industry standards and needs.

Guidelines based on this work will be useful for employers, for human resources professionals responsible for competency mapping and career development, and for individual professionals managing their individual career path.

The Education Commission gratefully acknowledges the support of the data collection team and all those who provided data by submitting their curriculum detail or taking the survey.

References

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Appendix 1
Information about the survey respondents

Information about the survey respondents is summarised in Figure 1 and Table 2.

Figure 1 a, b and c: Demographic information about survey respondents

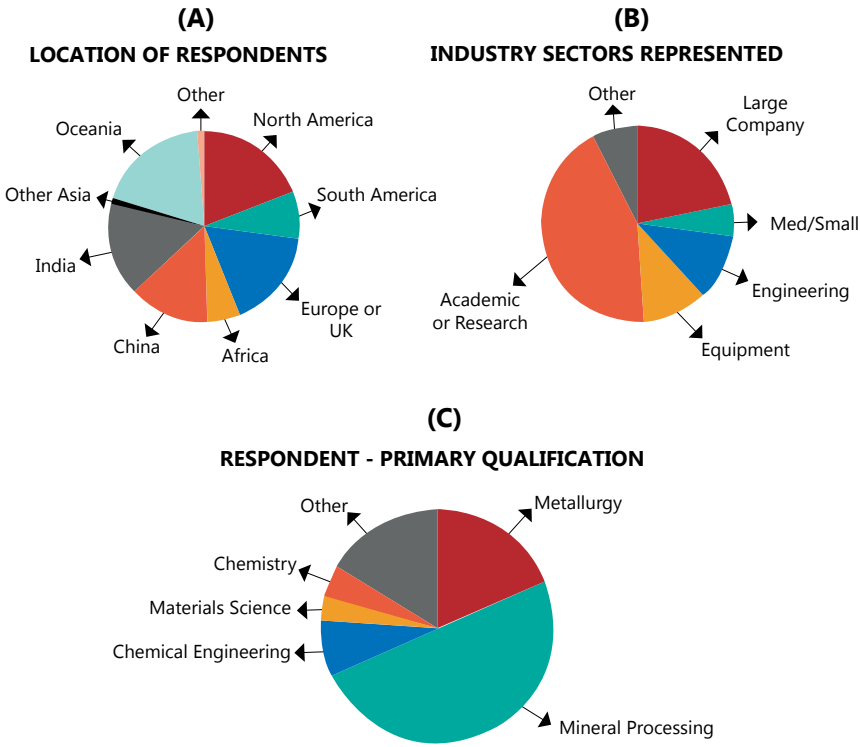

Table 1: Summary of demographic information about survey respondents

QUESTION: What mining industry sector do you work in?		
Answer Options	**Response Percent**	**Response Count**
Large Mining Operations Company	21.7%	20
Medium or Small Mining Operations Company	5.4%	5
Engineering or Consulting Company	10.9%	10
Equipment Manufacturing or Sales Company	10.9%	10
Academic or Research Institution	43.5%	40
Other (please specify)	7.6%	7
Answered question		92
QUESTION: Where are you located?		
North America	19.1%	17
South America	7.9%	7
Europe or UK	16.9%	15
Africa	5.6%	5
China	13.5%	12
India	15.7%	14
Other Asia	1.1%	1
Oceania (Australasia and Pacific Islands)	19.1%	17
Other (please specify)	1.1%	1
Answered question		89
QUESTION: Where is your minerals engineering capability located?		
North America	14.6%	13
South America	5.6%	5
Europe or UK	15.7%	14
Africa	5.6%	5
China	13.5%	12
India	14.6%	13
Other Asia	2.2%	2
Oceania (Australasia and Pacific Islands)	20.2%	18
Other (please specify)	7.9%	7

Answered question		89
QUESTION: How would you describe your own primary qualification?		
Answer Options	**Response Percent**	**Response Count**
Metallurgy Science or Engineering	18.7%	17
Mineral Processing Science or Engineering	49.5%	45
Chemical Engineering	7.7%	7
Materials Science	3.3%	3
Chemistry	4.4%	4
Other (please specify)	16.5%	15
Answered question		89
Other included: Policy-Business, mining engineering, geology, valuation of Mineral Properties, rock mechanics, mechanical engineering, mineralogy, recycling, analytical geochemistry, quality control		
QUESTION: How often do you interact with graduate or early-career minerals engineers (less than 5 years experience), either as a supervisor or collaborator?		
Daily	45.1%	41
Weekly	20.9%	19
Monthly	11.0%	10
Every 2 - 3 months	8.8%	8
Less often/Never	14.3%	13
Answered question		91