Global Mineral Engineering Curriculum Review

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Introduction

The IMPC Commission on Education was established in 2008 to address concerns about the worldwide supply and demand of mineral processing talent, and the degree to which minerals engineers possess the skills needed to make the best use of available tools and technology. The Commission has already published a comprehensive study of graduate supply and demand (Cilliers 2013), and the current focus is on the content and quality of undergraduate Minerals Engineering programs.

Anecdotal data collected during the supply/demand study in 2011 suggested that there is a mismatch between what is being taught in some minerals engineering schools and current industry needs. Today's undergraduate students will enter a very different industry from the one for which much of the mineral processing curriculum was developed. Education providers need to 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 industry of the 21st century is global, not regional; it is driven by cost, not value and the license to operate is of critical importance to all. There is a strong focus on risk, technical expertise is often off-site, and reliable process diagnostics are often scant despite vast amounts of data being generated by modern processing plants and operations.

The Commission on Education approached a broad cross-section of Mineral Engineering academics to find out what is currently taught. This is the first time that a set of international data has been collected in this way. It provides an important backdrop to the ongoing work of the Commission as they work to develop international guidelines for educators.

Summary of Findings

Not surprisingly, curriculum varies from place to place. Mineral processing undergraduate programs vary in length from 3–6 years, and content also varies significantly. Programs range from those with a heavy focus on mineral processing topics to materials or chemical/process engineering programs which are more generic.

There are regions of the world (Australia, South Africa) where it is common for chemical engineers with no mineral processing education to be employed as mineral processing engineers. Specialist expertise is developed on the job or via professional development programs. Even in undergraduate programs where minerals engineering is a strong focus, there is considerable variety in duration, content and depth.

This means that the ongoing professional development needs for graduates will not be the same in all regions.

The data collected in this study do not indicate any consistent employer preference for one kind of program over another. Ongoing IMPC work may be able to investigate this issue in more detail. In the meantime, some employers report that they exploit this by hiring from a range of different types of program.

Methodology

The Commission on Education has access to an international network of academics able to provide information about a broad cross-section of programs from around the world, including the kinds of programs being delivered, course content and stated learning outcomes. Although this is not sufficient for a rigorous study of global curriculum, it provides valuable insights into the current state of minerals processing tertiary education.

The commission collected 21 different examples of curriculum from 13 countries, representing all global mining regions. Contributors are listed in Table 1 below.

Table 1: Contributors to 2014 IMPC Curriculum Review

Professor Jan Rosenkranz	Professor and Chair of Mineral Processing, Luleå University of Technology	Sweden
Professor Güven Önal	President, Turkish Mining Development Foundation; lecturer in Mineral Processing Engineering Department of Mining Faculty of Istanbul Technical University	Turkey
Professor John Herbst	Robert E. Murray Chair of West Virginia University's Department of Mining Engineering.	USA
Professor James Finch	Gerald Hatch Chair in Mining and Metallurgical Engineering, McGill University	Canada
Professor Juan Yianatos B.	Universidad Técnica Federico Santa María	Chile
Professor S. Subramanian	Professor, Indian Institute of Science	India
Professor Aleks Nikoloski	Chair, Extractive Metallurgy and Mineral Science at Murdoch University	Australia
Professor Chris Aldrich	Professor Mineral processing at Curtin University	Australia

Professor Robin Batterham	President at Academy Technological Sciences and Engineering, University of Melbourne Ausralia	Australia
Professor Han Long	Vice-President at BGRIMM	China
Professor David Deglon	Anglo American Platinum Professor of Minerals Processing at University of Cape Town	South Africa
Dr Kate Tungpalan	Assistant professor, College of Engineering, University of the Philippines	Philippines
Dr Sam Palyaniandy	Process Manager at Nippon Eirich, Australia	Malaysia
Dr Philip Thwaites	Manager, Process Control at Glencore XPS	Canada
Professor Turgut Yalcin	Bharti School of Engineering, Laurentian University	Canada
Professor Jocelyn Bouchard	Assistant Professor, Département de génie des mines, métallurgie & matériaux; Faculté des sciences et de génie	Canada
Dr Bianca Foggiato	Ausenco Engineers, Brisbane Australia	Brazil

Each example of program curriculum provided by team members included information about the program name, description and duration; the total number of credits required, and a list of core and elective subjects or courses.

Contributors were also invited to comment on the management of course content, accreditation standards, whether or not they had steering committees and industry advisory boards and stated graduate outcomes. Other information provided included information about practical industry experience and research projects.

The Commission intends to build on this data and conduct regular reviews and updates.

Results

IMPC's Education Commission has assembled a comprehensive cross-section of undergraduate Minerals Engineering programs from around the world. Key features are summarised in Table 3.

Table 2: Twenty-One Examples of Undergraduate Curriculum from around the world

Country	University	Program Name	Years	Credits
Sweden	Lulea Technical University	Sustainable Process Engineering	5	300
Turkey	Istanbul Technical university	Mineral Processing Engineering	4	152
USA	Virginia Tech (specialty within Mining Eng)	Batchelor of Science in Mining Engineering	4	128
USA	University of Utah	Metallurgical Engineering	4	129
Canada	McGill University	Mining and Materials Engineering	3	148
Chile	Universidad de Concepción	Metallurgical Engineer	5.5	207
Chile	Santa Maria University	Ingeniería Civil Metalúrgica	6	198
Chile	Universidad de Chile	Bachelor of Mining Engineering with minor in Extractive Metallurgy	6	198
India	Vijayanagara Sri Krishnadevaraya University	M.Tech (Mineral Processing)	3	125

Country	University	Program Name	Years	Credits
Australia	The University of Queensland	Bachelor of Chemical Engineering (Metallurgy)	4	64
Australia	Murdoch University	Bachelor of Engineering *	4	96
Australia	West Australian School of Mines WASM	Bachelor of Engineering (Bachelor of Extractive Metallurgy)	4 (3)	600 (450)
Australia	University of Melbourne*	MSc Chemical Systems	5	600
China	North Eastern University	Mineral Processing Engineering	4	174
South Africa	University of Cape Town	Bachelor of Chemical Engineering	4	582
The Philippines	University of the Philippines	Batchelor of Science in Mining Engineering	5	203
Malaysia	Universiti Sains Malaysia	Bachelor of Engineering (Hons)-Mineral Resources	4	135
Canada	University of British Columbia	Bachelor of Applied Science	4	150
Canada	Laurentian University, Canada	Extractive Metallurgy and Mineral Processing (Chem Eng)	4	150
Canada	Laval University, Canada	Baccalauréat coopératif en génie des mines et de la minéralurgie	4	120
Brazil	Universidade de São Paulo (USP)	Bachelor of Mines Engineering	5	282

These programs vary considerably. They have different lengths, different content and different levels of technical detail. Some focus on specific commodities of importance in the region, such as coal processing in Turkey and India, and copper extraction in South American programs. Some are just chemical or process engineering degrees with a little Mineral processing added in, while others are very specific in their mineral engineering focus.

Years of study

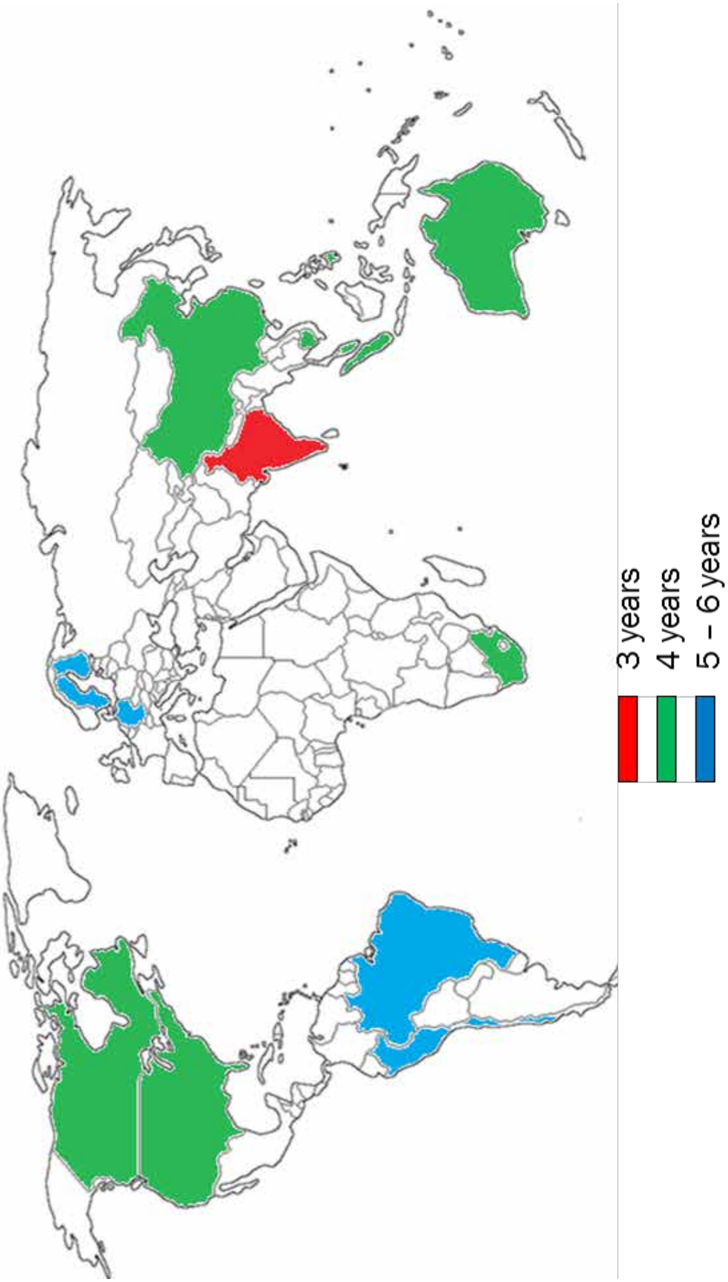
Program duration ranges from 3 years to 6 years, and although there are regional trends, there are exceptions.

Four-year programs are common in Australia, China, South Africa and North America and these are generally engineering degrees.

The three-year programs common in India tend to be applied science degrees rather than engineering. There are examples of these kinds of programs in other parts of the world including Australia and Canada (see table 1).

Engineering programs in Chile and other parts of South America tend to be the longest, with up to 6 years of study. Long degree programs are also common in Europe, but theirs is a quite different model, combining a 3 or 4-year generalist engineering degree with a postgraduate qualification specifically focussed on Mineral Processing topics. An example of this, the “Bologna” model, was discussed in the 2012 IMPC Education Symposium (Batterham 2012).

Figure 1: Variation in Degree Course Duration



Diversity of Content

Although undergraduate programs vary considerably in content, they can be grouped into a few main categories.

This variation was explored by taking the curriculum data supplied for each institution and grouping the core and elective subjects into the following five categories:

1. Basic science or maths topic
2. Chemical or process engineering topic
3. Mineral processing or metallurgy topic (including pyro- and hydro-metallurgy, and also including mineral economics and minerals industry experience)
4. Basic engineering including professional skills (report writing, seminars) and research project/thesis
5. Broader electives

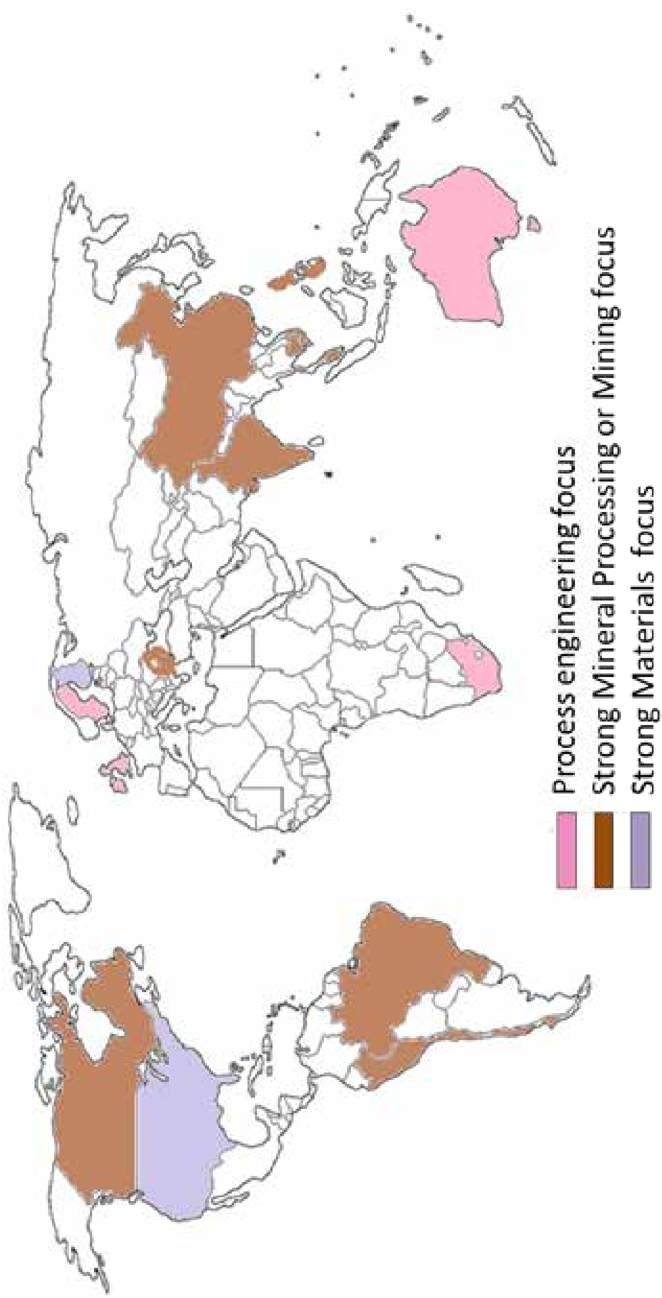
This allowed calculation of the total credits in each category. As an example, data from five of the Universities is presented in detail in Table 4, showing the variation between programs.

Table 3: Preliminary review of program content – Examples from five countries

	Study time Years	Part of Program	Mineral Processing/ Metallurgy	Process Eng	Basic Science Maths	Basic Eng	Electives	TOTAL
Vijayanagara Sri Krishnadevaraya	3	%	51%	22%	9%	19%	0%	100%
University INDIA		credits	73	31	13	27	0	144
The University of Queensland,	4	%	34%	25%	19%	13%	9%	100%
Australia		credits	22	16	12	8	6	64
Santa Maria University	6	%	28%	4%	24%	37%	8%	100%
CHILE		credits	55	8	47	73	15	198
Lulea SPE	5	%	30%	15%	33%	15%	8%	100%
Sweden, Europe		credits	90	45	97.5	45	22.5	300
University of UTAH	4	%	18%	12%	35%	13%	22%	100%
USA		credits	23.5	15	45	16.5	29	129

Using this analysis, and based on the 21 sets of data collated for this study, a diagram could be constructed showing the predominant kinds of degree programs in different regions (Figure 3). However, although certain types of programs predominate in certain regions, there are also many exceptions.

Figure 2: Predominant focus of Undergraduate program



The classic mineral processing and metallurgy curricula with core mineral processing or metallurgy making up around 50% of content is seen in Universities in India, Canada, China and South America. These programs also tend to be strong in other mining-related content. Students in these programs often share classes with other students preparing for careers in the minerals industry, like geologists and mining engineers.

A second group could be described as chemical or process engineering programs, designed to equip graduates to work with a range of industrial technologies. These programs have little or no focus on broader aspects of the mining industry, but are often popular with employers because they build a solid foundation in general engineering and process technology. Universities reviewed from South Africa, Europe and Australia tended to have a strong focus on process engineering, with up to 25% of program content falling into this category, compared to 12 – 15% in other programs. These tend to be quite weak in core mineral processing content.

There is anecdotal evidence (Drinkwater 2011) to suggest that in some of these countries it is common to employ Chemical Engineers graduating with little or no mineral processing content in undergraduate degrees to work in mineral processing plants. However, these countries also have programs strong in mineral processing and materials engineering, and it is not uncommon for employers in these regions to deliberately employ a recruitment strategy drawing from a mix of feeder courses, taking advantage of the situation to achieve a broad skill-set within their professional teams.

A third group of programs has a strong focus on materials engineering, and many are derivatives of the traditional "physical metallurgy" programs. Some of these programs are strongly focussed on the mining industry; others focus more on manufacturing. Examples of universities whose programs have a strong materials engineering focus include Finland and the USA, though there are many others.

Accreditation

Most programs combine several levels of accreditation, and it is important to understand the way this is done. In many instances accreditation is driven by engineering competency standards. There is much less focus on mineral processing competency.

Engineering accreditation is globally managed and subject to review by international bodies and boards, including the Accreditation Board for Engineering and Technology (ABET) in the USA, the Canadian Engineering Accreditation Board (CEAB), Engineers Australia (EA), the Institution of Chemical Engineers (IChemE), and international standards such as the Washington Accord (McCaffery et al 2015).

Accreditation of the mineral processing course content is largely a regional matter, and mostly overseen by the regionally based Professional Institutions such as the Society of Mining Engineers (SME), Canadian Institute of Metallurgists (CIM), IOM3, The Australian Institute of Mining and Metallurgy (AusIMM), South African Institute of Mining nd Metallurgy (SAIMM), The Nonferrous Metals Society of China TNMSC, and others. In many cases this is advisory only as these organisations do not have the same resources as engineering boards.

Table 4: Some examples of program accreditation processes

India	The curriculum is set by the Board of Studies of the respective University/autonomous institutes. Suggestions from industries are taken into consideration while drafting the syllabus. There are two independent government bodies for accreditation [1] National Board of Accreditation set up initially by All India Council for Technical Education. [2] National Accreditation and Assessment Council set up by University Grants Commission

Turkey	Main accreditation body in Turkey is the Council of Higher Education (YÖK). Accrediation of engineering programs: • (MÜDEK) Association for Evaluation and Accreditation of Engineering Programs • (ABET) Accreditation Board for Engineering and Technology (ABET is a recognized accreditor in the United States (U.S.) by the Council for Higher Education Accreditation.
Canada	Universities set their own program but for the program to be accredited it must be approved by the CEAB.
USA	Joint accreditation by ABET with input from the SME
Australia	Engineering programs accredited by EA and need to meet AusIMM course "recognition" requirements
China	China – centrally managed by China Ministry of Education
UK	Accreditation by the Engineering Council UK with input from IOM3 (Institute of Materials, Minerals and Mining).
Philippines and other ASEAN countries	Programs are compliant with the Washington Accord

Conclusions

This review represents an important part of the work being done by the IMPC Commission on Education to establish how well available education programs match industry needs.

There is a lot of variety in duration, content and focus of minerals engineering undergraduate programs. This means that the ongoing professional development needs will not be the same for all graduates.

Employers sometimes take advantage of this and pick and choose a range of graduates.

Accreditation is mostly driven by engineering competency standards rather than mineral processing competency. There is an opportunity for the IMPC to engage with some of these accrediting bodies and provide ongoing accreditation guidelines for mineral engineering education and training that can be used as an international standard for steering committees, industry advisory panels and employers.

Acknowledgements

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.

IMPC Education Commission will continue to review and update this information.

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