

Minerals Industry

Education and Training



Editors:
Jan Cilliers
Diana Drinkwater
Kari Heiskanen



Minerals Industry Education and Training

A collection of papers from the Special Symposium on Human Resource Development, held during XXVI International Mineral Processing Congress (IMPC 2012), September 24-28, 2012, New Delhi, India

Editors

Jan Cilliers (Imperial College London, UK)
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Foreword

The mining and minerals industry has for many years voiced its concern about the availability of well-trained, young professionals. As a result, the International Mineral Processing Council created in 2008 a Commission on Education to explore this issue and report back to Council. The task of the Commission was to determine the number of mineral engineering graduates worldwide, and to compare that to the demand from industry.

After an extensive survey was performed by the members of the Commission, chaired by Professor Cilliers from Imperial College London, the initial findings were published at several conferences in 2010 and 2011.

As a result of the interest these findings generated, a dedicated session on Minerals Engineering Education was proposed by the Council as part of the XXVI IMPC Congress held in September 2012 in New Delhi. With the support of Congress President, Dr. Pradip, a Special Session on “Human Resource Development” was organized, with twelve papers being presented. The session was well received and the lecture room was packed, with insightful questions and discussion. During the session a proposal was put forward to separately publish the papers presented as a collection; this book is the product of the same.

There are three main messages from the session and which are running themes throughout this collection of papers that we hope will be further explored in future IMPCs.

Firstly, mineral engineering education, in terms of numbers, is shifting from developed countries to countries where the exploitation of earth resources is seen as a way to enhance the economic development of the society. China has for the first time been included in such a survey. In sheer numbers it dominates the annual graduation of engineers with over 50% of a total of 5700 graduates a year. There are several countries where the number of graduates has, as claimed, decreased to unacceptably low numbers. It was estimated by Professor Cilliers and his team that in Australia, North America and Europe the number of graduates seems to be low compared to the demand. This has happened much because of policy choices made by the universities. Mineral engineering has always been a small, specialized discipline not easily fitting the quest for larger and more generic engineering disciplines driven by many universities. This has caused the discontinuation of many programs in US and Europe. At the other end of the spectrum are the countries where mineral production is large, but training of engineers has not grown to meet the demand: Africa, Asia (China not included) and partly South America.

The growth numbers presented by Professor Cilliers, as well as presenters from various countries, showed that many South American countries estimate their graduate numbers to increase substantially (over 50%) during the coming years.

According to the survey, the growth in numbers in the other parts of the world are very modest or even stagnant or declining. Especially India, Australia and most of African countries seem to stay well below the numbers expected to be needed by the industry.

Another issue pointed out in the session, is the “leakage” of engineers from the minerals engineering discipline to other professions. This is especially marked in Europe and Africa. In Africa, an academic degree seems to open up a large variety of career paths resulting in only half of the graduates to follow a career in minerals engineering. In Europe, many of the graduates find their way to careers, which are part of the larger mining cluster, foreign exchange, banking, technology and engineering companies, and even law.

The second strong message from the session was that with the joint effort of academia and industry very high quality training of engineering graduates with different non-mineral backgrounds can be achieved. There were several programs reported where employed young engineers were participating in industry-sponsored training. Examples came from Australia, South Africa and Finland. All these programs had similar basic educational ideas. They all had a strong interaction with the industry when developing their curriculum. All the curricula contained on-site, hands-on training intertwined with more theoretical studies. Skill development in metallurgical accounting, plant surveys, process mineralogy and process control were central issues in teaching. They all had also elements of leadership and economics included.

Professor Batterham, when discussing the European Bologna agreement to harmonize European higher education degrees, delivered the final message. There appears to be an international trend in universities in Europe, North America and Australia that bachelor studies are becoming more generic in their engineering learning outcomes. One can even say that in some cases we see engineering giving way to natural sciences. The important message is that the risk increases that several important learning needs required for a career in Minerals Engineering will not be taught. One can mention, for example, the deep understanding of interactions between particulate size, liberation and mineral occurrence and properties in each particular ore. Development of that generic understanding requires establishing a theoretical background, knowledge of the techniques available for study and also practical training. This type of interdisciplinary skills cannot be taught in generic programs.

All this may point towards a future where academia and industry work even more closely together to create international programs, which will train students from more generic engineering backgrounds. It is important that such programs also address the issue of strengthening emerging Minerals Engineering programs the world over.

Kari Heiskanen

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Section 1

Supply and Demand

The Supply and Demand of Minerals Engineers: A Global Survey

Jan Cilliers

Imperial College London, SW7 2AZ, United Kingdom

Introduction

In 2008 the International Mineral Processing Council created a Commission on Education. The role of this commission was clearly defined by the Council: to study and determine the supply and demand of mineral processing talent, worldwide. This was plainly a three-part question; how many graduate mineral processing engineers are produced each year, what is the demand for such engineers, and do these two match.

The Commission on Education set about this task by first addressing the supply side question. A team of colleagues was established to collect and collate data from all the key regions of the world. The data were collected from universities and government agencies to give a view of the current position (2010) and a five-year future outlook for the number of mineral process engineering graduates. This is the most complete set of data ever collected on this question, and covers all the key regions of the world.

The data collected included a number of additional statistics, including the proportion of graduates that are female, an estimate of the fraction of graduates that enter the mining industry, as well as the number and age of teaching staff.

It was extremely difficult to get and collate data for the talent demand from industry. In many cases this was considered commercially confidential, but in most cases it was simply not available.

To assess the demand side, an approach based on the world production of minerals by region will be used as a proxy for absolute numbers. While this

allows a comparison between regions to be made, it does not, necessarily, show whether the supply and demand are in balance.

The Supply of Minerals Processing Engineers

1. The data collection team

The 13-strong data collection team is shown in Table 1. Data was collected from all major regions of the world. In many regions the team member themselves had a team below them that collected the data on a local level and which was then collated by a team member. This was facilitated by an agreed standard data collection format that allowed effective data collation.

Table 1: The IMPC Commission for Education data collection and collation team

Region	Name	Affiliation
Chair	Prof. Jan Cilliers	Imperial College London, UK
India	Prof. SP Mehrotra	National Metallurgical Lab, India
China	Prof. Hu Yuehua	Central South University, China
South America	Prof. Juan Yianatos	Santa Maria University, Chile
Central America	Dr. Alejandro Uribe-Salas	CINVESTAV, Saltillo, Mexico
North America	Prof. Jan Miller Prof. Jim Finch	Utah University, USA McGill University, Canada
Europe	Prof. Kari Heiskanen	Aalto University, Finland
Africa	Prof. Dave Deglon	U. Cape Town, South Africa
Australia	Dr. Wayne Stange	AMIRA (then), Australia
Middle East	Prof. Guven Onal Prof. Zafir Ekmekçi	Istanbul Technical U, Turkey Hacettepe University, Turkey
Russia	Prof. Vladimir Vigdergauz	Russia

2. The supply side

2.1 University data collected

The supply data was collected and refined over a period of a few years, with the majority reported during 2009. This was collated in 2010, and

presented as a preliminary report on the demand side at the Brisbane IMPC, at which requests for further information were made. During 2011, with assistance from delegates from those regions, the data was refined and made more complete. Table 2 summarizes the data collected.

Table 2: The supply-side questions

1. Undergraduate student numbers	How many graduated in past 5 years
	Prediction of numbers up to 2015
	% that entered the industry
	% that are female
2. Academic staff	Numbers
	Age distribution

The data collected is extensive, but cannot be regarded as being fully complete. It is certain that many universities are not included, either due to being accidentally missed, or because the data was not received. In some cases the data was incomplete, and estimates were made from other universities or regions.

In particular, the data is unique as it includes for the first time accurate data from China, as well as from Russia and the former Soviet States. Furthermore, the data collected here gives a more detailed picture of South and Central America than previously reported.

Nonetheless, there remain some significant gaps in the data. Only limited data was available for the Middle East. However, data from Turkey was especially helpful and regarded as representative of the region. Data from Europe was also sparse, but it is known that this region is only a small supplier of minerals engineers, and the estimates are not material to the global situation. Detailed data from Canada were not available; these were estimated as 50% of those of the USA.

The biggest region for which data was not available was Asia, with the exception of China and India. This is unfortunate, as this area is a large mineral-producing region of the world. Considering the number of

universities in the region that train minerals engineers, and other subjective indicators such as the number of minerals-related papers published from that region, it can be inferred that the number of graduates is not substantial, and likely to be fewer than 100 per annum.

It is therefore unlikely that any of these shortcomings would have had a material effect on the overall conclusions, and this data can be regarded as the most complete such study to date. It can be said with confidence that this allows a reasonable global view of the number of minerals engineers currently graduating annually in each region of the world and that can be expected to graduate in 2015.

2.2 The supply of minerals engineers

Table 3 summarizes the current and 2015 predicted graduate numbers for all the regions surveyed.

Table 3: Global distribution of mineral processing graduates

	Current	2015
Africa	400	450
Australia	40	60
China	2920	3040
North America	175	205
India	140	150
Russia& Eastern Europe	370	350
South & Central America	1165	1850
Turkey & Middle East	470	470
Western Europe	50	50
WORLD TOTAL	5730	6625

It can be seen that the largest predicted growth in numbers is in the South and Central American region, and these numbers should be explored in greater detail. The breakdown by country is shown in Table 4.

Table 4: South and Central America broken down by country

	Current	2015
Brazil	350	525
Perú	250	375
Chile	220	396
Argentina	30	54
Mexico	145	230
Others	170	270
TOTAL	1165	1850

It can now be seen that the largest numbers are from Brazil, Perú and Chile, where there is also a significant growth expected (>50%).

Although China currently produces by far the greatest number of mineral processing graduates (~50%), only a modest increase in 2015 is expected.

Most surprising is the small number of graduates produced both in Australia and Africa, where so much of the world's mineral wealth resides.

2.3 Female graduates

The approximate proportion of graduates that are female is shown in Table 5, for those regions for which the data was available.

Table 5: Percentage of graduates that are female. Numbers in brackets are for 2015, if forecast to change

	% Female
Africa	48
Australia	30
China	18
North America	25
South & Central America	18 (30)

Worldwide there is little change predicted in these proportions, except in South America, where the proportion of female graduates is expected to rise from 18% currently to 30% in 2015.

2.4 Graduates entering the industry

The proportion of graduates that enter the industry after graduation is shown in Table 6, for regions where data was available. It can be seen that the proportion is very high for all regions except for Africa, where it can be surmized that there are many and wide opportunities for graduates.

Table 6: The percentage of mineral processing graduates entering the industry after graduation

	% of graduates entering the industry
Africa	50
Australia	80
China	85-95
North America	90
India	100
South & Central America	85

2.5 Academic staff details

Concern has been expressed about the reducing and ageing number of academic staff available to teach the undergraduate population.

Table 7 summarizes the data, for the regions where it was available.

Table 7: Academic staff numbers (Numbers in brackets are for 2015, if forecast to change)

	Academic staff
Africa	85
Australia	80
China	405 (516)
North America	30
South & Central America	377 (557)

It is of interest that only South America and China are forecasting a growth in the number of academics. In South America, this is in line with their growth in student numbers, to maintain the student:staff ratio at about 3.2. In China, the growth in academic numbers is faster than that of the number of students, so decreasing the student:staff ratio from the current 7.2 to 5.9 in 2015.

The average age of academics across the world approximately is between 40 and 50.

The Demand for Minerals Processing Engineers

3. The demand side

3.1 Introduction

As noted previously, obtaining data of the current and predicted demand for mineral processing engineers was nigh impossible. Approaches to the major mining companies proved to be largely unsuccessful. In some cases this was because the numbers were not available, and, in others, when available, they could not be released.

An alternative approach is simply to argue that most graduates (>80% for most of the world, Table 6) enter the industry, and that there is therefore an estimate of demand. This clearly is not satisfactory, as it does not address the potential demand.

In this study, an attempt is made to correlate the world mineral production by region with the number of graduates from a region. While this also does not allow an estimate of talent demand, it may indicate regions where there is an apparent talent shortage or oversupply. Further, should the correlation be linear, and if the shortage or excess in one region be estimated, this can then be used to extrapolate to other regions. This may be useful to estimate graduate numbers for the Asia region, for which data was not available.

3.2 World mineral production

For this study, the World Mineral Statistics was contributed by permission of the British Geological Survey. Table 8 summarizes the world mineral production data by the same regions as considered in Table 3, with the addition of Asia.

To allow comparison between regions, the percentage that each region produces of 14 major mineral and metal products was averaged. This average percentage is used as a proxy for the need for minerals engineers.

In Figure 1, this average of mineral production is compared to the fraction of Minerals engineers produced in each region (Table 3). Note again that Asia is not represented.

Table 7 shows some interesting results. Note that China produces the largest average fractions of the largest mineral groups the next largest mineral producing regions are Australia, and Central- and South America, closely followed by Eastern Europe and Russia, Africa and North America.

3.3 Comparison

The mineral production figures can be compared with the proportion of engineers graduating in each region. In Figure 1, a linear trendline shows the nominal correlation between them. It is known that in China most of the engineers enter the industry (85-95%). If we also assume that China has adequate mineral process engineering talent, the line shown is probably too steep, and should pass closer to the point for China.

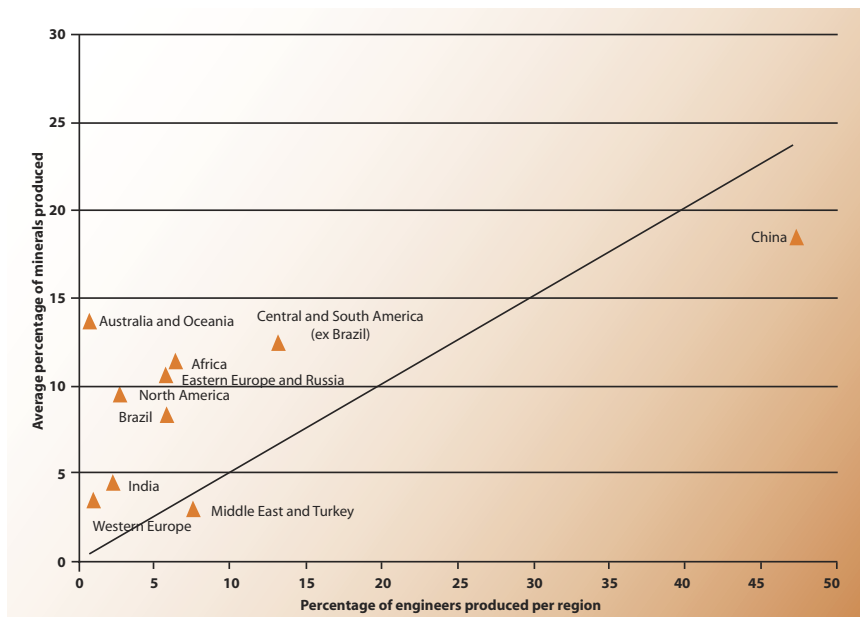
This simplistic comparison between mineral production and number of engineers indicates that there is likely to be a significant shortfall of Mineral engineering talent in all regions, with Australia most affected and Central- and South America better positioned.

From the nominal correlation, the number of engineers being trained in Asia can be estimated as approximately 450 per annum, similar to Africa and the Middle East. It would be interesting to see whether this is borne out by data.

Table 8: World mineral production (World Mineral Statistics were contributed by permission of the British Geological Survey)

Percentage of mineral production, per mineral, per region												
Region	Western Europe	Eastern Europe and Russia	Middle East and Turkey	Asia	Africa	North America	Central and South America	Australia and Oceania	Brazil	China	India	Total mineral tonnes [Average per year per region, 2005-2009]
Alumina	8.2	10.5	0.4	0.9	0.8	7.6	9.7	25.1	9.4	23.4	4.1	75,196,304.70
Bauxite	1.2	6.5	0.3	6.2	9.7	0.1	12.5	31.6	12.6	11.3	8.1	199,078,354.50
Chromium	2.4	21.0	10.0	0.6	41.6	0.0	0.0	0.4	3.0	1.1	19.9	21,335,195.60
Coal	4.7	13.0	1.2	4.8	3.9	17.1	1.5	6.2	0.1	39.8	7.7	6,420,126,582.22
Copper	1.2	12.4	2.0	7.3	5.8	11.8	44.6	7.0	1.2	6.3	0.2	15,059,583.96
Gold (kg)	0.5	9.3	0.7	10.9	20.7	14.4	18.7	3.2	10.0	11.6	0.1	1,844,727.23
Gypsum	16.9	5.1	11.9	6.7	6.7	15.6	7.1	2.3	1.5	24.1	2.2	151,941,285.9
Iron	1.3	9.9	1.9	0.3	3.1	4.0	2.6	16.0	16.5	34.5	10.0	1,982,182,824.58
Lead	3.8	6.2	1.2	1.1	3.0	14.2	10.8	18.5	0.4	38.7	2.1	3,555,440.10
Magnesite	3.8	6.9	4.5	2.4	0.2	0.4	0.0	50.5	0.8	29.9	0.6	49,317,067.00
Manganese	0.0	13.3	0.3	0.8	28.6	0.0	1.2	13.4	7.2	28.3	7.0	34,275,782.58
Phosphate Rock	0.5	6.7	8.0	1.9	26.8	20.2	0.6	1.4	3.9	28.9	1.1	156,029,630.60
Silver (kg)	2.0	15.8	1.5	2.4	1.7	9.9	44.4	9.3	0.1	12.7	0.4	21,330.86
Tin	0.0	0.7	0.0	24.6	4.1	0.0	22.7	1.5	42.7	0.0	3.7	301,502.38
Uranium	0.1	27.2	0.0	5.7	17.2	27.0	0.0	19.8	0.6	1.8	0.6	42,580.64
Zinc	6.1	7.4	1.7	1.4	2.9	12.9	21.7	12.7	26.4	5.1	1.6	11,131,080081
Average Percentage of mineral production by region	3.3	10.7	2.9	4.9	11.0	9.7	12.4	13.7	8.5	18.6	4.3	

Figure 1: Average percentage of mineral production and proportion of minerals engineers graduated by region



4. Summary and Conclusions

The IMPC Commission for Education has put together a detailed picture of the world supply of minerals engineering graduate talent.

The numbers are encouraging, and almost 7000 minerals engineers are expected to graduate in 2015. Of these, 45% will graduate in China, and a further 28% in South and Central America. This is encouraging, as these regions also produce significant proportions of the world's minerals and metals. Academic staff numbers are also increasing here to accommodate this growth.

Africa (particularly Southern Africa) and the Middle East (particularly Turkey) also produce significant numbers of graduates. In Africa, however, the numbers actually entering the industry is low, possibly as they fill

talent gaps in other fields. There is clearly a great scope for increasing the proportion of female engineers.

On the demand side, data was harder to come by, and an alternative approach was taken. The average proportion of 14 key minerals and metals produced in a region was used as a proxy for mineral processing talent demand. Comparison with the supply indicated there are apparently too few minerals engineers graduating in regions where mining is very important; Australia being the most significant. In North America and Europe, the numbers of graduates are also disappointingly small.

The almost complete employment of mineral processing graduates in China can be used as a benchmark for adequate supply. This indicates a significant talent shortfall elsewhere, and that requires addressing urgently.

Closing the Skill Gaps and Labor Shortages: A Priority for Mining Companies and the Chilean Government

H Araneda

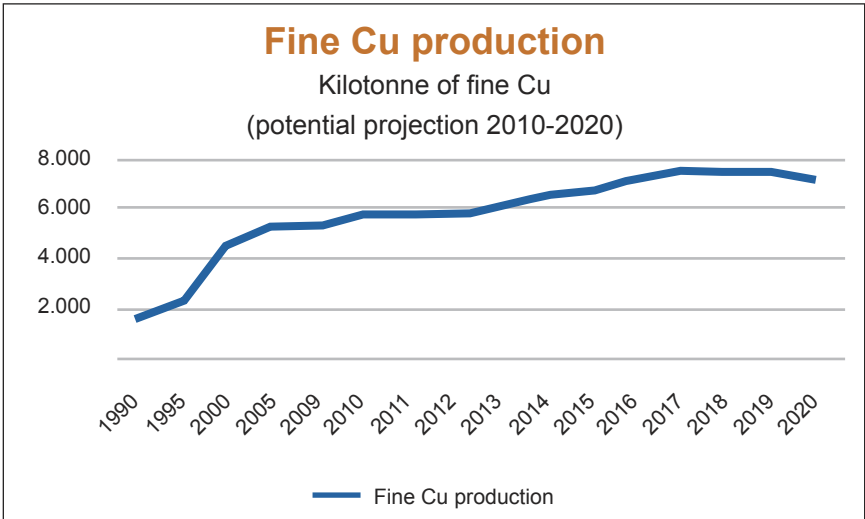
Fundación Chile

Presented by R Kuyvenhoven, GECAMIN

Introduction

Throughout Chile’s history, mining has consistently been a leading industry in the country. The 1990s marked the beginning of a boom in Chile’s mining industry, especially in copper mining, due to both foreign and local direct investment in the sector. Figure 1 shows a 359% increase in projected copper production from 1990 to 2020.

**Figure 1 : Increasing investment and production in mining in Chile
1990 – 2020**



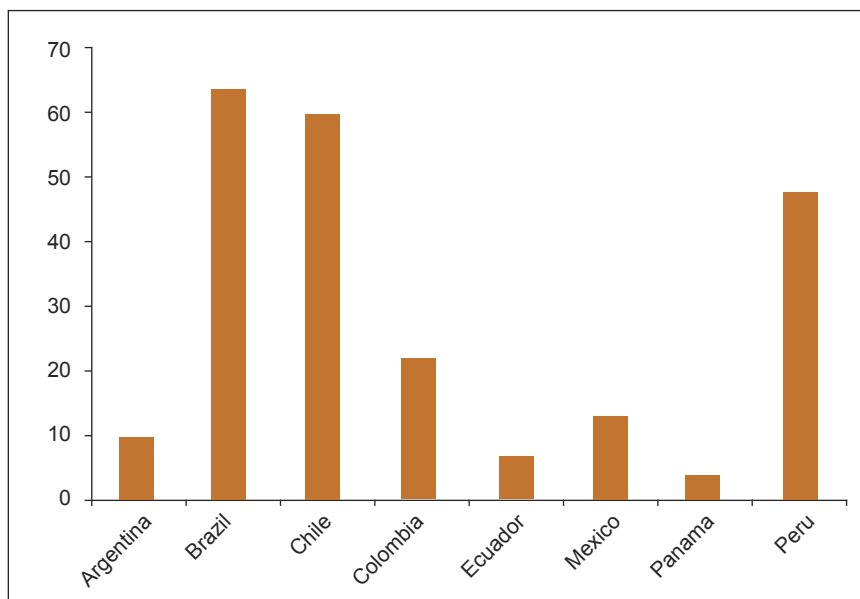
Source: COCHILCO

Mining's contribution to the GDP was 15.6% at current prices in 2009, and it accounts for 59% of the country's exports. Chile's copper market share reached 35% in 2009, while the investment portfolio in mining in Chile for the coming decade has been estimated at 90 billion US dollars.

Table 1: List of main projects US\$ 90.000 MM 2012-2020

Company	Project	Before 2012	2012	2013	2014	2015	2016	2017	2018	2019	2020
Collahuasi	Expansión Collahuasi										
Quebrada Blanca	Quebrada Blanca, fase 2										
Antofagasta Min	Antucoya										
Codelco	Chuquicamata Subterránea										
Codelco	Mina Alejandro Hales										
Quadra Mining	Sierra Gorda										
Xstrata	Lomas Bayas II										
BHPB	Organic Growth Project 1 OGP1										
BHPB	Proyecto Oxide Leach Area Pad										
BHPB	Escondida concentrate pipelines										
BHPB	Truckshop										
Kinross	Lobo-Marté										
Barrick	Pascua-Lama										
Barrick y Kinross	Cerro Casale										
Goldcorp	El Morro										
Pan Pacific Copper	Caserones										
Antofagasta Min	Proyecto Integral de desarrollo de la mina Los Pelambres										
Xstrata	El Pachón										
Codelco	Proyecto Nueva Andina										
Codelco	Nuevo nivel mina										

**Figure 2: Projected mining investment in Latin America 2012-2015
(1000 MM US\$)**



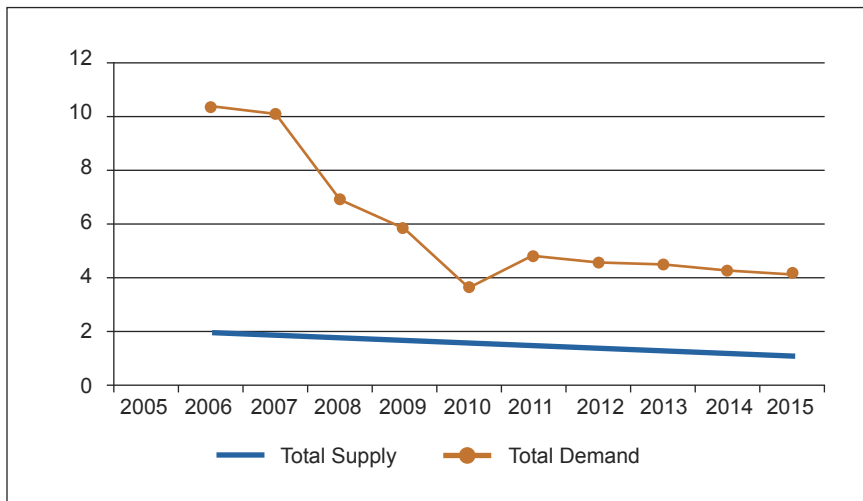
The Cost of “Doing Nothing”

17 of the 20 projects that are scheduled to come into production between 2011 and 2020 represent a net present value (NPV) of 79.412 MM US\$. If the start up of one project (assume 8% of total investment portfolio) were to be delayed by one year, the NPV decreases with 325 MM US\$ to 79.087 MM US\$.

Supply vs Demand

The acute scarcity of human resources currently experienced by the mining sector in Chile will be accentuated in the coming decade as a result of this scenario of investments. The situation is, additionally, similar to the one confronted by other countries involved in the mining industry such as Australia, South Africa, Canada, and in Latin America includes Peru, Colombia and Brazil. Figure 3 shows the gap predicted in Australia between supply and demand 2010 to 2020 (Lowry et al. 2006).

Figure 3: Projected annual growth rates, demand and supply in Australia (Lowry 2006)



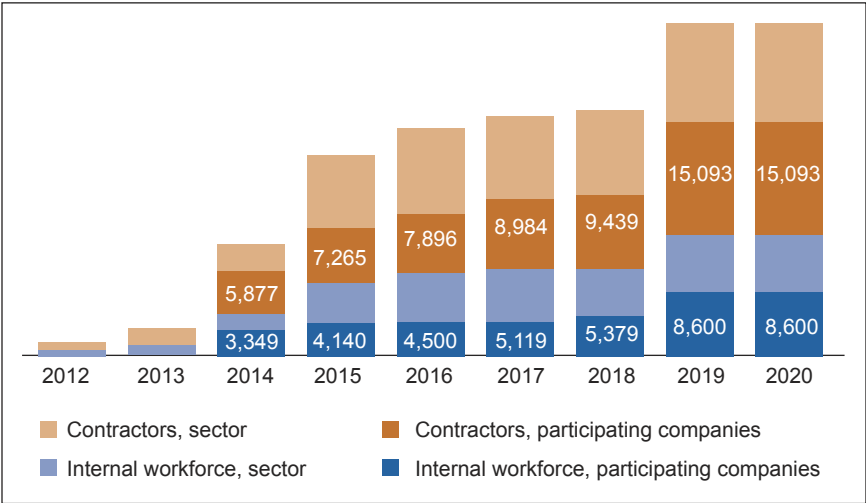
A study carried out by Fundacion Chile, Labor Force in the Chile Mining Industry, Diagnostic and Recommendations, 2011-2020” shows the projected labor shortage for the operation of projects in the development stage, considering only the requirements of the process of extraction, processing, and maintenance.

The information generated by this study is required to adequately plan the development of human capital to assure sustainability and growth projections for the mining industry for the next 10 years. Base line information is valid for initiatives that point at closing the gaps. Five mining companies participate, representing 83% of current Chilean Cu production and over 90% of the projected year-2020 production. These companies are Anglo American, AMSA, BHPB, Codelco and Collahuasi.

Projected Demand

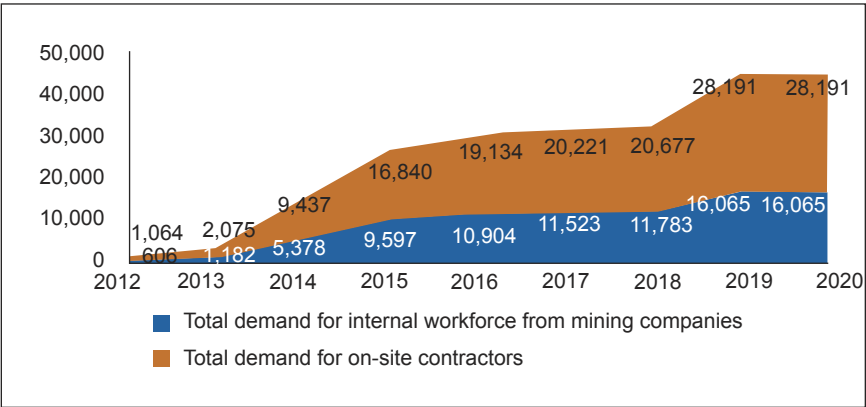
Figure 4 shows the projected increase in labor force from 2012 to 2020 estimated by Fundacion Chile. Total numbers are predicted to increase

Figure 4: Demand—A 53% increase in labor force (Fundacion Chile)



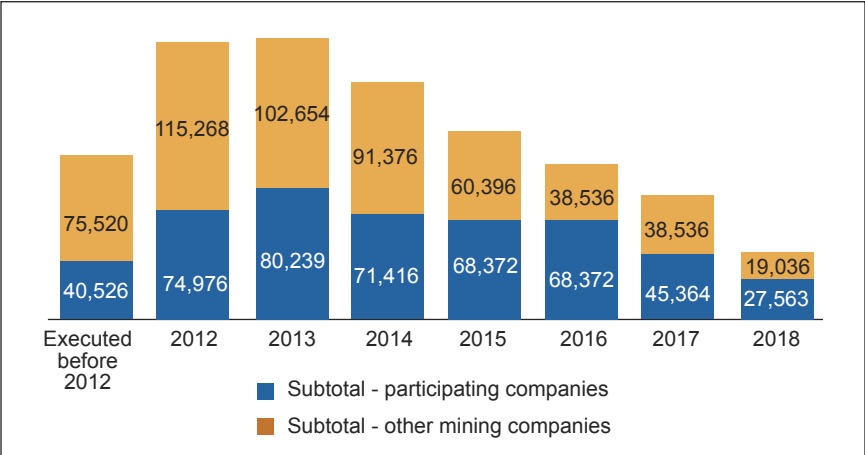
from 69.133 to 106.120 employees, which represents an increase of 53%. This demand for additional workers will have two critical periods of rapid increase: between 2013 and 2015, and between 2018 and 2019. Figure 5 shows the same numbers split into domestic workers and external contractors.

Figure 5: 53% Increase in demand—Domestic workers and contractors



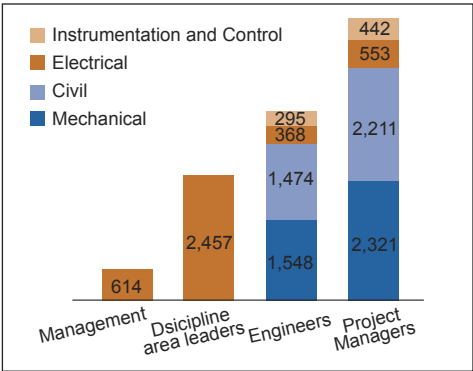
Note that these figures refer to the operational workforce, and do not include the human resources that will be required for the prior stage of the engineering and construction of the projects (brownfield and greenfield). The demand for technically skilled workers and professions for the stages of engineering and construction of the projects that have already received investments is estimated to be 190,000 people for the period 2012-2020.

Figure 6: Chilean Chamber of Construction estimates of manning requirements for engineering and construction



The peak in the demand for Engineering was with witnessed in 2012, with a figure of more than 12,000 professionals required for all of the Engineering specialties. This is further broken down into the sub-disciplines of Civil, Mechanical, Electrical and Instrument Engineering in Figure 7.

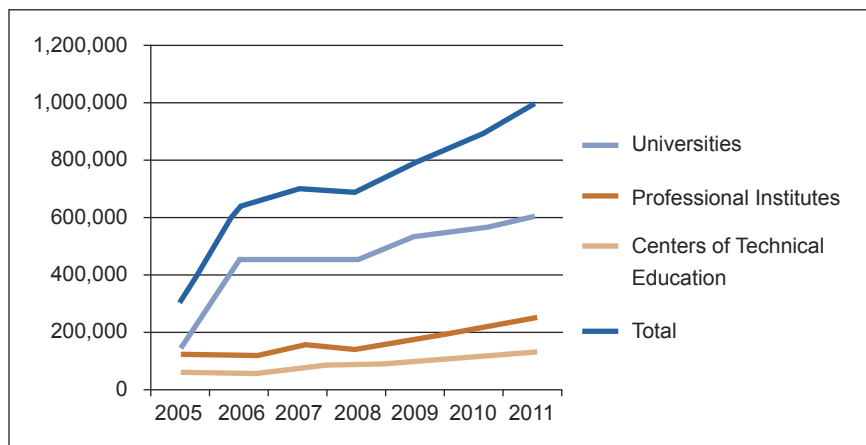
Figure 7: Projected demand for engineers



The Supply Side

The analysis of the formation of human resources at the tertiary level (where tertiary includes technical/vocational and academic degrees at the undergraduate level) for mining and related majors demonstrates that the programs are scarce with a bias towards theoretical contents and they are excessively long (40% longer than comparable programs in Australia, Canada, and in OECD countries). The completion rates are low, especially in the technical-vocational programs, which have a completion rate of only around 30%.

Figure 8: Increase in number of students at universities, professional institutes and centers of technical education



Finally, the rates of attraction of technically skilled labor and professionals towards careers in mining are insufficient to reduce the identified skill gaps. In the case of university professionals such as geologists, mining engineers and mineral processing engineers, 80-90% will work in mining. In the case of graduates of relevant majors, that cover skills also utilized by other industries, not only mining – such as maintenance workers, operators of fixed and mobile equipment, etc.– the mining sector appears to be unattractive for reasons such as shift schedules, geographical location of work sites, and other factors.

Table 2: The challenge of attracting graduates for the mining industry

Entrance Profile	Attraction Rate	
	Existing 2010	Required in Peak Year
Geology professional	80%	-
Mining extraction professional (Mining engineer)	90%	-
Processing professional	2.4%	5%
Maintenance professional	1.9%	14%
Mine extraction supervisor	2.0%	7%
Processing supervisor (Metallurgy/Chemistry)	2,4%	6%
Maintenance supervisor (Mech/Elec/Inst)	1.6%	19%
Plant process analyst	1,5%	2%
Extraction process analyst	1.5%	2%
Maintenance (Mech/Elec/Inst)	1.6%	55%
Mobile equipment operator (extraction background)*	-	
Fixed equipment operator*	-	

* The profile of operator does not have any relation with the education system and thus "attraction rate" does not apply.

Mining represents 2.5% of the country's workforce. If the shortfall is to be covered, an additional 33% of graduates need to be attracted into careers associated with mining. If we limit our requirements to the more prestigious institutions, we would need to attract an additional 60% of these graduates to meet the demand.

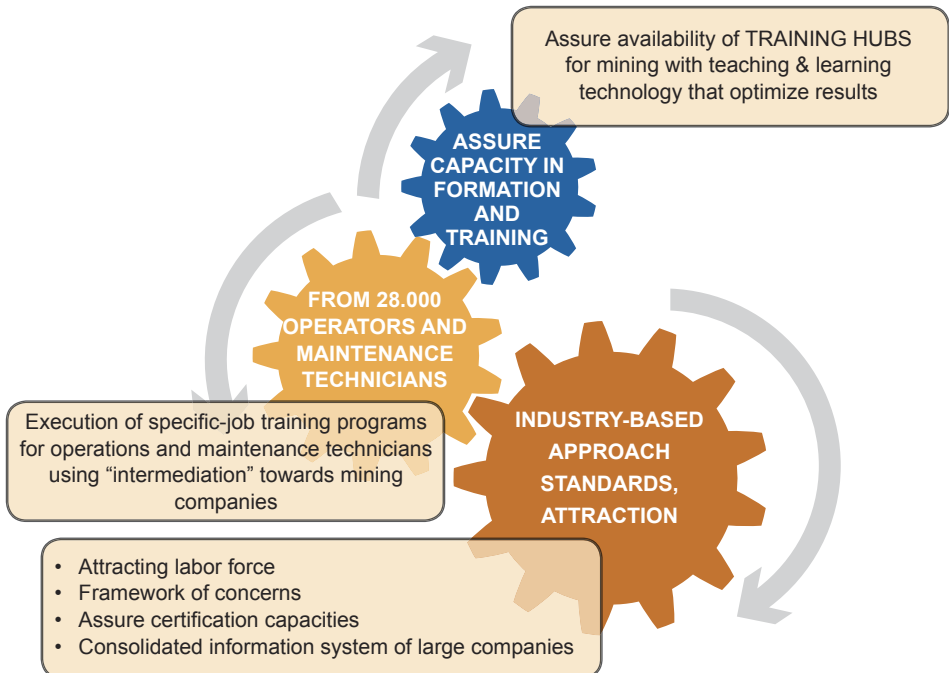
Proposed Solution

On the basis of the available diagnosis a strategy for the sector has been developed (Workforce Development and Skills Strategy) (Figure 9). The strategy has a short term component to cover the gap between 2011-2015 and a long term component focussed on installing capacity to assure quality and quantity. The overall objective is:

- (i) to define a Mining Qualifications Framework to identify the critical roles to be filled
- (ii) to start, with public resources, a “fast-track” training program to assure the availability of at least 28,000 operators (machinery operators, truck drivers, etc.) and maintenance specialists in 2015
- (iii) to promote the development of training hubs for mining that utilize educational technologies to train technical labor and professionals on the basis of world class standards
- (iv) to design and implement a campaign oriented toward the perception of mining as an attractive field of employment opportunity
- (v) to develop curricular innovations for tertiary education programs, on the basis of international benchmarks.

The Workforce Development and Skills Strategy will address some key issues that have been identified relating to attraction and education.

Figure 9: Proposed industrial strategy



Attraction – key issues

1. Identify specific segments of society that could be interested in mining (sex, age, regions, countries)
2. Reduce asymmetries of information that complicate offer-demand matching
3. Develop campaigns focused on attracting labor force: key messages (regional labor market, occasionally even global; highly technological, etc.)
4. Make the large cities close to mine sites more attractive.

Education – key issues

1. Industrial alignment of formation and training based on demands and focused on skills.
2. Install new capacities: training hubs, innovation in education, certification of educational professionals worldwide
3. Fast-track programs to accelerate formation of human capital and reduce gaps
4. Certification as guarantee of quality of results and as a sign of confidence towards the labor market
5. In University programs, curricular innovations (Australia, etc.), mining scholarships and other incentives.

Conclusion

Projected demand for human resources in the Chilean minerals sector indicates an acute scarcity in the period 2012 to 2020. The Workforce Development and Skills Strategy has been developed to address this situation and ensure that the supply of minerals industry professionals will increase to effectively meet the forecasted demand.

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Section 2

University Training

The Impact of the Bologna Model on Mineral Processing Education: Good, Bad or Indifferent

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Introduction

The Bologna Process started in 1999 with a declaration signed by ministers from mostly the European countries. Contrary to the belief, the Process was not an EU Commission or EU Parliament initiative, it had stemmed from the countries themselves who noted the competitiveness of European universities falling behind that of the United States of America (Charlier and Croché 2008). As of 2012, the Bologna Process has 47 participating countries (EHEA 2012).

The purpose of the Process was to create a more open and uniform system and to allow movement of students between countries. It was expected that this would lead to more employability of graduates and a more competitive Europe.

Alexandre et al. (2008) point to the reasons it as to why moving to the Anglo-Saxon three tier system of Bachelors, Masters and PhD would be an improvement over the analogous continental system: graduates would enter the work force earlier, less damage from a poor first choice and more flexible progression, etc.

The need for common quality standards was always envisaged as part of the process but this aspect still requires much work (Charlier and Croché 2008). There is currently considerable criticism of the variability of standards, for example the same unit taught in one country might be

taught in far fewer contact hours. The realities are however that this is a minor point compared with the way higher education is changing as modernization of both content and learning proceeds (Caddick 2008). The days of staff/student ratios of 5.9 (in Hungary in 1990) are long gone (Pusztai and Szabó 2008).

Progress with the Bologna Process

It is clear that much progress has happened (Huisman and Van der Wende 2004) and continues but with significant challenges in some countries, see for example the progress report on Germany by Wex (2007). What is clear however is that the benefits are starting to be seen (for example, see Particio 2010).

Most importantly, there is ample evidence that students prefer Bologna Process degrees with their greater flexibility and shorter times to reach a first qualification (Portela *et al.* 2009). Despite the student preference for the Bologna Process degrees at this stage in some countries (for example, Germany), the international mobility of students was slow to increase (Finger 2007) and still remains low in some countries (Schomburg and Teissler 2011).

What is clear to date is that many benefits have been realized from the Bologna Process and that students in particular prefer the greater flexibility. This is also the anecdotal evidence of this from outside of Europe, for example Australia, where Melbourne University has adopted a similar scheme and others (for example, University of West Australia) are now following. As in Latin America and Turkey, such major changes do not come without challenges that must be overcome (Vukasovic 2011).

Impact on Mineral Processing

A survey was undertaken amongst members of the International Mineral Processing Council's Commission on Education (IMPC 2012). A letter was circulated inviting comments on how education has changed, particularly in light of the Bologna Process. There were 20 responses ranging from

summary points to several pages. The responses are available at (Mitchell 2012) and represent an excellent summary of mineral processing education in a wide range of countries.

What is clear from the responses is as Finch (2003) also noted at the XXII IMPC, that “developed countries are in the midst of re-structuring education in minerals-related disciplines”. This was much in response to falling numbers for 10–15 years and the need to diversify courses to make them more attractive to students. Results in Canada and Australia reflect this trend. To this extent then, many countries that are not in fact part of the Bologna Process are indeed following the model or already had a system of bachelor, master and PhD degrees and hence notice no difference.

Similarly, countries that have changed to the Bologna model, for example, Sweden and Hungary, find little difference as they were already into five year courses and at one level have merely changed from a 2+3 to a 3+2 year system.

The recent strong growth in the industry has highlighted the shortage of mineral processing engineers and other professionals for the mining industry. Pallson (2006), who also responded to the survey, noted prophetically that in changing the mineral processing course to attract more students, the changes were effective (as in Canada), but that a major problem remains that the production and recruitment of graduates are out of sync.

One response to the out of sync demand for engineers for the industry has been the introduction of graduate training programs, either in the University as a master’s degree or in some cases, largely on the job, like the part time MBA courses that have been popular for many years. Certainly at Melbourne University one finds that some of the specialist master’s courses are heavily oversubscribed and have no difficulty in attracting full fee paying students.

From the survey we can then conclude that in many countries, the fall off in demand for places has driven universities to make more flexible offerings in much the same way as what is happening as a result of the Bologna

Process. Consequently, we can comment that while the roll out of the Bologna Process is seen in higher education circles as a very significant change, for mineral processing, falling student numbers over many years forced changes which just happen to fit broadly with the Bologna Process.

Conclusions

Overall, the Bologna Process has demonstrably changed higher education in many countries to allow for considerably more flexibility in course offerings.

The falling demand for places in mineral processing courses over many years however has driven changes that would have happened in any case. They are co-incident with what one is seeing in the Bologna Process in other disciplines.

Finally, while student interest has picked up in many countries, the current shortages seen in many countries (for example, Australia, China and Canada) remind us that the industry demand and the production of graduates have long been out of sync.

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Appendix

Selected comments from a range of countries

These comments reflect directions from the submissions but do not cover the depth and detail. The reader is referred to Mitchell (2012) for the wealth of detail available in the submissions.

Australia

- After years of falling numbers, demand an increase in number
- More flexible course offerings but not as comprehensive

Belgium

- Relatively few students
- Bologna simply changed a 2+3 into a 3+2 offering

Brazil

- Course structure set by State, comprehensive
- MERCOSUL area introducing its own “Bologna”
- Academic themes of some PhDs seen as limiting

Bulgaria

- Steady (small) number of graduates
- No particular changes noted

Canada

- More flexible offerings now in place in response to years of low numbers
- Still not clear if mineral processing is better in undergraduate or masters level
- French Canada with emphasis on engagement/experience with industry

China

- Pressing demand for graduates
- Particular technological demands in China (for example, grade and recovery)
- Further education needed to update knowledge of practitioners

Greece

- July 2011 directives will force changes, not clear as to extent
- Expect courses to shorten in line with Bologna

Hungary

- Mineral processing embedded in wider courses
- Implemented Bologna type system

India

- The industry not seen as attractive to students, hence low entrance levels
- Recent improvement in student numbers
- Overhaul of course curricula seen as needed

Norway

- Still on a five year masters, but this is similar to Bologna 3+2
- Student numbers again increasing

Poland

- Implemented Bologna system
- Significant numbers of students and wide ranging curricula

Russia

- Several universities teaching mineral processing
- Generally negative view of the Bologna Process but greater exposure of the students to industry seen as a benefit

Sweden

- Student numbers now increasing
- Still on a five year masters, but this is similar to Bologna 3+2

Turkey

- Mineral processing taught at masters level
- Strong demand for graduates

USA

- Traditional four year course still going strong
- Research funding harder to find so links between research and teaching more tenuous

Status and Prospect of Chinese Mineral Processing Education

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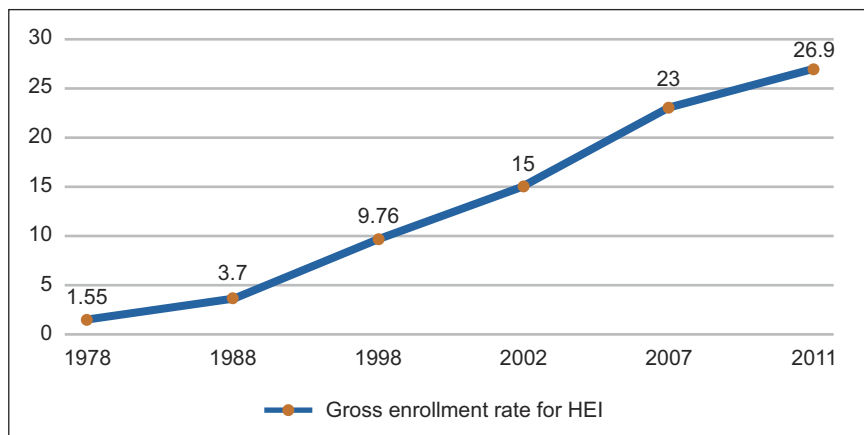
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Introduction

This paper gives an overview of the status of mineral processing education in China.

Figure 1: Percentage of 18-21 year old enrolled as undergraduate students



First, the overall position of higher education is presented, including the number of students, educators and higher education institutions. After briefly introducing the history of mineral processing in China, the number of students specifically in that discipline are shown, as well as aspects of the curriculum.

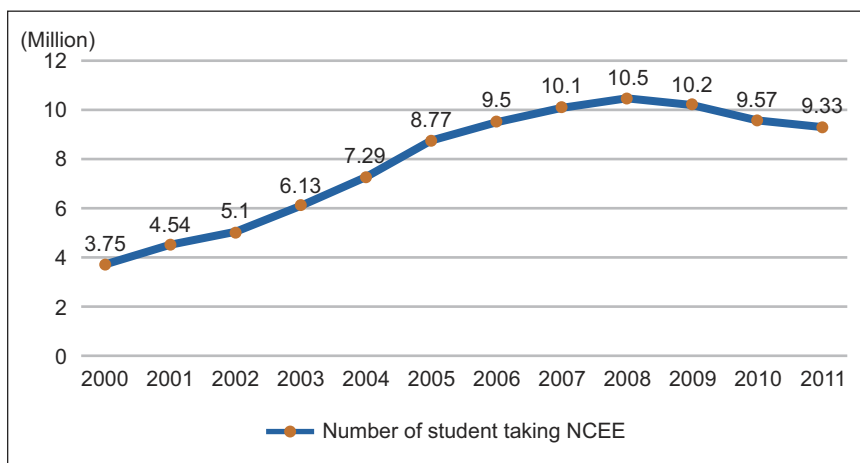
Finally, the vision for the future of education in China, as well as the possible hurdles are outlined.

The Overall Higher Education Position in China

Figure 1 shows the percentage of 18 to 21 year olds in China that enroll into Higher Education Institutions in China. It can be seen that this has steadily increased from below 15% upto 2002 to currently almost 30%. This translates to annual student numbers enrolling from 2.8 million in 2000 to 9.2 million in 2010. Chinese higher education has been transformed from a period of elite education to the current period of popularization.

In China, all students wishing to gain entrance to higher education must take and pass the National College Entry Exam (NCEE). Figure 2 shows the number of students that take the NCEE, and Figure 3 the percentage of students taking the NCEE that gain entry to higher education.

Figure 2: Number of students taking the NCEE



The continuous increase in enrollment before 2008 (figure 2) can be attributed to an increase in the number of students taking the NCEE, with a relatively steady percentage (~57%, figure 3) gaining admission to higher education institutions. Since 2008 there has been a decrease in the number of students taking the NCEE (from 10.5m in 2008 to 9.3m in 2011, figure 2) due to a decline in the annual Chinese birth rate (from 23.5m in 1990 to 15.9m in 2004) and a larger number of students choosing to study abroad. This has been offset by an increase in the NCEE admission rate up to 72% in 2011.

Figure 3: National college entry examination—percentage of students gaining admission to higher education

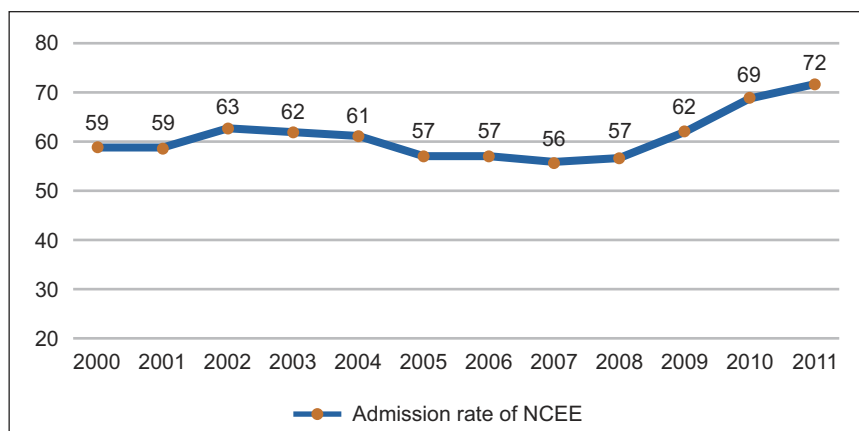


Table 1 summarizes the overall position of universities and colleges in China, and shows the significant changes that have taken place from 2000 to 2010. Some key trends are highlighted in figures 4 and 5.

Figure 4 shows that the number of colleges and universities has more than doubled, while the number of adult and private colleges has reduced significantly. It is as a result of large scale expansion of public U&C since 1999 which squeezes the room for private U&C development.

Table 1: The number of universities and colleges, faculty and full-time teachers; 2000 and 2010

Items		Number of U&C		Number of Faculty		Number of Full-time Teachers	
		2000	2010	2000	2010	2000	2010
College & Universities	Universities & Colleges	599	1112	757,944	1,548,043	370,838	935,493
	Junior Colleges	442	1246	162,099	603,201	86,640	404,098
	Total	1041	2358	920,043	2,151,244	457,478	1,339,59
Adult Colleges		772	365	179,652	77,108	93,402	45,887
Private Universities & Colleges		1282	836	56,501	38,140	29,515	17,794
Total		3095	3559	1,155,196	2,266,492	580,395	1,403,272

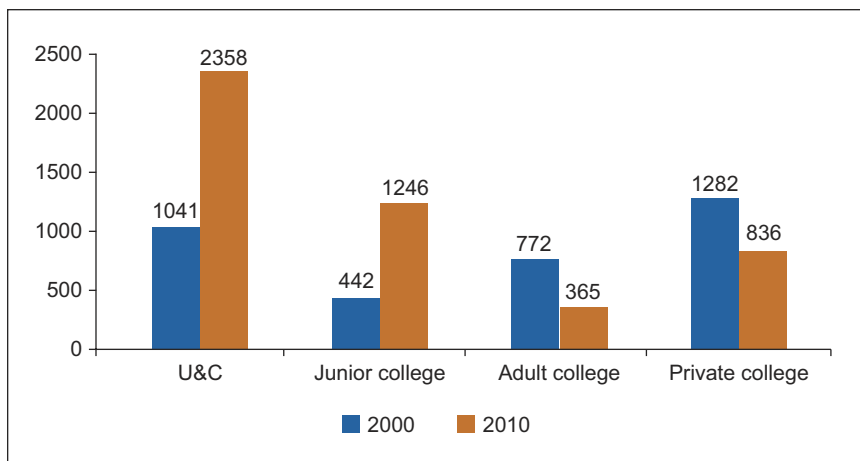
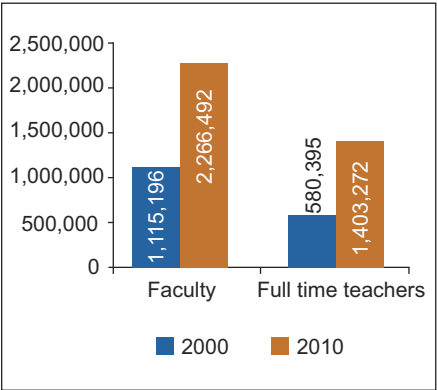
Figure 4: The number of higher education institutions of various types in China, 2000 and 2010

Figure 5 shows that there has been a commensurate and significant increase in teaching staff. From 2000 to 2010, the number of faculty and full-time teachers in colleges and universities has increased significantly.

Figure 5: The number of higher education institutions of various types in China, 2000 and 2010



The number of faculty has more than doubled, while the number of full time teachers has been increased by more than 820,000.

Table 2 summarizes the number of students in various types of higher education in China in 2000 and 2010. Some key trends are highlighted in figure 6.

The numbers of students in higher education in Chinese colleges and universities has expanded significantly in the last 10 years (Figure 6). In 2010, the total

Figure 6: Annual student recruitment, graduates and total enrollment in China, 2000 and 2010

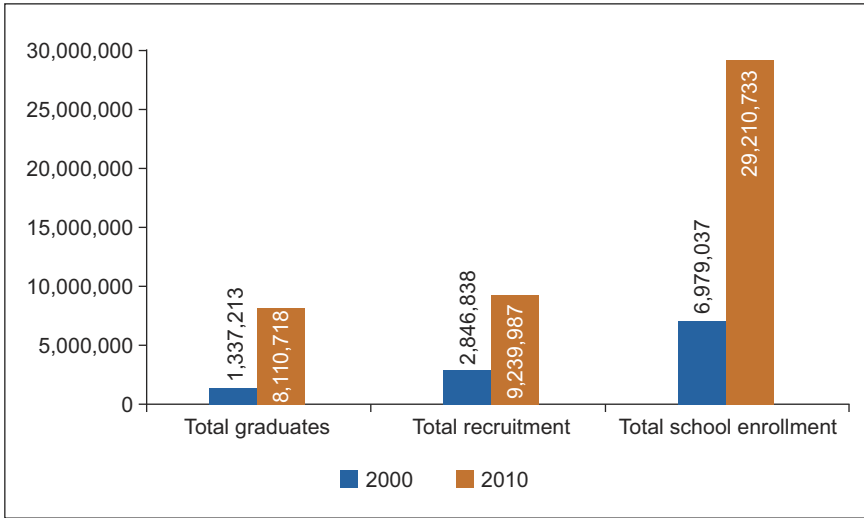


Table 2: The number of students in higher education in China in 2000 and 2010

Items	Graduates		Students recruited		School enrollments	
	2000	2010	2000	2010	2000	2010
Post Graduate Education						
	PhD	11,004	48,987	25,142	63,762	258,950
	Master	47,565	334,613	102,923	474,415	1,279,466
	Sub-total	58,569	383,600	128,065	538,177	1,538,416
Regular Undergraduate Education						
	Undergraduate	495,624	2,590,535	1,160,191	3,515,563	12,656,132
	Junior college	454,143	3,163,710	1,045,881	3,104,988	9,661,797
	Sub-total	949,767	5,754,245	2,206,072	6,617,551	22,317,929
Adult Undergraduate Education						
	Undergraduate	212,71	8,039,15	37,053	853,319	2,250,457
	Junior College	307,606	1,168,958	475,648	1,230,940	3,109,931
	Sub-total	328,877	1,972,873	512,701	2,084,259	5,360,388
	Total	1,337,213	8,110,718	2,846,838	9,239,987	29,216,733

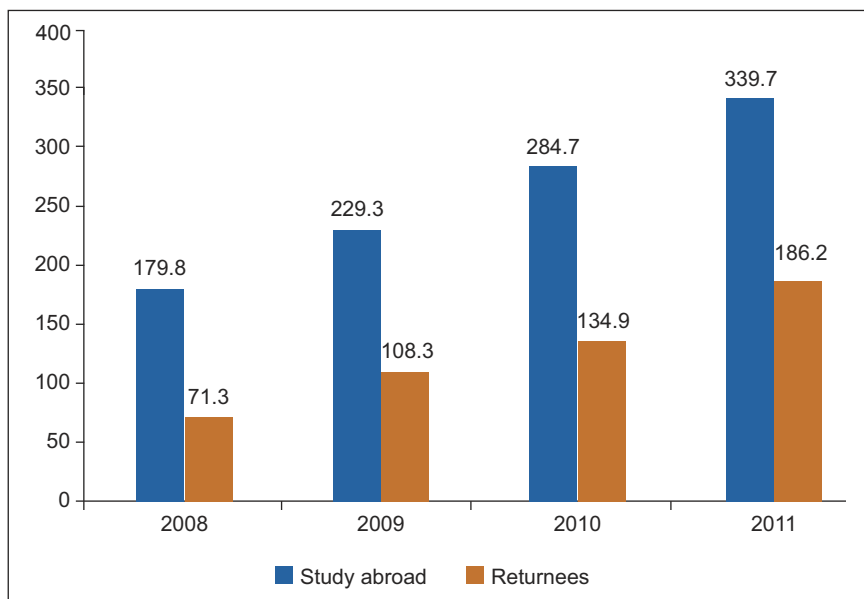
number of graduate was more than eight million, an increase of almost 65% since 2000. The annual recruitment was more than nine million students, yielding a total student population of almost 30 million in the year 2010.

Studying Abroad

From 1978 to 2011, 2.24 million Chinese went abroad to study. Since 1978, the total number of students returning has reached 818,400.

In 2011, the number of students leaving to study abroad was almost 340,000, with 186,000 returning in that year. By the end of 2011, the total number of students travelling abroad to study was 1.4 million, of which 1.11 million are studying or doing research in foreign countries. Figure 7 shows that the numbers are increasing significantly in the past few years.

Figure 7: The number of students studying abroad and returning to China



Chinese Mineral Processing Education

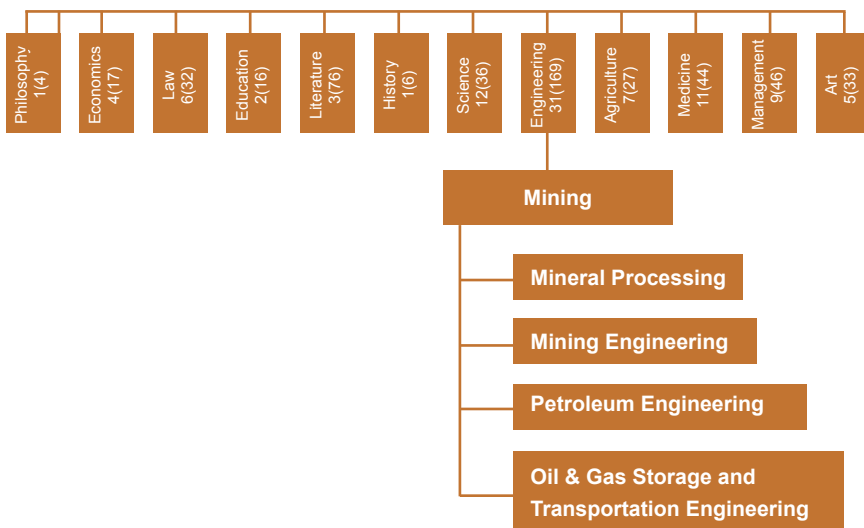
History

Mineral processing education in China started in the 1920s at Peiyang University. It was from here that such famous names as Professor Ni Tongchai, the expert in gravity separation, graduated in 1924; and where Professor Hu Xigeng, studied. Before 1949, there were many mineral processing majors available from PeiYang University, NEU, Guangxi University, the Jiaozhuo Institute of Technology, Tangshan University of Communications, amongst others.

After 1949, the first mineral processing subject was set up in Shengyang Institute of Technology, which merged with NEU in 1950. In 1952, the Central South Institute of Mining & Metallurgy (now CSU) and CUMT established the mineral processing discipline.

In the Chinese Higher Education System there are clearly defined Discipline Categories (figure 8), of which Mining is an Engineering discipline, with mineral processing as a distinct sub-discipline.

Figure 8: Discipline categories in the Chinese higher education system



Chinese Mineral Processing Education – Universities and Colleges

As a sub-discipline under mining engineering, mineral processing discipline is now established in 33 Chinese universities and colleges.

The mineral processing discipline recruits around 2600 undergraduate students, 540 postgraduate students and 100 PhD students each year. There are more than 400 teachers dedicated specifically to mineral processing higher education, including more than 100 professors. The number of students studying mineral processing in China is the highest in the world.

Chinese Mineral Processing Education – Graduate Employment

Every year around 3000 mineral processing graduates join the industry or one of the various education and research institutions. As shown in table 3, these graduates are highly sought-after, and since 2007 more than 95% of graduates find employment in this field.

The breakdown of destinations of graduates is as follows:

- Further education both in China and overseas (~20%)
- Related industry, i.e. Mining and Processing plant operations, equipment /reagent manufacturers (~60%)
- Universities and Colleges, Research and Engineering Institutes (~15%)
- Investment related companies (4%)
- Others (1%)

The average monthly salary for half year is approximately 3300 yuan (US\$ 530).

Table 3: Employment rate for mineral processing graduates

Year	2004	2005	2006	2007	2008	2009	2010	2011
Employment rate for mineral processing graduates	≥85%	≥90%	≥90%	≥95%	≥95%	≥95%	≥95%	≥95%

Chinese Mineral Processing Education – Problems and Challenges

Chinese mineral processing education suffers many similar challenges to those in other countries. Some of these include:

- The continued gap between the supply of qualified graduates and the demands of industry
- The attraction of mineral processing as an occupation attraction to graduates
- The flaws in the design of the teaching system; for example in the course design only 120 to 150 class hours are dedicated to covering the mineral processing text book
- Skill training imbalances between different colleges (teaching facilities and teachers)
- A low level of international orientation

The Future

The 12th Chinese “Five Year Plan” for Higher Education development has the following objectives:

- To have 33.5 million people receiving higher education in 2015;
- Number of students in U&C up to 30.8 million students, including 1.7 million post graduates;
- A gross higher education enrollment rate that increases from 26.5% in 2010 to 36% in 2015, and 40% in 2020;

- The number of people who received higher education will increase from 119.64 million in 2010 to 150 million in 2015.

Key factors that may affect achievement of these goals are the continued growth of the Chinese economy, as well as industrialization, and urbanization in coming years.

However, it appears that with China leading the number of graduates in mineral processing worldwide, we have a promising future for Chinese mineral processing education.

Data Sources

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Manpower Development and Training in Mineral Engineering in India

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Abstract

The paper reviews the development of Mineral Engineering education and training programs in India. It highlights the major academic programs and describes the evolution of the curriculum and design of courses in response to the changing requirements of India's mineral and coal industries.

An outline of the efforts needed to sustain and further improve the existing programs is also provided.

Introduction

Mineral Engineering education in India has experienced constant and consistent change over the last century in order to keep pace with change in the mineral industry's policies and requirements.

In its early years, the Indian mining and metallurgical industry was dealing with mineral ores that needed only marginal improvement in grade prior to marketing or other utilization.

As ore grades decreased and mineral upgrading became more important there was a need to design new academic programs at diploma, degree and postgraduate levels. Those programs and the skills they developed became the basis for curriculum and manpower development in India throughout the 20th century.

Phases of Manpower Development

1. Phase I

The first phase of manpower development was structured around basic mechanical operations, geology, and material handling.

This phase of development produced the pioneering academic program of MSc (Ore dressing) at Andhra University, Waltair (now Vishakapatnam) for graduates in Chemical Engineering and post-graduates in Geology. This innovative program produced a pool of human resource who went on to become scientists, engineers and academicians of national and international acclaim.

2. Phase II

This pioneering effort inspired some of the leading engineering/research institutions to conceive programs at post-graduate level. Many MTech/MS level programs were conceptualized and launched by the Indian Institute of Technology (IIT) at Kanpur, Bombay, Madras and Indian Institute of Science (IISc) at Bangalore.

The IIT programs were specialized courses designed to provide basic engineering and process knowledge relevant to the mineral processing discipline, and added to the existing skills of engineering graduates and science post-graduates. The students of these courses had the scope and opportunity to venture into doctoral programs in mineral processing and later move on to teaching and or research careers. Many made significant contributions to knowledge of grinding, froth flotation, coal preparation, pelletization, modelling and simulation.

The MSc Engineering program in Metallurgy at Indian Institute of Science (IISc) was novel in that it opened up a new area of study in mineral processing, namely bio-hydrometallurgy and bio-mineral processing. The course combined process metallurgy and biotechnology and resulted in tremendous growth and visibility in this area of study and research.

During the same period, two major developments took place, which raised the manpower development efforts to new heights. A three year Master of Applied Sciences (MASc) post-graduate course in mineral processing and a three year Bachelor of Science (BSc) degree course in mineral processing were created.

The MASc program was launched by Karnatak University in 1975 at the post-graduate Center, Nandihalli. Thus the first authentic course with mineral processing as the main subject became a reality in India. The location of the center in the midst of scenic beauty on the hills and near the mining town of Deogiri/Sandur gave the students first-hand exposure to the ambience and challenges of mining and mineral processing.

Students with a three year degree in Science – Physics, Chemistry, Maths and Geology – were admitted to the course. Besides basic sciences, skills in basic mechanical and electrical engineering, mineral processing unit operations, mining methods, material handling and metallurgy were imparted to the students.

The second and final year students were taken to mines and processing plants for practical training and industrial visits. Final year project dissertations required identification of a genuine plant problem and providing solutions to them. Students of this particular program now occupy most of the technical manpower positions in mineral and coal processing plants, research laboratories and academic institutions in India.

The BSc program in mineral processing at Garividi in Andhra Pradesh was a welcome initiative of M/S FACOR Limited. Students of this program graduated with knowledge of basic sciences, basic geology and material handling and mineral processing unit operations. Graduates of this program who obtained MTech or PhD qualifications have risen to the top positions in many leading industrial R&D establishments in India including TATA steel R&D, NMDC and SAIL and internationally, at Arcelor, Mittal and Roche Mining.

3. Phase III

The drive for the third phase in manpower development in Mineral Engineering was provided by the vision and dynamism of Professor GS Marwaha, the then Director of Indian School of Mines, Dhanbad.

3.1 Post Graduate Diploma in Mineral Engineering

A novel, 1½ year DISM in Mineral Engineering program was started in 1975. The program, besides admitting fresh graduates, also admitted practicing engineers from the industry as sponsored candidates.

The DISM program involved one year of course work and six months of project work. The fresh graduates were assigned projects of relevance to the coal and mineral industries while the sponsored candidates were encouraged to take authentic problems in their plants and carry out their project at the plant site itself. Such an arrangement provided real benefits to industry, with a steady stream of working engineers going through the program. The interaction between the fresh graduates and the sponsored practicing engineers resulted in a healthy exchange of theory and practice that benefited the students, department, institution and especially the industry. The outcomes of projects were practical and provided improvements in yield or recovery and grade of clean coal or mineral concentrate.

3.2 MTech (by Research) in Mineral Engineering

The second step was the introduction of another unique program – M.Tech (by Research) where working engineers can register for the program and pursue their studies without needing to relocate. The number of subjects was decided by the Indian School of Mines Department based on the work experience and the candidate's selected topic of research. This program also provided unique opportunities for interaction between the institute and industry.

3.3 BTech in Mineral Engineering

The third and most important step was the proposal of a project to Ministry of Mines, Government of India on “Manpower Training in Mineral Engineering”. After a series of evaluations of the proposal, inspection by the

Institute and feedback from the user industries, the project was approved for five years, with a grant-in-aid out of ₹ 429 lakhs (42.9 million).

The proposal envisaged a three-pronged approach towards manpower development and training.

- a) Four year BTech Program; for freshers in Mineral Engineering
- b) Three year BTech Program; Lateral entry to BSc graduates in Mineral Engineering and Diploma holders
- c) One year Advanced Diploma; for working BSc graduates in Mineral Engineering and Diploma holders

In 1984, the three programs became a reality and are still going strong.

The systemic approach to the development of curriculum encompassing mineral and coal beneficiation subjects, material handling, maintenance engineering and environmental and management aspects of plant operations, provided a source of well-rounded graduates to address the needs of industry.

The graduates and students of these programs have proved themselves in industries, universities and research establishments in India and abroad. The steady flow of research internships from the universities abroad including British Columbia, Utah, New South Wales, Queensland and the Camborne School of Mines, testify the quality of the students and the program. Other graduates of this program have been gainfully employed in the coal, ferrous, non-ferrous and industrial minerals industries.

Early efforts in manpower development attempted to add to existing engineering and science qualifications. This approach was found to be inadequate due to the increasing need for specialist skills, and was not supported by graduates of other disciplines such as chemical, mechanical or material engineering. Programs needed to be autonomous in order to be successful.

Recent Efforts in Manpower Development

The Council of Scientific and industrial Research (CSIR), a premier science and technology body under the GoI Ministry of Science and Technology

has embarked upon an initiative whereby laboratories are encouraged to offer academic and research programs to develop manpower in their domain areas, in order to cater to the manpower needs in the research laboratories and the user industries.

The CSIR laboratories – Institute of Minerals & Material Technology, Central Institute of Mining and Fuel Research have launched programs in mineral processing and Coal Preparation respectively, and a few more laboratories are contemplating similar initiatives.

Agenda and Action Plan

4. The agenda

Despite the many developments and improvements made in the past, Mineral engineering as a discipline and mineral engineering professionals do not enjoy the status and position that they deserve. Though there is an increasing awareness of the need for, and relevance and importance of the discipline, its status as an independent field of engineering is yet to be fully realized.

This is due to the continuous reluctance of the industry to raise the discipline from an auxiliary activity to an independent and integral activity in the overall mineral resource development. Mineral engineering professionals are placed under the mining, metallurgical, mechanical or chemical cadres of human resource which limits professional development. A few coal and mineral industries have realized this and created a cadre of coal preparation and mineral processing, but this needs to be more broadly implemented to have a significant effect.

The agenda for the next few decades should be to strengthen the existing manpower development efforts and to formulate strategies to enhance the position and prestige of the Mineral Engineering profession. This requires a well thought out action plan and implementation strategy.

5. The action plan

The recommended course of action should be developed with involvement of all the stakeholders who are in the profession of Mineral Engineering.

A few mechanisms are suggested:

- (i) Effective networking of all the institutions offering academic programs in Mineral Engineering.
- (ii) Encouraging interaction between the students of different institutions.
 - The institutions offering academic programs in Mineral Engineering should meet periodically to exchange information about developments in different sectors of the Indian mineral industry.
 - Regular student conventions (two-three per year) could be organized in mineral rich regions. This will provide an avenue for exchange of knowledge and practical experience for students.
 - A students' data base and group e-mail could be created for regular exchange of information.
- (iii) A strong collaborative approach to activities relevant to the industry by the faculties of these institutions.
- (iv) Developing linkages between industry and institutions on a regional basis, and transfer of knowledge, expertise and experience of specialist staff of institutions to the benefit of the industries.
- (v) Organized training programs and research programs to encourage interaction between students, faculty and industry.
 - This interaction would enable a regular, critical review by industry of curriculum to cater to the changing needs of the industries.
 - Industry-specific discussion, meetings and workshops at plant sites to inform plant operators and management of the latest technology developments and also provide a platform for the plant personnel to highlight their performance and present operational problems.
 - Regular meetings between academics, researchers and industry executives to formulate research programs that are relevant to the industries. This would build stronger relationships between researchers and practitioners.

Role of Professional Bodies (IIME)

Indian Institute of Mineral Engineers (IIME) could play a pivotal role in fulfilling this agenda and action plan, since its members are all stakeholders.

- a) Comprehensive goals should be set with immediate and long-term targets identified.
- b) A core team consisting of members from the academic, research and industrial establishments should be formed.
- c) Periodic review meetings need to be held for monitoring, evaluation and mid-course correction as required.

TOGETHER WE CAN, WE SHOULD AND WE WILL

Section 3

University-Industry Supported Training

Mineral Industry Education and Training Trends in North America: Challenges, Opportunities and a Framework for the Future

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Abstract

This paper discusses current workforce demand projections for mineral processing engineers and emerging trends in mineral processing education. Attempts are made to identify gaps that often result in a mismatch between skills taught and skills needed by the practicing engineer. Clear examples of this include a less than uniform training in chemical aspects of mineral processing, and an understanding of the statistical and experimental design tools necessary to tame the often large variation in operational parameters and plant data. The end goal is an educational system modernized to prepare mineral processing specialists for productive careers in the sustainable development of natural resources. A framework for revamping education based on an integrated modular approach is also presented.

Introduction

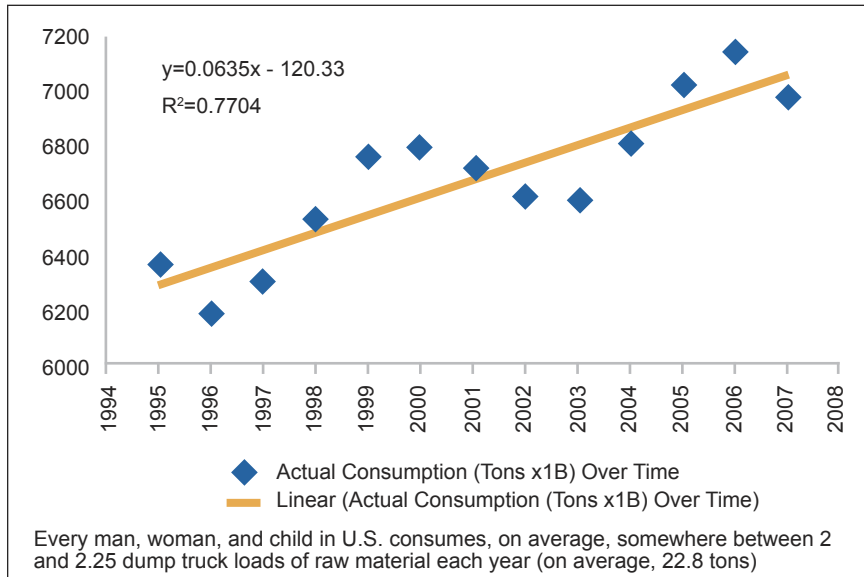
This paper highlights challenges and opportunities and a framework for the future for mineral processing training and trends in North America. The possible scenarios of educational systems for training mineral processing engineers for careers in sustainable development of natural resources have been discussed. The current status, gaps in skills required by the employers and the education systems, and how they can be met have also been presented in this paper. In preparing for this paper and for the presentation at the 2012 IMPC, in addition to authors' collective experience of several decades, opinions from a number of mining and mineral processing departments, program heads and companies in the USA, as well as from industry forums (Kral, 2006) were collected. The thoughts expressed in this paper are those of the authors and we have made an attempt to capture the spirit of those comments and opinions we received, which are not necessarily complete.

Role of Mineral and Coal Industry in the US Economy

The mining and mineral industry workforce¹ in the USA amounts to less than 0.25% of the total workforce, yet its value-added contributions are reported to be 13-14% of the roughly 14.5 trillion dollar US economy. According to US Energy Information Agency projections, the mining and minerals industry sector will continue to grow over the next decade requiring an additional skilled workforce. The consumption of minerals in the US (see Figure 1) and North America, and around the world, will continue to increase. In the US alone, every woman, man and child on the average consumes about 23 tons of natural resources and raw materials each year (Brandon, 2012). In other words, we need about 700 million dump truck loads of raw materials each year to sustain the current living standard. The population in the US and worldwide is increasing and the standard of living is on the

¹ Mine Safety and Health Administration definition of mining labor force: "To be included in the head count for a mine, an individual has to work in the benefaction process within the mine footprint. This includes contractors and mine employees; basically, anyone at risk from the benefaction process." (Brandon, 2012)

Figure 1: Change in U.S. consumption of minerals (x1B Tons) over time



Source: Brandon, 2012

rise in developing countries. As a result, more and more raw materials are going to be required. Under these circumstances, the importance of the mineral industry and coal industry cannot be overemphasized.

The US is more than 50% dependent on imports for a majority of its non-fuel mineral materials as noted by the US Geological Survey in the 2010 *Mineral Commodities Summary*. The competition for natural resources is going to be increasingly more acute and any trend towards mineral resource nationalism can be highly disruptive for critically needed minerals and metals. Recent example of changes in the rare earths supply coming from China are indicative of what could happen if similar practices are adopted by suppliers of other imported minerals. Given the importance of the mineral industry to the U.S. economy and its long term sustainability, the current situation where there is an insufficient number of qualified personnel creates a strategic difficulty for the U.S., which requires a well-trained workforce to power the mineral industry.

Demand for Mineral Industry Workforce in North America

Is the US ready to rejuvenate its mining industry to meet the domestic and global demand for strategic raw materials? In the next 10 to 15 years, will the US more readily embrace domestic mining? Our answer to these questions is cautiously affirmative. If so, will there be a readily available well-trained work force? The answer to this query is much less certain. Although the demand for mineral and coal processing engineers remains healthy, the number of schools and graduating engineers over the last several decades has shrunk considerably². Additionally, retiring faculty have not been replaced in a number of schools that still continue to train mineral processing engineers, except for those schools that are solely focused on programs closely tied to the mineral processing industry.

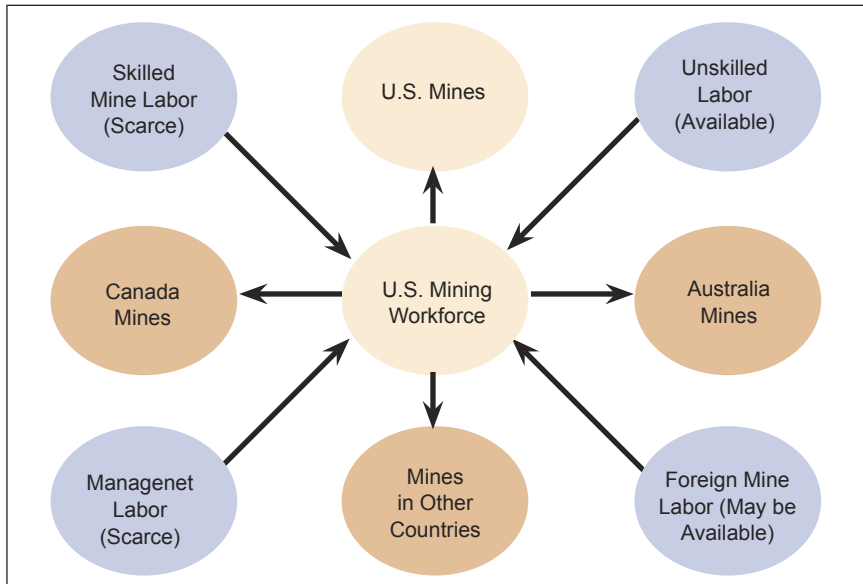
Some of the increased demand for minerals processing personnel is being met by attracting mineral processing engineers from other parts of the world to the USA for example from Canada, Australia, Latin America and South America. However, there also seems to be some competition from other countries to attract qualified professionals from the USA (see Figure 2).

Another short term solution has been to recruit engineers from other disciplines, such as chemical or even electrical engineering and train them to work in mineral processing plants. Often such strategies meet short term needs but these strategies are perceived to be not healthy in the long run because the depth and breadth of training of re-purposed engineers is quite often not as desirable as traditionally trained mineral processing engineers.

Updating and learning new skills is becoming the norm rather than the exception. For example skilled engineers or scientists may undergo training in order to keep pace with developments in technology and practices in the mining and mineral processing sector. This inevitably requires a

² In 2004 there were fewer than 15 minerals-related programs which accounted for only 87 engineers. In 1980 there were 22 programs that graduated 570 engineers [Kral, 2006].

Figure 2: Internal and external drivers: U.S. Mine Workforce



(Source: Brandon 2012)

philosophy of lifelong learning for both the individual and the organization. However, even if a strong demand exists, universities find it difficult to justify creating or expanding their mineral engineering education capacity due to budget constraints, inadequate industry support and the drain on resources by other high-profile disciplines such as bio-related fields. Thus it is very difficult for any university to make a business case for creating or reviving mineral processing programs even though there may be a strong demand for well qualified professionals, unless there is a strong mandate or support directly from government or industry.

Current Status of Mineral Processing Training

We recognize that university-industry cooperation has been on the rise for the last several decades; however, this cooperation targets research, but does not help education. Moreover governmental funding agencies promote research cooperation among universities, but for the most part

they do not promote educational cooperation to the same extent, at least in the United States. We believe that in Europe and other parts of the world the situation is different.

At the undergraduate level in the USA and Canada, the traditional four-year accredited programs remain the norm, in contrast to attempts in Europe and Australia where the Bologna model (European Commission, 2013) (a distributed education model) of higher education is being evaluated and implemented (McDivitt, 2002). Additionally there are no major attempts foreseen in North America to develop university consortia for teaching mineral processing courses where students rotate among participating universities to complete their degree programs³. This model has been successfully implemented by some European universities and alleviates the need for each university to maintain its own base of faculty expertise in all the required courses.

Alignment of skills demanded by the industry and the training provided by the universities varies among programs. Comments from the industry practitioners indicate that not all training programs are well aligned with what the industry is looking for. There is a broad range of subjects required to produce highly competent mineral processing engineers with a sufficient foundation to respond to the current and future challenges to support a sustainable industry. It requires marshaling a range of talents rarely found within a single department or university.

At the post graduate level, we have MS courses often without a thesis and PhD courses requiring a thesis. Not all schools train their mineral processing engineers with the same depth and breadth. A case in point is training in the chemical aspects⁴ of mineral processing, statistical design tools, etc. In some schools one particular aspect is emphasized more than others, but in general practitioners indicate a lack of in-depth knowledge of chemical aspects of mineral processing education. It seems that the

³ Accreditation by ABET in such a scenario might be difficult

⁴ Aquatic mineral chemistry, high temperature inorganic chemistry, mineral and reagent surface chemistry, reagent design, etc.

pace of change in academic educational focus can sometimes be out of step with the needs of traditional industries such as mineral processing. There needs to be a realignment of the education strategy with the needs of a modern, sustainable and economically healthy mineral processing industry in the U.S.

Famework for Future Training of Mineral Processing Engineers

One option is to establish a cooperative education program that is based in the university but includes industry in designing and delivery of the curriculum. Industrial partner involvement beyond the occasional review of sponsored program work would go a long way towards making the education more relevant and effective. Ways to improve industrial partner involvement include not only acting on industry advisory teams, providing scholarships and endowing faculty posts, but also participating as visiting professors and running student internship programs (McDivitt, 2002). Moreover this approach can involve a number of universities so that no single university has to have a comprehensive education program in the mineral processing area. Another option is to design a 5 (3 + 2) year MS degree program (post-high school) that requires one year apprenticeship or internship in a company. This idea of an integrated combination of classroom work with industrial experience is not new and should be reconsidered as a course of action to ameliorate the gaps in our current educational programs⁵. Such programs can provide valuable pathways for employees' future professional development. These programs also allow students to acquire business and/or finance skills or some other special skill that may supplement their education in minerals engineering.

⁵ C.W. Grate (1963): "Basically the cooperative plan is a supervised integration of classroom work with periods of actual industrial experience, designed to broaden the knowledge and experience of the participant. The employment constitutes an important phase of education of the student and must be well planned in progressing order of difficulty of assignments and increases in pay, and must parallel as closely as possible his progress through academic phases of his education."

Distance learning options that currently exist or are on the horizon provide additional opportunities for a wide variety of people already in the workforce. We should encourage and strengthen current content providers, and solicit new sources in order to ensure an adequate supply of well-trained mineral processing professionals. Another suggestion is that since there is a shortage of faculty looming over the horizon, we can fill that gap by recruiting professors of practice from industry. It not only strengthens practical aspects of the training, but can also provide valuable guidance and much needed help on the curriculum side. This can also reduce the gap between skills needed by the industry and those provided at the universities. Similarly, the industry can create a flexible environment wherein faculty members may spend meaningful time in the industry to educate and learn. A close collaboration between industry and university will also help in modernizing traditional curricula developed many decades ago.

Role of Professional Societies such as SME in Mineral Processing Workforce Training

Professional organizations such as the Society for Mining and Metallurgy Exploration, Inc. (SME) can act as a hub for knowledge repository and for providing accreditation assistance to programs, especially when that program is run among a number of cooperating universities. An example of this was the synergistic role of the Canadian Institute of Mining, Metallurgy and Petroleum (CIM) and EduMine⁶ in developing a certificate program in Mining Studies with the University of British Columbia (Scoble, 2005).

Acknowledgements

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⁶ The professional development division of InfoMine Inc.

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Skills Gap for the Minerals Industry - A Case for Zambia

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Abstract

The mining industry is known to be a potential major contributor to the industrial development of any economy. Large scale mining has been going on in Zambia for the last 100 years. The impact of mining in Zambia has been to create a development corridor along the line of rail to the Copperbelt Province, where hitherto, mining was concentrated, and then to develop a large consolidated high density economic zone covering an area of about 72 km by 60km. This area is home to a number of very large integrated copper/cobalt mining complexes. The mining zone has expanded to the Northwestern Province in the last 10 years, where the largest copper mine in Africa now exists, having produced about 300 000 tonnes of copper in 2011. The total output of the Zambian mining industry is now about 820,000 tonnes per annum with projections of reaching 1.5 million by 2015, due to new Greenfield investments expected to come online by then. These new mining industry developments have come on the back of strong and sustained high base metal prices, in the last 10 years or so, due to demand mainly from China and India. This new lease of life has increased the contribution of the sector to the national treasury.

The mining industry in Zambia has undergone a very important ownership restructuring with the sale of the previously Government owned parastatal, Zambia Consolidated Copper Mines (ZCCM) which dominated the sector, to allow for private sector participation. The privatization process lasted from about 1995 to about 2002.

The recent growth of the mining sector has unfortunately not been matched by an adequate supply of skilled manpower for various reasons. These include:

- (i) A lack of strong in-house training strategies by the new mine owners;
- (ii) Decrease in industry support to the training institutions;
- (iii) The demise of and restructuring of ZCCM which has consequently limited the Government human resources planning tools for the mining sector;
- (iv) The cyclic nature for the fortunes of the sector has lead to fluctuating interest of student recruitment into training institutions;
- (v) Limitations, both staff and equipment, in the training institutions; and
- (vi) A re-structuring of the training institutions.

This paper examines the current status, and student output from tertiary training institutions for the mining sector in Zambia. This is then compared to the skilled labor demands of the sector. The various cause and effect issues are considered and a proposal on how this skills gap could be addressed sustainably is proposed.

Background

Zambia is well endowed with mineral resources, particularly with copper. It is in fact estimated that Zambia hosts about 3.5% of the worlds copper reserves as shown in Table 1.

Table 1: Estimates of world copper reserves by country shares (%) reserves between 1995 and 2008

Country	1995	2000	2005	2008
Chile	26.7	24.6	38.3	36
Peru	3.9	6.2	6.4	12
United States	14.8	13.8	7.4	7.0
China	1.3	5.7	6.7	6.3
Poland	5.9	5.5	5.1	4.8
Australia	3.8	3.5	4.6	4.3
Mexico	4.4	4.2	4.3	4.0

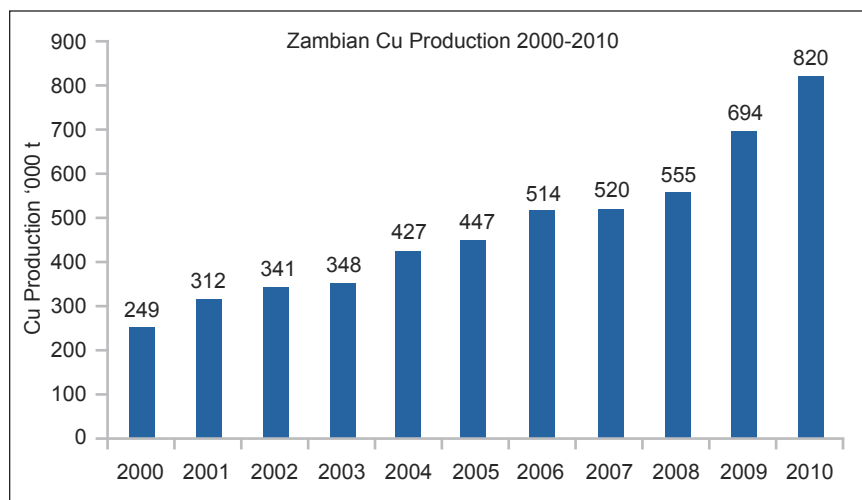
Country	1995	2000	2005	2008
Indonesia	2.5	3.8	4.0	3.8
Zambia	5.6	5.2	3.7	3.5
Russia	4.9	4.6	3.2	3.0
Kazakhstan	3.3	3.1	2.1	2.2
Canada	3.8	3.5	2.1	2.0
Others	19.2	16.9	11.7	11.0
World Total	100	100	100	100

Source: *Role of copper in the Chile and Zambian Economies* (Global Development Network Series, June 2011).

The Zambian mining industry has enjoyed a resurgence in the last 10 years due to sustained demand for base metals (copper) mainly from China and India. This demand has seen a steady rise in the world price and a concomitant increase in output from the mining industry in Zambia (Figures 1, 2 and Table 1).

Figure 1: Copper prices between January 1998 and October 2011
(After InfoMine.com)



Figure 2: Copper production in Zambia between 2000 and 2010

Source: US Geological Survey Minerals Yearbooks, 2007 and 2010

In line with these changes, the production capacity of the Zambian mining industry has increased to its current levels, as illustrated in Tables 2 and 3.

Table 2: Zambian copper mines operations—capacity (1.1 million mt)

Mine	Process	2007 Capacity (Kt/y Cu)	2011 Capacity (Kt/y Cu)
Baluba	Concentrates		25
Chambishi	Concentrates SX- EW		28 8
Chibuluma South	Concentrates		18
Kansanshi	Concentrates SX-EW	164*	160 90
Konkola	Concentrates		90
Lumwana	Concentrates		160
Mufulira Mufulira and Nkana	Concentrates SX-EW	210**	120 100
Nampundwe	Concentrates		1
Nchanga Nchanga TLP	Concentrates SX-EW	316***	70 100

Mine	Process	2007 Capacity (Kt/y Cu)	2011 Capacity (Kt/y Cu)
Nkana Slag Dumps/ Chambishi Cobalt Plant	SX-EW		25
Nkana South and Central Orebodies	Concentrates		120
Grand Total		690	1 115

Source: International Copper Study Group, Paper No 2, 2007, and 39th Regular Meeting, April 2012

*First Quantum (Kansanshi), ** Mopani Copper Mines Combined assets, *** Konkola Copper Mines combined assets

Table 3: Zambian copper mines operating smelters and refineries

Smelter	Process	2007 Capacity (Kt/y Cu)	2011 Capacity (Kt/y Cu)
Nchanga	Concentrates		250
Mufulira	Concentrates	180	200
Chambishi	Concentrates		150
Nkana Cobalt Plant	Concentrates	20	20
Nkana Smelter	Concentrates	150	Closed
Grand Total		350	620
Refinery	Process		2011 Capacity (Kt/y Cu)
Nkana (Kitwe)	Electrolytic	180	300
Mufulira	Electrolytic	265	265
Nchanga TLP	Electrowining	100	100
Mufulira and Nkana (Combined)	Electrowining		100
Kansanshi	Electrowining	80	90
Nkana slag Dumps	Electrowining		25
Chambishi (SX-EW)	Electrowining		8
Sable Zinc	Electrowining		5
Grand Total		625	893

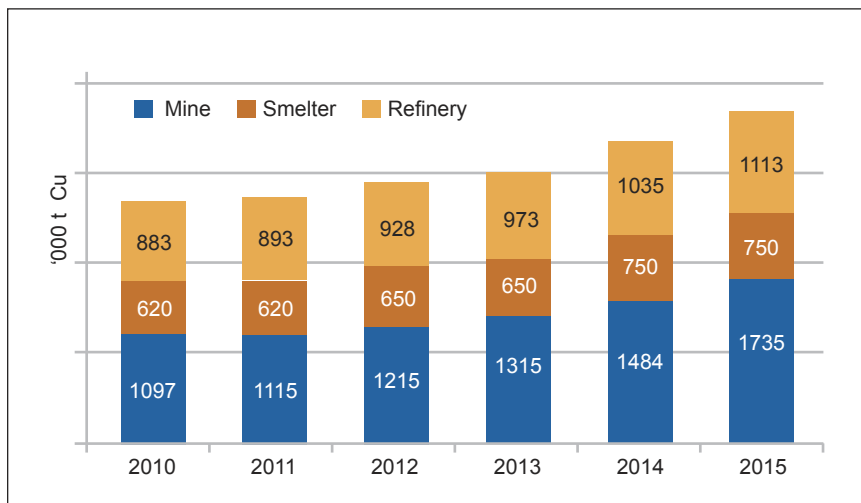
Source: International Copper Study Group, Paper No 2, 2007, and 39th Regular Meeting, April 2012

The current installed, and projected capacity of the Zambian mining industry is given in Figure 3. The figure shows that the total installed capacity is projected to increase by about 30% between 2012 and 2015 (International Copper Study Group, 39th Regular Meeting, April 2012). This is a very significant increase by any standards, but it obviously assumes continued world base metal (copper) demand over the period and beyond.

The likely sources of this increase in Zambian mining production capacity includes a new shaft being sunk at Nkana mine owned by Mopani Copper Mines aimed at accessing a 115 million tonnes of copper ore by 2018. This will also extend the mining operations life by 25 years, expansion of the Nkana Cobalt plant from 2,800 tpa to 3,500 tpa cobalt by 2020 and a projected expansion of the Barrick Gold owned Lumwana mine from 24 to 45 million tonnes per annum. Lumwana is also looking at uranium processing to produce 2 million pounds uranium oxide per year over a six to seven year period. Lumwana has a 358 million tonne at 0.76% Cu indicated resource, and with a 564 million tonne at 0.63% Cu inferred resource (International Mining, 2011, Country Report-Zambia). The Konkola North Project jointly owned by Vale and Rainbow Minerals is currently developing a mine that has so far defined a 300 million tonne resource at 2.57% total Cu with a life of 28 years and is expected to reach full production in 2015. First Quantum Minerals intends to bring Trident Mine on-line in 2014 with an initial copper output of 150 000 tonnes of contained copper with a possible increase to 300 000 tonnes per annum at a later stage. Further, additional expansion production works continue with existing operations including by such companies as Konkola Copper Mines.

In support of these production expansions, the U.S. Geological Survey observes that Zambia has reserves of 19 million metric tonnes of contained copper, as well as a reserve base of 35 million metric tonnes of contained copper. As such, it has been estimated that, even in the absence of new discoveries, Zambia has sufficient reserves for at least

Figure 3: Current and projected mining, smelting and refinery capacity in Zambia (2012- 2015)



Source: International Copper Study Group, 39th Regular Meeting, April 2012

another 60 years of production at current rates (International Copper Study Group, Paper No 2, 2007).

Current Labor Status

On the back of the increase in copper production, data on direct employment in the mining industry submitted to the Zambian Government through the Ministry of Mines Energy and Water Development, has shown a steady increase, going from about 28 000 persons in 2000 to about 59 000 persons in 2011, as illustrated below in Table 4, and Figure 4. Much as the general trend is upwards over the whole period, the data shows the vulnerability of the employment levels in the mining sector to fluctuation in world prices, for example, the -29% decrease experienced in 2009 was as a result of a dip in world copper prices (Figure 1), resulting from the onset of a world recession.

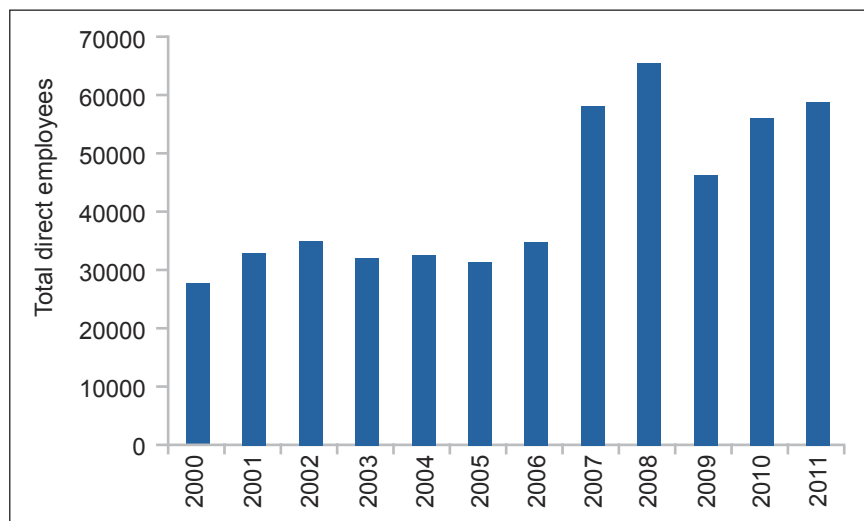
Table 4: Direct permanent employment levels in the Zambian mining industry

(2000 and 2011)

No	Year	Number of Employees	% Change (year on year)
1	2000	28 050	-
2	2001	33 111	+18
3	2002	35 138	+6
4	2003	32 255	-8
5	2004	32 503	+1
6	2005	31 455	-3
7	2006	34 948	+11
8	2007	57 913	+66
9	2008	65 311	+13
10	2009	46 246	-29
11	2010	56 054	+21
12	2011	58 672	+5

Source: Ministry of Mines, Energy and water Development, Statutory Data, 2012

Figure 4: Total number of direct employees in the Zambian mining industry (2000 - 2011)



Source: Ministry of Mines, 2012

Table 4 is a consolidated list of all permanent employees within the mining sector as reported to the Mines Ministry between 2000 and 2011.

Status of Skilled Labor

It is informative to consider a recent Mines Safety Department report (Hamukoma, 2011), that discusses the current status of the demand and supply of skilled labor in the Zambian mining sector. The objective of the paper was to determine the mismatch between the demand for and the supply of skilled manpower in Zambia's mining industry and estimate the extent of such a skills gap. The report is based on responses to a survey from 12 mining and associated companies operating in Zambia namely: Lumwana Copper Mine, Kansanshi Copper Mine, Konkola Copper Mines, Chibuluma Mine, Mopani Copper Mines, Luanshya Copper Mines, Albidon Mine, Copperbelt Energy Corporation, Sandvik, Ndola lime, ZAMEFA and a Lumwana based contractor.

The 12 companies that responded to the survey had a total of 32 515 workers out of whom 9,978 (31%) *were skilled workers, including 1,636 (5%) graduates, 1,427 (4%) technologists, 970 (3%) technicians and 5,943 (18%) crafts persons (Table 5).*

Table 5: Distribution of skilled employees by skill level and discipline

	Graduate	Technologist	Technician	Craft Certificate	Total
Geology	62	4	2	-	68
Mining	210	146	237	802	1,395
Metallurgy	394	103	25	124	646
Engineering	396	241	493	4,273	5,403
Production Management	5	6	20	120	151
Finance including IT	126	96	57	30	309
Human Resources	153	151	6	88	398

	Graduate	Technologist	Technician	Craft Certificate	Total
Medical	88	479	33	203	803
Commercial/ Supply	101	107	60	87	355
Safety Health and Environment	38	47	9	55	149
Risk mgt/ Security	11	15	8	82	116
Administration/ Legal	54	32	20	79	185
Total	1,638	1,427	970	5,943	9,978

Source: Hamukoma, 2011

Some 300 workers were expatriates mostly employed in technical and managerial positions, while approximately one-fourth of all workers in the workforce of the surveyed companies were indirectly hired from manpower agencies. In the coming five years, the report estimated that around 11,000 skilled workers would be needed to maintain the current level of production. This means that for example, in 2012, an additional 400 skilled workers may be needed for the surveyed companies. However, the reality is that the demand for skilled manpower maybe higher due to the increase in new mines expected to come online in the near future.

The eight mining companies that responded to the survey contributed 77.3% of the total revenue collected by the Zambia Revenue Authority in 2009 (ZEITI Reconciliation report, 2012). However, their 32,515 employees represented only 58% of the total labor strength reported to the Mines Ministry in 2010 (56,054). Assuming that these eight mining companies are representative of the labor skills distribution of Zambian mining companies then it is possible to project the distribution of the total Zambian mining sector skilled labor force to be as given in Table 6.

Table 6: Projected distribution of skilled employees by skill level and discipline based on 2011 mining houses labor strength

	Graduate	Technologist	Technician	Craft Certificate	Total
Geology	107	7	3	-	117
Mining	362	252	409	1383	2405
Metallurgy	679	178	43	214	1114
Engineering	683	415	850	7367	9315
Production Management	9	10	34	207	260
Finance including IT	217	166	98	52	533
Human Resources	264	260	10	152	686
Medical	152	826	57	350	1384
Commercial/ Supply	174	184	103	150	612
Safety Health and Environment	66	81	15	95	257
Risk mgt/ Security	19	26	14	141	200
Administration/ Legal	93	55	34	136	319
Total	2825	2460	1671	10247	17202

Recruitment in the Mining Sector

The Mines Safety Department Report observes that the average number of graduates recruited annually by the surveyed companies in the period 2001-2010 in Mining was 31, Metallurgy 34 (total of 65) and Engineering was 38. The other skilled levels at Technologist, Technician and Craft level were as indicated in Table 7.

Table 7: Annual recruitment by skill level and function, 2001-10

Skill Level	Mining	Metallurgy	Engineering	Other Disciplines	Total
Graduate	31	34	38	59	162
Technologist	16	5	17	93*	131
Technician	38	1	37	14	90
Craft Certificate	103	12	312	53	480

**Higher than average figure is due to high attrition rates for Registered Nurses*

Source: Hamukoma, 2011.

Whilst it is recognized that the surveyed companies reflected in Table 7 represent only 58% of the total reported labor force in the mining sector in 2010, the recruitment rate is accordingly expected to be an understate of the total required. Despite this fact, the data is indicative of the new graduate labor demand by the mining industry over the period.

Graduate Training

The mining graduate training programs in Zambia are provided by the University of Zambia (UNZA), and the Copperbelt University (CBU). The University of Zambia is the oldest public university in the country, established in 1966. It currently has nine schools. The School of Mines was established in 1973, which has three departments, namely, geology, mining and metallurgy and mineral processing. Between 1973 and 2010, the UNZA School of Mines produced a total of 953 graduates (Sikazwe, 2010).

The Copperbelt University was established in 1987 as an offshoot of the UNZA, with the School of Business (formerly the School of Business and Industrial Studies), and the School of the Built Environment (formerly School of Environmental Studies) and the School of Technology where mining related courses are taught. It started with a total student population of 514. In 2008, the student body had risen to 5,155 in six schools.

These two universities are the primary source of local graduates that serve the Zambian mining industry. Table 8 shows the number of students who have graduated from these two universities between 2002 and 2009.

Table 8: Distribution of graduating students by skill level (2002-2009)

Year of Graduation	Degree					Grand Total
	Mines UNZA	Mining/ Met CBU	Sub total	Eng UNZA	Eng CBU	
2002	37	28	65	92	78	235
2003	34	18	52	88	92	232
2004	31	27	58	62	92	212
2005	26	27	53	60	92	205
2006	20	62	82	65	94	241
2007	18	64	82	77	131	290
2008	22	59	81	72	99	252
2009	44	76	120	78	186	384
Total	232	361	593	594	864	2051

Source: Hamukoma, 2011

Figure 5 given on the following page compares the graduate supply and demand status in the Zambian mining industry, and reflects that on the whole there is a shortage of supply of skilled labor. Unless interventions are made, this shortage is expected to get worse due to the increase in the number of new mines projected to come on line between now and 2015. These new operations include Trident, the First Quantum Project, the new Kansanshi Smelter and Acid Plant, Konkola North Mine by Vale and Rainbow Minerals.

It is interesting to note that student enrollment appears to be strongly linked to the attractiveness of possible employment opportunities in the mining industry as clearly reflected by the variation of student enrollment

Figure 5: Plot of mining school graduates and estimated annual recruitment by the mining industry

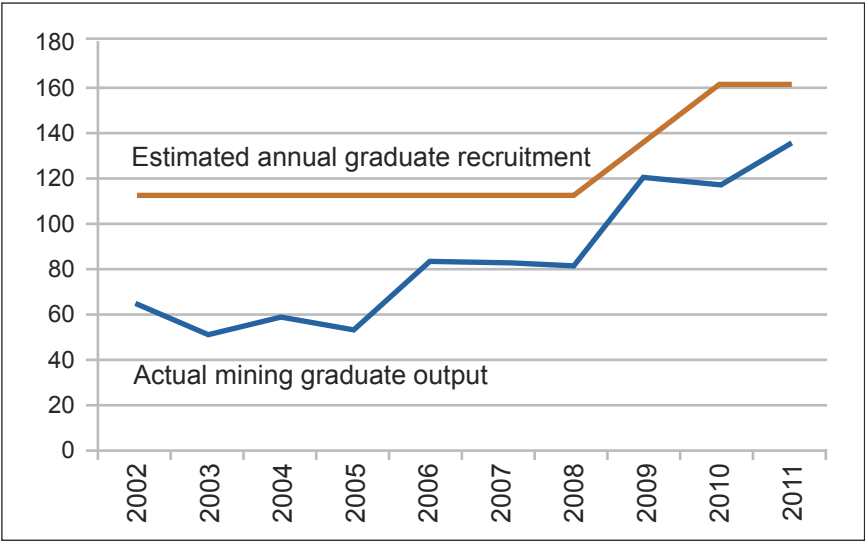


Figure 6: University of Zambia School of Mines student enrollment, 2003-2011

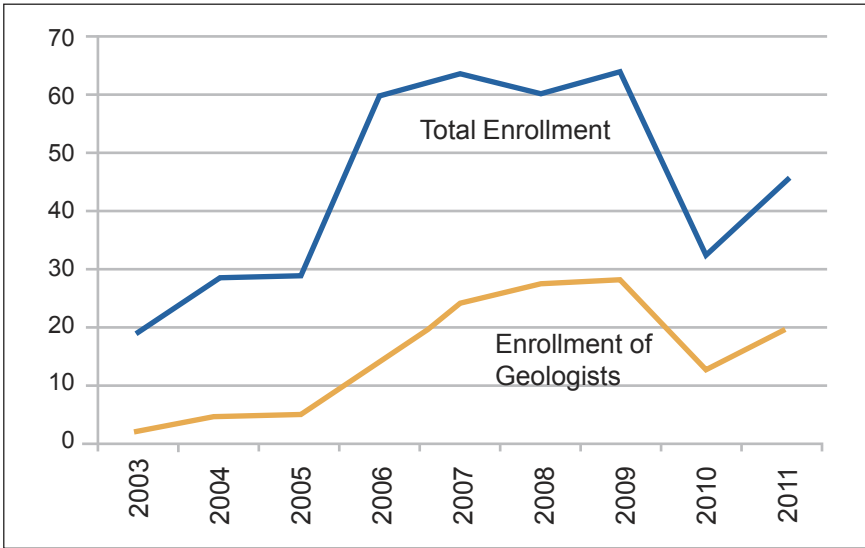
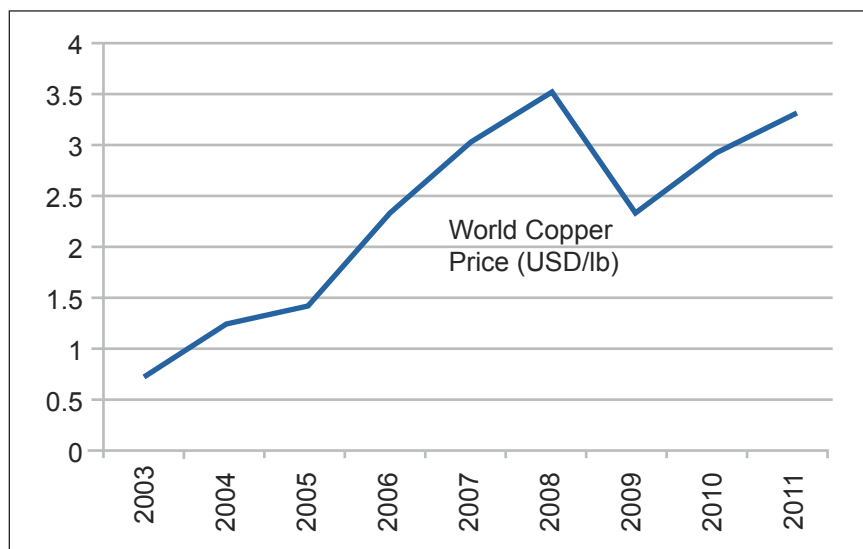


Figure 7: World copper prices (USD/lb) between 2003-2011



within the University of Zambia, School of mines between the period of 2003 and 2011 (Figures 6 and 7), compared to the world copper prices. It is seen that in 2010 the total enrollment went down following the dip in the copper prices the previous year, 2009.

Quality of Graduates

There are a number of challenges faced by the two Zambian universities, and these adversely affect the quality of graduates. These challenges include limited interaction at high level between the training institutions and industry. Prior to the privatization of the Zambia Consolidated Copper Mines, there was a centralized human resource planning unit within the company that coordinated labor demands with the training institutions and ensured long term labor planning and training. However, this does not exist anymore as the human resource planning units at the new private mine owners operate independently and do not relate in any meaningful way to training institutions. Training institutions do not have any idea of the human resource requirements of the industry both in the short and long term,

and therefore the training of mining graduates is not effectively related to the requirements of the industry. There are limited research opportunities presented to the universities as some of the new mine owners prefer to use universities from their home countries. This limited interaction has also resulted in inadequate research facilities at the two universities due to lack of reinvestment. Finally, there has also been a significant drop in student sponsorships, with the attendant reduction in financial support for the students and the universities. This has contributed to the diminished interest by students to take up careers in the mining sector.

The Zambia Chamber of Mines Council meeting of November 1, 2002, took note of the low interaction between the mining industry and training institutions providing human resources. In anticipation of increased mining activities the meeting resolved to pursue the establishment of the Zambia Mining Sector Education Trust (ZAMSET) to facilitate the provision of skilled manpower to the Zambia Mining Sector and to provide liaison with institutions dealing with training skilled manpower (Hamukoma, 2011). Such a body was expected to facilitate long term strategic human resource requirement planning and provide direction to human resource training and retraining. Further, it would support training institutions with research facilities, thereby improving the quality of graduates. The universities look forward to the realization of this Trust.

Conclusion

The future of the mining sector in Zambia is very bright given the substantial world class copper deposits in Zambia. However, the mining industry in Zambia must deliberately and effectively engage the local training institutions in order to address the mining sector's human resource requirements. The Zambia Government can help by creating a fiscal arrangement that will encourage research, such as providing for all money that a mining company invests in research becoming tax deductible. This will drive research forward that will benefit the nation. Without such an intervention, mining like other extractive industries is notorious for failing to horizontally engage in local economies, and employing very limited numbers of people compared to the capital investment due to mechanization.

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Minerals Industry Engagement in Metallurgical Education in Australia

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Abstract

The Minerals Tertiary Education Council (MTEC), over the past decade, has worked closely with Australian higher education partners in metallurgical education to build capacity in this discipline to deliver high quality graduates for the Australian minerals-industry. This paper explores the benefits of industry engagement through a national innovative collaboration, the Metallurgical Education Partnership (MEP), and specifically the final year Process Design Project (PDP), over the four year period from 2008-2011. Some of the benefits discussed in this paper include outcomes of the student experience during an industry-intensive workshop, collaboration between higher education providers and aligning graduate attributes to meet industry requirements.

Keywords: Metallurgical Education Partnership (MEP), higher education, collaboration, industry engagement

Introduction

The Minerals Council of Australia (MCA) represents Australia's exploration, mining and minerals processing industry, nationally and internationally, in its contribution to sustainable economic and social development. MCA member companies produce more than 85% of Australia's annual mineral output, contributing some \$154 billion in 2010-11 (52%) of Australia's total exports (Minerals Council of Australia, 2012).

Minerals-related higher education courses (mining engineering, metallurgy and earth sciences) have been chronically underfunded in Australia, requiring the industry to subsidize these courses heavily. The Minerals Tertiary Education Council (MTEC) – the higher education arm of the Minerals Council of Australia (MCA) – engages with the tertiary education sector in Australia to help ensure the sustainability of this sector and so influence the supply of suitably educated and trained professionals for the minerals industry.

Since 1999, over \$25 million of industry funds have been allocated to assist MTEC in the development of industry-focused courses and in the employment of academic staff and educational specialists (Minerals Tertiary Education Council, 2012). MTEC fosters the partnership between industry, government and academia to promote and provide opportunities in the tertiary education arena by working with a network of selected university partners. These partners are dedicated to achieving world-class education by cooperating in the development and delivery of undergraduate and postgraduate programs in the specialist disciplines of mining engineering, metallurgy and earth science (specifically minerals geoscience). MTEC works with 15 partner universities across Australia – four in mining engineering, three in metallurgy and eight in minerals geoscience in building capacity in the higher education arena to deliver high quality graduates to industry. Through industry engagement, Australia not only has the capability to produce high quality graduates but also the opportunity of delivering tertiary minerals education to the global minerals industry.

Importantly for the minerals industry in Australia, the MCA reports an increase final-year students at MTEC-supported universities over the years 2007-2011 by 94% in minerals geoscience (Honours), 84% in mining engineering and 50% in extractive metallurgy (Minerals Tertiary Education Council, 2011a). These increases are encouraging but, considering that employment in the Australian minerals industry has doubled over the same period, the gap in delivering professional skills is not only widening, but these professions are falling behind in their ability to meet industry's demand for skilled engineers and geoscientists.

Metallurgical Education in Australia

In this paper, metallurgical engineering refers specifically to primary and extractive metallurgy, including minerals processing rather than the more general chemical engineering or the downstream physical metallurgy or materials engineering disciplines. Good definitions of these terms can be found on the website of the Australasian Institute of Mining and Metallurgy (AusIMM, 2012).

There are 11 Australian universities that teach chemical engineering and six that teach materials engineering undergraduate programs. Chemical engineering programs at all these universities often contain elements of primary and secondary metallurgy but none (except for the University of Queensland) have a metallurgy major. The materials engineering program at the University of Wollongong has a focus on the steel industry and is recognized by the AusIMM whereas, the materials engineering, physical metallurgy and process metallurgy programs at the University of NSW and the materials engineering program at the University of Queensland do not appear to have a mining/minerals focus.

Table 1 summarizes the status of University Metallurgical Engineering in 2011 (and compares it as well as possible with the status in 1993).

Only The University of Queensland, Curtin University and Murdoch University teach four-year undergraduate programs in metallurgy. Between them they produce about 40 graduates a year and have done so since 2008. This is an increase on the long-term average of about 30 per annum since 2000. Disappointingly, only about 60% of first year undergraduate metallurgy students make it through to final (fourth) year, with most falling by the wayside during or after first year or by electing to enroll in double degrees, usually with a non-engineering specialization in the second degree.

Murdoch University has a four-year degree program called Bachelor Extractive Metallurgy and a three-year Bachelor of Science in Mineral

Table 1: The status of metallurgy undergraduate degree programs in Australian universities (as developed and provided by Dr. Kevin Tuckwell, 15 May 2012)

University	1993	2011	
	Status ¹	Status	Comments
The University of Queensland ²	School of Engineering. Department of Mining and Metallurgical Engineering	Faculty of Engineering, Architecture and Information Technology. School of Chemical Engineering	Four-year Bachelor of Chemical and Metallurgical Engineering (Dual Major). AusIMM recognized
Curtin University ²	Western Australian School of Mines. Department of Minerals Engineering and Extractive Metallurgy	Faculty of Science and Engineering. Western Australian School of Mines. Department of Metallurgical and Minerals Engineering	Four-year Bachelor of Engineering (Extractive Metallurgy), and Four-year Bachelor of Engineering (Minerals Engineering) with double degree options. AusIMM recognized
Murdoch University ²	Mathematical and Physical Sciences. Discipline of Mineral Science	Faculty of Science and Engineering. School of Chemical and Mathematical Sciences. Discipline of Chemistry and Mineral Science	Three-year Bachelor of Mineral Science or Four-year Bachelor of Extractive Metallurgy. AusIMM recognized
The University of New South Wales	Faculty of Applied Science. School of Mines and Department of Mineral Processing		

University	1993	2011	
	Status ¹	Status	Comments
University of South Australia	Gartrell School of Mining, Metallurgy and Applied Geology ³		
University of Ballarat	Ballarat University College	School of Science, Information Technology and Engineering	Three-year Bachelor of Applied Science (Metallurgy). Honours available AusIMM recognized

Notes:

¹ The 1993 organizational status may not always be accurate or complete

² Member of the MCA/MTEC sponsored Metallurgical Education Partnership (MEP) consortium

³ The Gartrell School of Mines closed in 2006

■ No undergraduate degree programs with a metallurgy major

Science. Some Bachelor of Extractive Metallurgy students do not complete and join industry after three years study graduating with a Bachelor of Science in Mineral Science.

Curtin University has a four-year degree program called the Bachelor of Engineering (Metallurgical Engineering) and a three-year Bachelor of Science (Extractive Metallurgy). Similar to Murdoch University, some Curtin University students do not complete and join industry after three years study, graduating with a Bachelor of Science (Extractive Metallurgy).

In an attempt to overcome the issues of low and falling student numbers in metallurgy, The University of Queensland created a dual major in Chemical and Metallurgical Engineering in 2005 (which does not provide an intermediary award option). Since the introduction of this course, student enrollments have increased substantially. There is no intermediary award option at The University of Queensland with the four-year program (and a new five-year option) being the minimum outcome.

Australian Minerals Industry Involvement in Metallurgical Education

Simply, without direct industry financial and in-kind support, extractive metallurgy programs at Australian universities would be under severe threat of closure, predominantly due to low historic enrollments as described previously and universally high teaching costs associated with these programs. Some core contributors to the increasing teaching costs of metallurgy degrees include:

- The failure of past Australian Governments to index higher education funding which has resulted in a growing inability of university departments to be viable under the student numbers-based system – especially when student numbers are low;
- A failure by the Australian Government to recognize metallurgy as a discipline of national interest and provide it with appropriate levels of funding;
- Universities investing in teaching and learning capabilities for high enrollment, low teaching cost courses (i.e. volume-driven programs);
- Shortages of skilled academic staff, compounded by the ageing profile of academics.

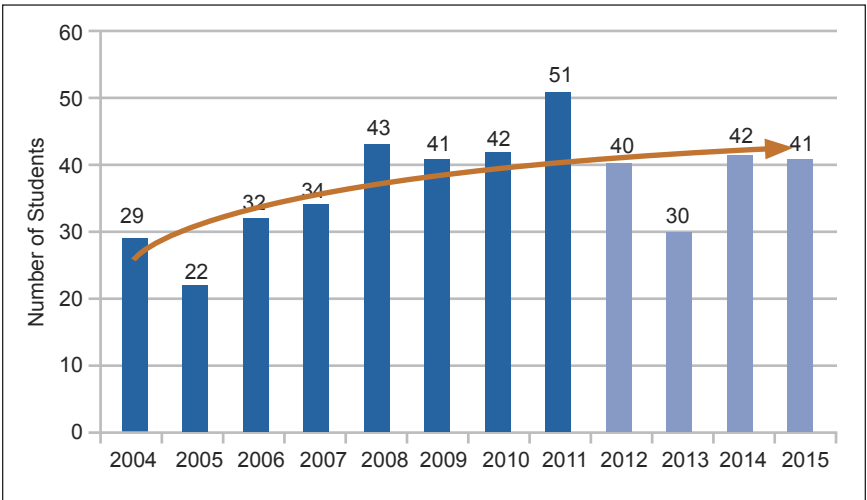
The Australian Government committed significant reforms in higher education in 2011 (DEEWR, 2012) through the reintroduction of indexation and a demand-driven student funding scheme. However, these reforms (realistically) are of little consequence or benefit to the extractive metallurgy departments in Australia as they do not address the chronic structural underfunding of this core discipline.

In addition, to secure a future supply of professionals for the minerals industry direct investment by the minerals industry, has been and is still a requirement. This investment ensures that universities can sustainably deliver high-cost/low-student number programs by increasing their capacity to attract and retain high quality academics and researchers. Industry involvement also facilitates the delivery of undergraduate programs that equip students with relevant high quality technical and decision making

skills that take account of the social, environmental and financial aspects of development. Graduates who have these skills can actively play key roles in delivering on the national innovation agenda, by accounting for the rights and interests of both current and future generations.

Figure 1 shows the actual and predicted graduations in the year 2015 (from the three universities identified already as being the only universities in Australia delivering four-year trained metallurgists). Total completions have stabilized at a plateau of about 40 graduates per year; a level which is well below that required to keep three metallurgy schools viable. It is also less than industry demand for graduates with skills in extractive metallurgy and therefore the minerals industry continues to recruit mineral science graduates and chemical engineers to meet the shortfall.

Figure 1: Actual and predicted graduations from MEP universities out to 2015



Metallurgical Education Partnership (MEP)

Minerals companies support the teaching of metallurgical engineering by funding some academic positions at universities and through MTEC for

the cross-institutional undergraduate Metallurgical Education Partnership (MEP) program to address the issues previously discussed. In 2007, the higher education arm of the Minerals Council of Australia – the Minerals Tertiary Education Council (MTEC) – and three partner universities formed the Metallurgical Education Partnership (MEP) to create industry-relevant collaborative education projects in metallurgy. The partner universities include Curtin University (through the Western Australian School of Mines), Murdoch University and The University of Queensland because fundamentally these three universities produce all the four-year trained graduate metallurgists in Australia. The MEP is a collaborative initiative that calls extensively on industry experts to address the issue of increasing the skills base of the graduates by providing guidance, and specific contemporary technical information on metallurgical plants and processes, to the MEP students who work in teams on their design projects (Churach & Smith, 2011).

MEP's first project, the Process Design Project (PDP), is now in its fifth year and is the first collaborative course of this nature to be run for minerals education in Australia. The aim of PDP is to give final year extractive metallurgy and chemical engineering students an in-depth experience at working as a team in designing a mineral processing plant. The course is intended to act as the quintessential vehicle for students to integrate all the technical content included in their undergraduate education, with the ultimate goal of completing a "mock" design for a commodity specific processing plant. Student groups are formed across university boundaries with the assigned "contract work" using relevant industry data. The student groups must apply their knowledge of mineral processing within limitations of a described ore body, economic, geographic and social parameters and energy and carbon constraints.

Outcomes of Student Experiences with MEP

A key component of the PDP project is a week-long industry based workshop conducted at the beginning of second semester, which is attended by all participating students. The rigorous 'kick-off' face-to-face induction sets the tone for the semester-long project and allows students to develop working relationships with members of their 'design' team.

These relationships continue after students have returned to their home universities and throughout the design process. The aims of the workshop are four-fold:

- To immerse students in technical information concerning their specific assigned commodity and the design process in general
- To expose students to information sessions from a wide ranging group of technical, business and environmental experts provided by industry supporters
- To provide a cross-fertilization of academic expertise and styles across the three universities, allowing students to access to a composite knowledgebase not available to any one university
- To develop a strong network of peers, on both a working and social level, which student participants can call on throughout the semester-long project and into their pending professional careers.

The value of PDP, as perceived by industry, is reflected in both their financial and in kind commitment to the program. Each year, in addition to a substantial financial contribution which affords students across the country the opportunity to meet in one central location, a number of industry representatives contribute a minimum combined total of 100 hours to delivering seminars at the workshop.

During the workshop and on-going cross-university team work, the PDP provides young metallurgists with an opportunity to form a network of contacts with peers and industry representatives, which have the potential to continue beyond the completion of the course.

Students are surveyed pre and post-workshop and again at the end of the program to not only understand the overall student experience but also to identify areas that require attention post-workshop but also post-course delivery. The consistency between the three surveys in question design and how the responses are collated, enables the student experiences to be mapped throughout the course. The results of these three surveys for 2011 gained from the 47 participating students are presented here.

Student expectations

Students were asked both pre and post the workshop to indicate their expectation of the hours required to complete the MEP design project and the grade they expected to achieve which was compared to actual hours spent and expected grade at the end of the project. Table 2 shows the survey results (as a percentage) of expected hours and actual hours per week committed to the project, and Table 3 shows the survey results (as a percentage) of the grade anticipated at the same intervals. The data gathered indicates that overall students had clearer expectations of the amount of time required to complete the project and their expectations of achievement were higher post the workshop. There was also better alignment of grade expectations and the time commitments with the overall course requirements.

Table 2: MEP student expectations of hours required per week (percentage)

	Hours per week (percentage)						
	1 – 5	5 - 15	15 - 25	25 - 35	35+	Unsure	% Total
Pre-workshop	2.1	17	31.9	15	10.6	23.4	100
Post-workshop	4.25	4.25	31.9	53.2	6.4	0	100
Post-project	3.45	24.13	24.13	17.24	31.04	0	100

Table 3: MEP student expectations of grade (percentage)

	Grade expected (percentage)						
	Pass	Credit	Distinction	High Distinction	Unsure	Did Not Answer	% Total
Pre-workshop	2.1	17	53.2	19.2	2.1	6.4	100
Post-workshop	4.2	12.8	47	27.6	4.2	4.2	100
Post-project	6.9	24.1	41.4	17.3	10.3	0	100

Student feedback

Prior to the workshop students were asked to rate their confidence and enthusiasm against specific aspects of the project on a scale of 1-5 (1-not at all, and 5-very confident / enthusiastic). Similarly post the workshop the students were asked to compare their confidence and enthusiasm to before the workshop on a scale of 1-5 (1-significantly less, 3-no change, 5-significantly higher). At the end of project students were asked to make similar comparisons with their post-workshop experiences. Table 4 summarizes the results which indicate that overall, the comparative enthusiasm and confidence levels of students for specific aspects of the project increased

Table 4: Mean student confidence and enthusiasm for MEP project aspects

Project aspect	Mean student Confidence level			Mean student enthusiasm level		
	Pre workshop	Post workshop	Post project	Pre workshop	Post workshop	Post project
Large projects / final report	3.44	3.76	3.68	3.43	3.30	3.31
Design projects	3.34	3.83	4.00	3.94	3.87	3.76
Team work	3.98	4.06	3.79	3.87	3.72	3.89
Defining team roles	3.98	4.00	3.58	3.85	3.68	3.86
Team assessment	3.72	3.89	3.65	3.7	3.66	3.65
Meeting protocols	3.47	3.94	3.65	3.55	3.68	3.83
Managing conflict	3.68	3.94	3.58	3.77	3.68	3.72
Working with different people	3.62	3.85	3.45	3.81	3.66	3.55
Time management	3.42	3.74	3.38	3.49	3.70	3.27

throughout the project. Students were also asked to rate how the workshop experience and post workshop assistance provided them with appropriate levels of guidance and preparation to meet a number of the assessment criteria. On a rating scale of 1 to 5 with 1 being extremely unhelpful, 3 unsure and 5 extremely helpful, students overall perceived the workshop as very helpful in providing the required assistance and guidance (Table 5).

Table 5: Mean level of guidance and preparation provided by MEP

Task element	Overall student mean
Expected time commitment	4.11
Delineation of tasks	3.77
Assessment requirements	4.00
Project planning	4.22
Identifying process options	4.27
Environmental OHS	4.11
Cost estimation	4.18

Students were asked to provide written responses to what they gained by participating in the workshop and the benefit of industry participation. Overall students felt they gained a better understanding of technical processes (knowledge) related to the requirements of the project, organizing group tasks and networking with industry representatives. Specifically related to industry involvement, students indicated the benefits centered around the presentation of relevant, up to date and practical information and knowledge. When asked about possible improvements to the workshop, no specific pattern in responses appeared with 15 students not providing a response. Overall, this feedback would suggest that students found participating in the workshop a positive, informative and educational experience.

The three student surveys have provided valuable information for both university academics and MTEC in tracking experienced and implementing strategies to manage student expectations whilst providing point-in-time data on which to build improvements to the overall program year-on-year.

Collaboration between Higher Education Providers

The MEP is guided by a Steering Committee and executed by an Implementation Committee. MTEC, as representing industry, chairs both of these committees in driving the desired outcome of building capacity in metallurgical higher education to increase the quantity of quality graduates required by industry.

On reflection of the positive aspects of the teaching experience in 2011, the MEP academics summarized the following factors contributing to them delivering quality graduates:

- The five day workshop works very well; this was the best workshop yet
- The new course model was more flexible and easier to coordinate
- The workload for students was intense and demanding but rewarding
- The real-world context of the project is a real positive
- Industry support was a highlight this year, both at the workshop and for associated activities outside the workshop
- The group-work aspect of the course was a highlight; both positive and negative experiences contributed to student learning.
- The broad scope and tight time-line is good preparation for the real world
- The professional peer review provided an opportunity for developing critical review skills
- Students were shown a pathway for professional technical development
- The collaborative teaching approach leads to ambiguity at times, forcing students to rely on their own judgement. This is excellent practise for real world situations.

Specifically, the academic staff from each of the three MEP partner universities had this to say about their 2011 collaborative teaching experience and industry involvement:

“I think that we had a good course this year, with some shiny moments and some truly impressive speakers. The number of experts from

industry who are happy to donate their time and energy to our cause, which is to produce well trained metallurgists, continues to increase year to year. The relationships between the unit coordinators from the three universities and industry have developed further and an already successful course has been improved.”

“The opportunity to be involved in the workshop and industry interaction makes it an enjoyable teaching experience hence I’m happy to be back for round 3 next year.”

“This teaching experience provided the opportunity to get to know other universities’ teaching methodologies, research and teaching environment from other teaching members. This is also a chance to develop the network. During the teaching, there is a chance to share the experience and also help each other to solve problems.”

Aligning Graduate Outcomes to Meet Industry Requirements

Each of the four-year metallurgy undergraduate programs offered by the three MEP universities is recognized by the Australasian Institute of Mining and Metallurgy (AusIMM). The programs at Curtin University and The University of Queensland are also accredited by engineers Australia as meeting the academic requirements for membership at the level of professional engineer (Engineers Australia, 2012). The program at Murdoch University is not an engineering program and therefore has not been submitted for accreditation. As the engineers Australia accredited programs meet Washington Accord accreditation for professional engineer which ensures international mobility of graduates from these institutions, they therefore provide students participating in the MEP program with opportunities beyond Australia.

In 2010, the MEP undertook a review of whether the learning outcomes of the MEP program addressed the requisite Stage 1 Competencies as required by engineers Australia for Professional Engineer (Engineers Australia, 2011). The exercise concluded that the MEP learning outcomes

(Table 6) adequately addressed the competencies required. By proxy, students from Murdoch University, although not accredited by Engineers Australia, have comfort in the high quality outcomes of their program being a part of MEP.

Table 6: Learning outcomes of the MEP program

Broader contextual knowledge	
i.	Outline specific environmental, and occupational health and safety (OH&S) issues for the project;
ii.	Address sustainability and social issues relevant to the design project
Knowledge of discipline	
i.	Formulate a project management plan;
ii.	Analyze available processing options and select an appropriate one given a set of mineralogical and metallurgical data;
iii.	Develop and optimize the selected process using sound design and metallurgical principles and design tools;
iv.	Design a metallurgical process and plant at pre-feasibility level of complexity that includes a process flow diagram (PFD) and equipment, and mass and energy balances generated using appropriate software;
v.	Develop an appropriate plant layout;
vi.	Develop an appropriate process control scheme including some control loops;
vii.	Assess the economic feasibility of the project;
Creative thinking and problem solving	
i.	Demonstrate sound judgment in the process selection, and equipment selection and sizing, to a particular project;
Communication skills	
i.	Compose a written report that demonstrates knowledge of correct presentation of data including appropriate use of tables and figures, and good English including correct grammar, spelling and punctuation, and good style;
ii.	Conduct a professional-level technical presentation including the use of electronic visual aids such as PowerPoint;
Teamwork skills and interpersonal skills	
i.	Work productively both as an individual and a team member.

Further, industry commits significant resources to attend and contribute to the MEP workshop – through presentations, guest lectures, tutorials and panel question sessions – which adds significant value to the university-specific accreditation processes. Since 2008, industry contribution to the respective annual MEP workshop has run into the hundreds of hours. In fact, many approaches to contribute to the MEP workshop are turned away as a result of an already full and intensive program for the workshop which is usually finalized months in advance. Industry values being able to meet with the next generation of engineers and contribute meaningfully to their education, as noted in the following responses in past industry MEP workshop participants:

“Trust the students benefited not only from the industry presentations, but also from the opportunity to interact with colleagues from other universities.”

“Thanks and it was my pleasure. Great to see some of the groups incorporating sustainability into the project presentations.”

“It was a good experience for me too to interact with young engineers and the faculty members.”

“I enjoyed participating in the workshop and will be happy to present again in future years if I am available.”

Conclusion

The Australian minerals industry – through the Minerals Tertiary Education Council (MTEC) – is a proud initiator and supporter of national collaborative initiatives in higher education to build capacity in the core disciplines of

mining engineering, metallurgy and minerals geoscience to deliver high quality graduates which industry desires. The Australian minerals industry continues to experience professional skill shortages in its core disciplines and recognizes that its investment in higher education is one way to ensure the future employment pipeline.

This paper has highlighted how direct industry investment in metallurgical education on a national collaborative basis delivers benefits to students, universities and industry. The extensive student surveys are designed to manage expectations and implement early intervention tactics where required to ensure that the learning outcomes are achieved. The MEP workshop is highly valued by academic staff and students alike, particularly in the use of real-world data and industry experts imparting valuable knowledge in key technical areas.

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Section 4

Industry-Supported Professional Development

Transformational Curriculum for B.Sc. Graduates towards Mineral Processing Expertise

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Abstract

The paper discusses the experiences of a fast-track curriculum designed to provide the industry with engineers capable of working in minerals processing industry. The course was done once before as well and the second course has now been started. Students chosen have graduated from other fields of Engineering. For the first course 12 students were chosen from 152 applicants and for the second the 12 students were chosen from 96 applicants.

The basic idea of the curriculum is to alternate between theoretical studies at the university and work experience periods at industrial sites. In addition there are several one week assignment tasks at industrial sites.

The theoretical periods are six to eight weeks long and there are three of them. During the first period, teaching concentrates on unit processes and their chemical and physical background. The theme of the second period is mineral engineering systems; flowsheet development, process dynamics, control systems etc. The last theoretical period teaches environmental issues, leadership, project work and other similar topics. Each of the theoretical periods ends with an assignment week at industrial sites. The assignments are designed to wrap up the teachings of the period.

For the industrial periods the students are given learning goals, which have been discussed and designed with their industrial mentors. They are required to find relevant literature, make experimental designs, implement those designs, present the data and make conclusions of their results. During these periods a weekly meeting over the internet is compulsory.

Keywords: higher education, guided constructivism, transformational education

Introduction

In comparison to other fields of Engineering, the cyclic nature of the Mining industry as well as its relative size in terms of required graduates, has made this variant of Engineering challenging for the universities. The reputation often given to it, as an environmentally disastrous unsustainable activity, has made things worse. During the years of low recruitment all this led to the closure of many Minerals Engineering and Mining Programs and to modifications in the curriculum taught especially in Europe, North America and Australia. When the ongoing mega-trend of increased commodity demand and the ensuing strong prices caused the demand of enigneers to increase, universities were not well prepared to rise up to the challenge. There are, of course, large variations on the preparedness. The work done by Cilliers (2011), shows a large variation country-wise in the numbers of graduates.

Finland was in an almost similar situation, for long periods of time the number of mines were slowly decreasing. The situation has however now reversed completely. The number of new mines has increased rapidly with new projects ensuring that this rapid growth will continue. The difference in Finland was that strong technology companies continued hiring Mineral enigneers also when mines did not. Due to this the program at Aalto University (then Helsinki University of Technology) survived.

The challenge for a University in this kind of surge of demand is three-fold. Firstly the time factor, it easily takes six years for a freshman to become a Master of Engineering. The second challenge is allocation

of resources. Usually there are several expanding and new programs queuing for resources at any particular University. The last but not least of the challenges is to keep up the quality of teaching. Hiring highly qualified personnel is not an easy task.

In discussing the future needs with the industry representatives, a new solution was developed to train engineers from other fields in Minerals Engineering without compromising the quality. The special course would be run by the Adult Education Unit of the University and would combine academic and industrial work. An Industrial contact group was formed with representatives from all the companies wanting to participate. Its tasks were to agree upon the curriculum and follow the advancement of the education. The announcement in selected dailies produced a good response and 152 applicants were received. The university did set academic credential limits in order to short list the candidates. About 25 were short listed. From this list, the companies picked up candidates for interviews and psychological tests. Finally 12 students were accepted. On the second course the number of applicants was 96. The rest of the procedure was similar.

The companies agreed to hire students and pay them a small salary during the course. The University enrolled the students as special students without giving them the full student status (entitling them to get a degree from the University). However, the University acknowledged the course to be fully compatible with a first year of its Master studies. Some of the students with a BSc degree applied to the University's master courses and then executed the option.

Curriculum Development

As Passow (2007) has pointed out, there is a strong need to get industry involved in the discussion about the curriculum. The main questions to be answered were "Which competencies are important for professional practice" and "What should the relative emphasis be among them". This was done in our Industrial Contact group.

There is a need for studies of skills done by academicians and learned engineering bodies. Passow (2007) made a meta-analysis of 10 such studies, totalling 5978 answers. The result showed that:

- Problem solving skills
- Communication
- Ethics
- Life-long learning
- Experimental work
- Teamwork
- Skills in using engineering tools

ranked among the most important skills, before Mathematics, Science and Engineering. The discussion with our own industrial contact group yielded rather similar results. However, it was apparent, that contextual engineering skills were taken as granted. In designing the curriculum, the skills mentioned in the Passow list and elsewhere, were considered as a new skill layer that had to be taught along with teaching of contextual engineering skills.

Learning Outcomes

The learning outcomes defined together with the industrial contact group representatives were:

- The student shall be capable of operating a minerals beneficiation plant as a Junior Engineer and shall be capable of solving operational problems as also develop flowsheets by methodical use of available engineering tools.
- The student shall be capable of creating plausible engineering solutions and optimizing existing systems within his/her specialization to any mineral matter taking into consideration the constraints and systemic interactions of economy, legislation, environment, society and the availability of services and consumables as well as the requirements of the previous preceding beneficiation steps.

- The student shall be capable of partaking in applying new technologies and systems within his/her specialization.
- The student shall be able to develop effective lines of enquiry – literature, experiments, tacit knowledge.
- The student shall be able to communicate about Engineering – orally, in writing and graphically, for different kinds of audiences.
- The student shall be confident in working in groups and be capable to find his/her role in the group acting as a group expert member or leader.
- The student acquires a skill to make decisions based on acquired knowledge.
- The student is capable to assess the quality of his/her own work and work made by others.
- The student appreciates life long learning as a goal.

As discussed earlier, this calls for contextualized studies in the basics of mineral processing; unit processes, particle technology, mineralogy, metallurgical counting and plant analysis, fluid and powder dynamics, experimental design and process statistics, process dynamics and control and also studies in the basics of mining and bio, hydro and pyro-metallurgy. However, it will also call for a course structure, where many of the “academic skills” are developed.

Learning Theories Applied

The course aimed to work along the modern learning theories, where the cognitive activity of the students is emphasized. We have not gone to the extreme of social constructivism but maintained a fair amount of teacher guidance during the courses. “Pure” constructivist teaching is not efficient (Mayer 2004, Kirschner et al. 2006) as the cognitive structures created without guidance may be both slow to come into existence and may contain major flaws with respect to the laws of nature and the scientific body of knowledge accumulated over the years. Guided learning is effective as it activates appropriate knowledge to be used for making sense of new incoming information and helps to integrate it with an appropriate

knowledge base. It was also quite evident that the varying background of the students made guidance a requirement.

Another factor in our thinking was inspired by the works of Bruner (1960, 1966). His ideas of a spiral curriculum, i.e. revisiting the basic ideas several times while building more complex cognitive structures, has been one of the themes in designing the curriculum. He also stated that the students need enough freedom to become cognitively active in the building of the said cognitive structures.

Curriculum Structure

The curriculum structure was designed to broadly follow the CDIO outlines developed by KTH and MIT (Crawley et al. 2007) (CDIO = Conceive, Design, Implement and Operate). This allowed us to develop two important issues into our curriculum. The first was the spiral curriculum of Bruner and the second was the gradual development of afore defined “academic skills” interwoven into the contextual topic courses. We had no specialized courses for any of the academic learning outcomes.

The course was organized into 7-10 week modules alternating between theoretical studies at the University and assignment work at plants.

The first theoretical module sets the basic contextual basis and is the most traditional with some classroom lectures, small assignments, and first work on enquiring data to find relevant information for the assignments and some first 5-15 minutes presentations of their work in public.

The second theoretical module is designed more around assignment in groups. These assignments are to deepen the knowledge of the unit processes in a systemic plant wide context. A major theme is the flow sheet development for the beneficiation of different ore types. There will still be some more traditional lectures in process dynamics and control as well as in powder mechanics.

The third theoretical module consists of projects with very few introductory lectures attached to them. The project works are aiming to develop

systemic thinking and the skills of the student to assess his/her own work and that of others. The themes are environmental, safety, maintenance, leadership and economics.

During the course there are four industrial weeks at processing plants with the teachers at the end of each theoretical module plus one during the first theoretical module, their structure is always the same. On Monday morning the students are divided into groups of four and given assignments. The assignments are presented orally to the enigneers of the company on Friday afternoon. Usually a lively discussion follows the assignment. The student groups are expected to work on their assignments by obtaining information from the enigneers, shift bosses and operational crew. There is a discussion hour with the teachers every evening and a longer discussion on Wednesday evening. The weeks have a theme related to the theoretical week. The first (during the first module) theme is “experimental work”, which involves experimental designs, sampling, laboratory experiments and experimental error estimates. The second theme, at the end of the first theoretical module, is “processes” involving operational features of the process units, mass balances, circulating loads, reagent regimes, water balance etc. The third theme is “systems”, which consists of control systems, maintenance systems, work safety and consumables. The last theme is “cooperation”. In this the students have to tackle issues like environmental issues, relations with the society and management.

All students were obliged to have three feedback meetings with the professor and the course coordinator (a pedagogist) during the course. In these discussions issues like results, group performance and behavior, personal development and work ethics were discussed. Also, all grievances the student had were discussed. At the end, personal development goals until the next meeting were agreed upon.

Experiences from the Courses

The spiral curriculum idea of Bruner (Bruner 1960, 1966) worked well. The obtained cognitive structures were of high quality with most of the

students. The learning goals were fulfilled to a high degree. The student feedback on the spiral curriculum was positive.

One of the tenets of this course was to challenge the students with the Vygotskyan “zone of maximal development” (Vygotsky, 1978), where students are challenged with tasks that refer to skills and knowledge beyond their current level of mastery. This turned out to be a challenge due to the very different backgrounds of students. Sometimes it was quite evident that some of the students were challenged with daunting tasks, while aiming at the “zone of maximal development”. As Brainerd and Piaget (2004) point out “Learning experiences that are designed to teach concepts that are clearly beyond the current stage of cognitive development are a waste of time for both teacher and learner.” During the first course we could not maintain consistently the “zone of maximal development” resulting in a mental stress variation that caused motivation problems. The work levels did build up during the first theoretical period but being new and interesting it did not cause much stress. As the students returned from their first practical period and were already more knowledgeable in their own mind, the new challenges of problem solving caused the stress to build up fast. This affected motivation and learning achievements of some of the students adversely during the second theoretical period. It turned out that keeping up the workload at the high levels all the time, caused some fatigue in some of the students as their learning skills had vanished. The issue that the companies hired the students had some of the students saying that they only work normal office hours, something not accepted by the teachers. All this caused some friction between the teachers and students. It also caused some friction between the students and smaller competing study groups started to form. These frictions were dealt with in open discussion sessions, which called for some facilitating skills from senior teachers.

Conclusions

The first group of students have now been working in the industry for a good two years. Four of them have been promoted to a position of Mill Superintendent at various mining companies and four are working as Mill Research engineers. Engineering companies have employed three as Application engineers and one person is continuing her studies towards a Doctoral degree.

The fast track training turned out to be an effective way of transforming engineers from other disciplines to minerals processing experts. The idea of alternating theoretical and practical periods has also worked well. At the graduation ceremony, the students were well socialized into the Minerals Engineering community and were more mature in their skills than normally graduated students.

The program is very demanding for teachers and calls much attention to detail. The most difficult issues were the balancing of cognitive challenges with the developing capabilities of the students and maintaining the “arch of learning” during the industrial periods.

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Developing Technical Excellence in Young Australian Metallurgical Professionals – A New Graduate Development Program

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Abstract

As ore grades decline, ore deposits get harder and mineralogical complexity increases, metallurgical skills are more important than ever to ensure that today's mining operations are operating efficiently and profitably. Yet specialist undergraduate degree programs have all but disappeared and metallurgical skills training for graduate engineers in the workplace is often haphazard.

In response to this situation, specialists at the JK Center in Queensland, Australia, have put together a professional development program designed to fast-track skills development for early career metallurgical professionals. The program, called "MetSkill", is offered as a group training package for young metallurgists in the workplace. It is centered on a meaningful technical investigation negotiated between the JK Center delivery team and the client company. Alongside, learning about project management and data collection and analysis, the participants study specialist topics such as comminution, flotation and mineralogy under the tutelage of senior research and consulting professionals. The technical investigation provides an opportunity for immediate practice of these new skills and JK Center specialists are on hand to provide feedback and support throughout the program.

The participants are employed across different operations in Australia and the Asia-Pacific, and although they occasionally come together for group training activities they are often separated by considerable distance. Specialist educational professionals from The University of Queensland have provided an innovative web platform to support collaboration and communication between all participants.

This paper will describe the MetSkill program in detail, as well as provide a report on its initial roll-out to two groups of Australian graduate metallurgists in 2012.

Background

The modern mineral processing plant is a dynamic workplace where performance is the subject of daily scrutiny. Professionals working in this environment are generally young, energetic and self-motivated. They are aware that they need to be able to assess complex technical situations and make quick decisions, and this they do, often assisted by sophisticated analytical tools.

As the Australian mining industry is expanding, there is a need to effectively train more and more of these young professionals. Our educational institutions are struggling to meet demands, and graduates from Engineering and other technology based programs are commonly employed with little or no exposure to the theoretical fundamentals of flotation, mineralogy, comminution, etc. This can be rectified by on-the-job training for newcomers, and in fact for decades this was a routine process, but in busy workplaces in the 21st century providing experienced mentoring and support can be difficult. The pressure this puts on the sector is well documented (WCP and AusIMM, 2001; ADoITR, 2002, Duderstadt, 2005). A number of innovative strategies are in place within the industry to address this situation (MCA, 2008; Sweet et al. 2006), and companies are working with training providers around the globe to find more effective ways to deal with this situation.

This paper describes the MetSkill program, whose genesis can be traced back to a number of sources including the AngloPlatinum graduate

development program described by Sweet et al. (2006) and graduate development guidelines put in place in the 1970s and 1980s by companies such as Mount Isa Mines, as well as the current guidelines by the AusIMM.

The aim of the MetSkill program is to give graduates an early experience of a high quality metallurgical investigation, using best practice analytical methodologies and appropriate tools, facilitated by experienced specialists. The investigation is central to the learning experience, and for maximum benefit it should have the potential to make a real improvement to metallurgical performance.

The MetSkill Program

The best way to describe MetSkill is as a training package, delivered jointly by the JKMRC and JK Tech. It is designed to fast-track professional development of young metallurgists, especially specialist metallurgical skills. The program is centered on a plant-based optimisation task. It also includes workshops on key topics and ongoing facilitation via a purpose-built web platform. Outcomes include successful completion of the process optimization task but more importantly, development of a “Community of Knowledge” within the organization and relationships with technical specialists both within the company and externally.

The learning objectives are summarized as follows. On completion of the program, the graduates should be able to successfully:

- Assess process plant data using fundamental metallurgical principles and appropriately selected analytical tools
- Recommend a day-to-day operating strategy that demonstrates knowledge of industry best practice for a selected area of plant
- Plan and execute a mineral processing plant survey
- Conduct a technically competent optimization study of a selected area of plant demonstrating sound judgement and using appropriate modelling software
- Apply mineralogical information from a variety of sources to a metallurgical problem

- Compose a written project report that demonstrates knowledge of correct presentation of data for a selected audience
- Work productively on a technical project both as an individual and as a team member

Implementation of the program requires commitment by the industry partner to a one or two year program, and agreement on an appropriate program of modules. Specific learning modules included in the package are negotiated with clients, based on a model of “core” and “elective” elements, as shown in Table 1.

Table 1: MetSkill Program Modules

Core Modules	
1.	Collecting good data, experimental design, survey methodology
2.	Fundamentals of comminution, mineralogy, separation and ore testing
3.	Facilitated plant survey
4.	Sample analysis, mass balancing and modeling
5.	Process optimization
Elective Modules	
6.	Process control
7.	Sustainable processing
8.	Flotation theory and JKSimFloat
9.	Gravity processing
10.	Gold leaching and recovery
11.	Geo Metallurgy
12.	Metallurgical accounting

Next, a draft schedule needs to be established and an appropriate site must be selected for the technical investigation which forms the basis of the program. Note that the investigation should be only very broadly defined, as detailed scoping should be a part of the graduates’ initial activities when they commence the program.

Generally no more than three or four graduates come from a single site, so in addition to technical skills development, this program encourages graduates to develop technical-based professional relationships with their colleagues within the parent company.

The benefits to the client companies go well beyond educational and training outcomes, as the investigation should provide high quality survey data for a selected operation, allowing operational problems to be assessed and solutions provided in-house. Owing to the involvement of a large group of metallurgists, the technical knowledge developed is likely to stay in-house for much longer than is often encountered with consultant-based technical investigation.

Detailed Education Design

Underpinning learning model

The professional development model underpinning MetSkill is a small collaborative group and is project-based model, that incorporates mentoring to enhance its effectiveness (de Graaf and Kolmos, 2007), MetSkill uses an authentic, work-situated project to develop the skills of early-career metallurgists, who are supported and guided by experienced metallurgists and consultants. The project is central to the learning and the underpinning knowledge and collaborations are built around it.

Project-based learning has a long history of use in the world of Engineering. It originated in northern Europe, in Engineering education in the 1970's. Project-based learning uses an authentic, defined, complex problem to trigger the learning process. It is similar to problem-based learning in that the “learning is organized around problems”(de Graaf and Kolmos, 2007). In project-based learning, however, the problems are more structured and there is a defined end-deliverable, for example, a report(de Graaf and Kolmos, 2007). The participants are motivated to engage with the learning by having an immediate work-situated problem to solve(de Graaf and Kolmos, 2007). A project-based model of learning uses an experiential learning or ‘learning through action’ approach.

A small-group, collaborative model was chosen for this program to situate the learning within a supportive community. Face-to-face workshops bring the participants (10–15 people) together at a mine site to work with each other, and with senior metallurgists, to execute their project. Outside the workshops, project collaboration and expert mentoring is supported by an online project space.

According to the research literature, guidance by workplace experts is a key feature of successful workplace learning, “individuals need guidance from experienced workers in the form of coaching and modeling that focuses on transferring knowledge to new situations” (Barker, 2011). The use of ongoing coaching or mentoring can also increase the effectiveness of project-based models of learning. Mentoring is a particularly effective way to support novices or beginning professionals and has been used to provide support for professional development across a number of professions (Hansford et al. 2005). This support has ranged from career guidance to psychosocial support. In the MetSkill program, mentoring is used to provide skill development, coaching, feedback and networking opportunities.

The MetSkill learning model is made up of four main elements (see Figure 1.):

- **The project:** This forms the focus of the learning. In MetSkill, the project is to investigate an aspect of plant processing and make recommendations for processing optimization. By undertaking this project, the participants learn skills in applying key metallurgical tools and methodologies to improve the quality of plant operating practice.
- **Structured learning:** This is in the form of face-to-face lectures in a workshop format which provide the underpinning evidence-based knowledge to support the project.
- **Collaboration:** This occurs as two conversations around the project. One is between the early-career metallurgists who are collaborating with each other on the project deliverables, the other occurs between the teaching experts, project mentors and the early-career metallurgists, where the experts and mentors provide project guidance and support to the early-career metallurgists.
- **Facilitation:** The learning facilitator has an important role in MetSkill. They have a macro-view of the whole program, its different components and how they fit together. The facilitator is responsible for coordinating the MetSkill program. They ensure that participants

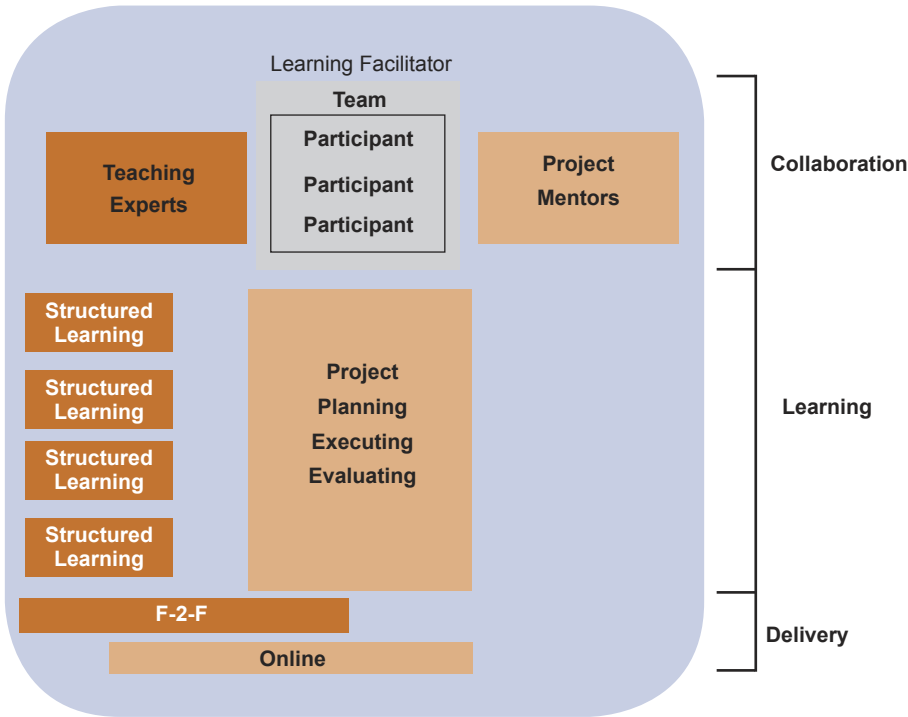
engage with learning, progressing their project deliverables and achieve their project milestones. They are also responsible for ensuring that experts and mentors understand their roles and are engaged with the participants.

The delivery model for MetSkillis was blended. It combines face-to-face workshops and activities, with online collaboration and mentoring.

Effective professional development principles

There is considerable agreement within the research literature and across professions about what constitutes effective professional development.

Figure 1: The MetSkill Learning and Program Delivery Model



MetSkill was designed using these best-practice, professional development principles:

- Learning is ongoing and continuous (1-2 years), rather than one-off “episodic updates of professional information delivered in a didactic manner” (Webster-Wright, 2010). Professional learning is a long-term process and effective professional development acknowledges this. The MetSkill program was designed to allow the participants to build metallurgical knowledge and skills over a one-two year period, by executing a long-term project.
- Learning is situated within the work context and is related to authentic work experiences. The most effective professional development occurs within the workplace, when professionals engage with authentic work experiences. The MetSkill program uses a work-based project that allows early-career metallurgists to work on process optimization at a nominated mine site.
- Learning is social and collaborative. According to the research literature, “learning happens through social interaction and collaboration” (Barker, 2011). In MetSkill, participants work collaboratively, with each other and with technical experts, to execute their project. This happens face-to-face in the workshops and site visits, and online using a dedicated web-space.
- Learning is learner-centered and self-directed. In MetSkill, early-career metallurgists determine the specific project they will work on, its planning and execution .
- Learning is active. MetSkill is an example of experiential learning, where participants learn by doing. Access to expert, evidence-based knowledge is underpinned by research. MetSkill is underpinned by the latest research and by expert knowledge in mineral processing.

Effective professional learning also requires organizational leadership and support. Organizational support for MetSkill was negotiated in the initial planning phase and included time-off for participants to attend the workshops, resources in the form of travel expenses, access to on-site data, equipment and personnel and support for, and involvement in, the program by management.

Online support

One of the features of MetSkill design was the online support. The MetSkill website provided a flexible workspace where participants, experts and mentors could continue to collaborate on their project when they were no longer face-to-face. The website was designed to provide:

- An overview of the program and workshops, i.e. learning goals, timeline, calendar of events, deliverables and teaching faculty
- A space for filing project data and deliverables
- A place where experts, mentors and participants could collaborate with each other around the project (See Figure 2)
- A place where workshop resources could be stored and accessed

The project space was the focus of the website. It used a wiki tool for filing project documents and facilitating participant communications about the project.

The website was designed using success factors for online groups. These were used to inform the design of the user interface, website structure,

Figure 2: Sample page from the MetSkill support website



website content and access control. The design goal was to make explicit, the people, content, structure and processes that are critical to group success. Defining roles, responsibilities, communication pathways and permissions to access website content, were areas that required particular thought. The main challenge in designing the online support was predicting how participants and others were going to use the website and their preferred ways of communicating and accessing information.

The Journey So Far

In 2012 the MetSkill program was delivered to graduates at two Australian based mining companies, MMG, whose graduate group comprises a total of 11 from five different sites, and Newcrest mining, with 16 graduates from six different locations. Each group had already undertaken a major survey at one of their sites with the support of consultants and research staff from the JKMRC and JK Tech, and is in the process of analysing the results. In both cases, the survey outcomes exceeded expectations in terms of data quality.

There are regular progress reports by the graduate groups to their own management, as well as discussion of opportunities available within the company to follow the current project with more activities. This is an important part of the learning process, as it provides the opportunity for graduates to embed newly learned skills into their everyday metallurgical practice.

A large team of technical experts has supported the data collection and analysis undertaken by graduates, drawn mostly from the JKMRC and JKTech but also included some external specialists. This team provides feedback and review on an ongoing basis, as well as provides specific instruction on tools and methodologies. The experience has been a rewarding one for many of these support staff, as many would not otherwise have many of these kinds of opportunities to pass on their skills to a large group of young professionals.

Evaluation

The framework that will be used to evaluate this program is based on Kirkpatrick's 4 levels of evaluation, i.e.:

- level 1- Learner satisfaction and engagement
- level 2- Learning outcomes
- level 3- Performance improvement
- level 4- Impact

Implementing and interpreting level 3 and 4 evaluation is challenging, mostly due to 'the difficulty of attributing any measurable changes to the program' Level 4 evaluation for MetSkill would ask the question, 'has this program impacted the performance of the plant at the local mine site of the participant?' Due of the complexity involved in answering this, only level 1-3 evaluation will be measured for this program.

Level 1 –How do the participants rate the quality and usefulness of their learning experiences?

This will be measured for the program as a whole, and for all the main elements of the learning program—II project, the structured learning, team collaboration, mentoring, facilitation and online support. Questionnaires will be administered to participants, teaching experts and project mentors at three months and at the end of the program.

Level 2 – Did the participants acquire the intended knowledge and skills?

This will be measured by pre and post-tests, by self-assessed achievement of workshop and program goals, and by the quality of the project end-deliverables.

Level 3 - Have the participants transferred the new knowledge and skills into their practice?

Both the degree and quality will be measured three-six months after program completion, by structured interviews with the participants and their local mine site manager. Questions about barriers to implementation will be included here.

Future Directions

MetSkill is still a new and evolving program and there is plenty of scope for streamlining of resources and fine-tuning of module content and schedules. However, the greatest opportunities are in extending the reach of the program by enhancing the capabilities of the supporting website, allowing some of the workshop material and activities to be delivered remotely, thereby providing access to larger or more remote groups of graduates.

There are also opportunities to apply this graduate development model to other professional groups within and without the mining industry, and JK Tech and The University of Queensland are actively exploring these options with other groups of professionals. We may well be looking at GeoSkill, EnviroSkill and Mining-Skill programs in the future.

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The AGDP in 2012 – Nine Years of Exceptional Graduate Training

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Abstract

The issues facing graduate training in the mineral processing industry are not too different today from those that prompted the initiation of the Anglo American Platinum Graduate Development Program (AGDP) in 2002. Graduate metallurgists in South Africa enter the industry from different undergraduate programs at various tertiary institutions, and so the knowledge and skills of the young graduates varies. Further, the geographical expansion of the industry combined with the downsizing of business units means that there are fewer opportunities for young graduates to be mentored through their first few years on site. Anglo American Platinum chose to address these issues by implementing an intensive, structured graduate training program for all their new metallurgical graduates, known as the AGDP.

The first two years of experience of the AGDP, from the viewpoints of both graduates and lecturers, were presented to the mineral processing community at the IMPC in Turkey in 2006 (Sweet et al. 2006). From the beginning, the program was structured in a modular fashion to include a basic technical “toolbox” including statistics, the scientific method and sampling protocols, while the mineral processing content comprised advanced learning in comminution, classification and flotation (later extended to include hydrometallurgy). Technical communication – both written and verbal – was included from the start. The program was focussed very strongly on site work (“learning by doing”), with a major integrated site campaign conducted and analyzed by each cohort.

In 2012, the AGDP will accept its ninth cohort into the program. This paper describes how Anglo American Platinum and the University of Cape Town have developed and adapted the program over the last few years, in response to the challenges of the global recession, skills retention, and the changing operational needs of the company. The program, which was drawn up to accommodate around 15 concentrator-only graduates, now accommodates 35-40 concentrator, smelter and refinery graduates annually. The program has also been modified to facilitate new graduates spending most of their first year on the operations. The benefits of the program for Anglo American Platinum have been tangible, and will be discussed in the paper.

Keywords: graduate training, technology transfer

Introduction

Anglo American Platinum (Amplats) has long recognized that graduates entering the industry from different tertiary institutions have varying levels of understanding of the technical aspects of its processing operations. However, irrespective of whether the new employee has graduated from a diploma-like curriculum with an experiential year or has a Metallurgical or Chemical Engineering degree, once employed by Amplats each graduate metallurgist has the same career prospects and the same performance expectations. As the mine sites become geographically more spread out, and the management structures become more streamlined, the availability of experienced senior people with the ability to mentor the young graduates through their early years on the operations reduces. These aspects together led Amplats to approach the University of Cape Town (UCT) Center for Minerals Research (CMR) to develop a program structured specifically to meet their graduate training needs.

Continuous professional development is a key criterion for membership of institutions such as the Engineering Council of South Africa. Registration as a professional Engineer in South Africa requires one to attend at least three days of relevant training per year (ECSA, 2005). However, there is no stipulation that the training must be directed towards any specific

job-related skills or that the courses relate to each other. Indeed, there is no requirement that attending these courses should change how one approaches one's day to day business. For a training program, success is probably best measured by the perceptions of everyone involved – the trainees, their immediate supervisors, the person who pays for the course, the course presenters etc. This perception needs to be evaluated in terms of the most important indicator of the success of the program: the extent to which the trainee *applies* the principles they have been taught to the benefit of their operation in the day to day practice of their profession.

In 2004, the first cohort of new graduates entered the Anglo American Graduate Development Program (AGDP). Now in its ninth year the AGDP has registered 177 graduates. The objective of this paper is to present how the program has been adapted to meet the challenges facing the mineral processing industry, while setting the standard for rapid technology transfer and uptake of relevant research outcomes that can potentially redefine industry best practice. The benefits to Anglo American Platinum which will be presented here have been tangible and have been felt throughout the company, even in some unexpected areas.

Background and History

The AGDP program was devised in 2003 to deliver mostly technical training to concentrator metallurgical graduates. It was envisaged that the program would not only further the engineering development of technical graduates, but that it would also encourage independent study as a basis for life-long learning and provide the basis for independent evaluation of personal performance against clearly defined milestones. From the company's perspective, it was also seen as an excellent mechanism for rapid technology transfer of the research outcomes from projects such as the AMIRA P9 project, of which Amplats is a partner sponsor.

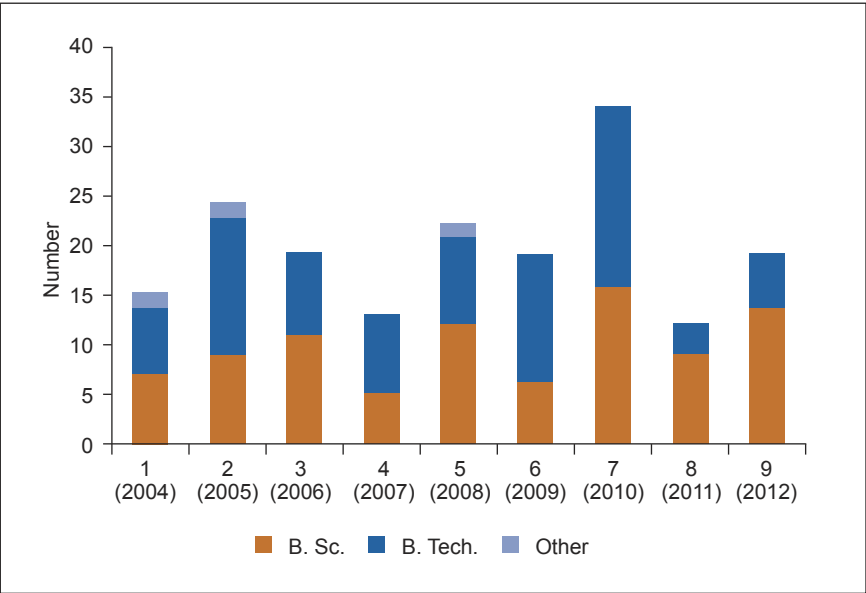
Participants' Demographics

The diversity of the participants' background and undergraduate education and experience was noted by Sweet et al. (2006). Twelve South African

tertiary institutions are represented in the nine cohorts that have entered the program to date. Each cohort has had a different ratio of graduates with a Bachelor of Science or Engineering (BSc or BEng) degree to those with a Bachelor of Technology (BTech) degree in Extractive Metallurgy or Chemical Engineering, as shown in Figure 1.

Most of the graduates who have attended the program were employed by Amplats either directly after leaving school or in their first years of study, and were offered study bursaries with an agreement that they would join the company as graduate engineers on completion of their degree. Each year the number of bursaries awarded and the individuals to whom they were awarded is determined based on future perceived operational needs. It can be seen that for cohorts six and seven in particular, many more graduates were employed from the universities of technology than from the traditional universities. This was in response to the company's expansion plans – the largest single stream platinum concentrator was commissioned in South Africa in 2009, and another concentrator was

Figure 1: Participants' previous qualifications

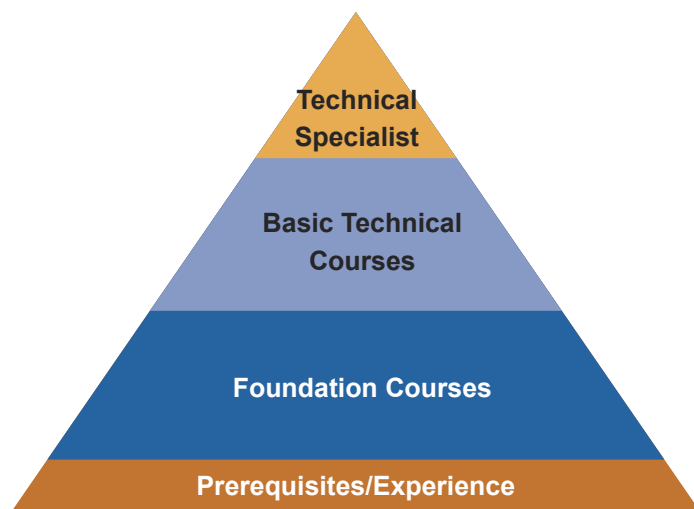


commissioned in Zimbabwe in 2010. Graduates from the technical universities significantly outnumber those from traditional universities and as such constitute a ready market when expansion plans need staffing in a hurry. Amplats also gives bursars a choice of tertiary institution at which to study and historically disadvantaged groups in South Africa often choose technical universities for a variety of reasons, not least of which is that history has seen the alumni of these institutions climb to the top of the ladder in the major mining houses. In recent years and notably since 2009, it has become clear that the practical focus of the BTech curriculum is not ideal preparation for an intensive technical program like the AGDP. Amplats has thus changed its approach with regard to where its bursars study such that the majority now studies at traditional universities, to the extent that 77% of graduates enrolled on AGDP in 2011 and 2012 came from the five such universities in South Africa.

Program Structure

In 2006 the initial structure of the program was presented (Sweet et al. 2006) as summarized in Figure 2.

Figure 2: Schematic of the basic AGDP program structure



The program was conducted over a two year period, with contact time being the equivalent to that of a taught Master's degree in Science or Engineering. Foundation courses were built on the undergraduate education and experience of the graduates. Technical courses consisted of comminution and flotation, which progressed from relatively basic introductory material to more complex analysis of survey data, including the use of state-of-the-art simulators such as JKSimMet and JKSimFloat. Should the candidate have the necessary undergraduate qualification, the ability and desire, as well as the blessing from their operation, they could then register for a Master's degree using the credits collected and complete a short thesis.

Each cohort has presented its own challenges, from changing class size and composition to the calendar having to accommodate plant commissioning or other operational requirements. It was decided early in the program to solicit feedback from the graduates and the mine sites where they were posted in order to gauge the perceived effectiveness of the program, as well as to fine-tune the delivery to remain as relevant as possible. Amplats commissioned Professor Jenni Case of UCT's Center for Research in Engineering Education to evaluate the program from the perspective of the graduates' perceptions as well as actual events and the cultural and social structures of South Africa. Many of the findings of her four reports (Case, 2007, 2008, 2009, 2010) were incorporated into the program structure to address some of the issues raised. The progression of the structure from that presented in 2006 to its present form is discussed in the following paragraphs.

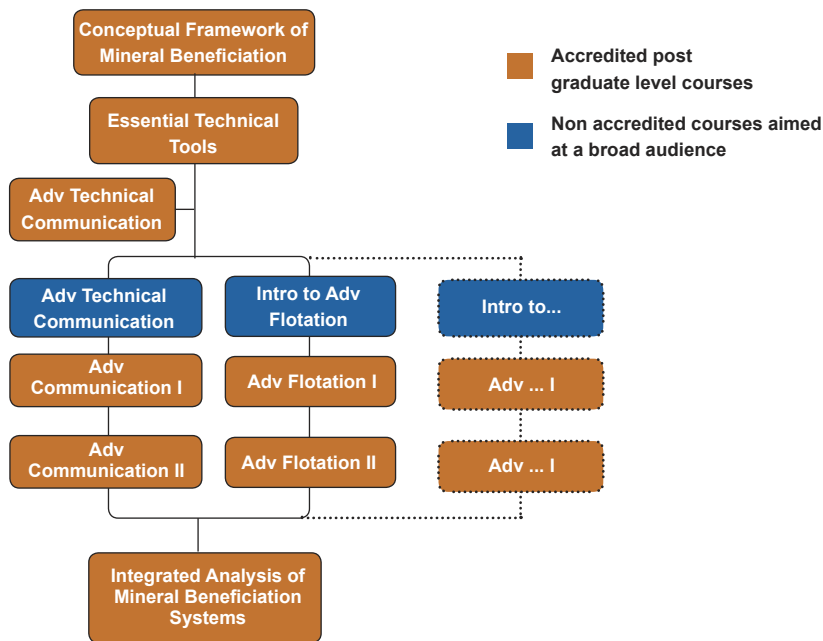
Progression of Program Structure

The first major change to the basic structure presented in 2006 and shown in Figure 3 was the splitting of the courses into first year and second year modules. All technical graduates took the foundation courses in the first year, and participated in the structured practical exercises. At the end of the first year, the graduate class was divided into "Concentrators", "Smelters" and "Refineries" streams for a mineral processing, pyrometallurgy or hydrometallurgy specialization in the second year.

It was recognized that not all graduates were able to cope with the advanced material presented in the second year. An academic criterion was imposed, that only graduates who had obtained an aggregate of 65% or more in the basic technical courses were allowed to progress to the second year.

One of the issues faced by the graduates was being able to balance their AGDP commitments with their site responsibilities, especially in the first year when they were still becoming acquainted with the operations. Therefore another change to the program structure from 2010 was to spread the first year over two years. Communication, Essential Tools and the Conceptual Framework were taught in the first year. The introductory level technical courses and the practical site work were undertaken in their second year, with the proposal being to complete the advanced technical material in the third year.

Figure 3: AGDP detailed structure as presented in 2006 (Sweet et al.)



While this change was in response to requests by both Amplats and the graduates, when implemented it was met with unhappiness from the graduates at it essentially delayed their completion of the program (linked to internal promotion) by a year. So a further adjustment has been proposed that necessitates a change to the scope of the content delivered. In its new form, the first year will still contain the foundation courses mentioned above. To this, basic generic courses related to concentrator, smelter and refinery operations will be added. Thus, by the end of the first year all graduates will have a basic working knowledge of all processing steps in the company. They will then be streamed into the three functional groups for the second year. This revised structure is presented in Figure 4 and Figure 5.

Details of the foundation courses and technical modules and the specifics of how they have been adapted is presented in the following sections.

Figure 4: Foundation courses in 2012/2013

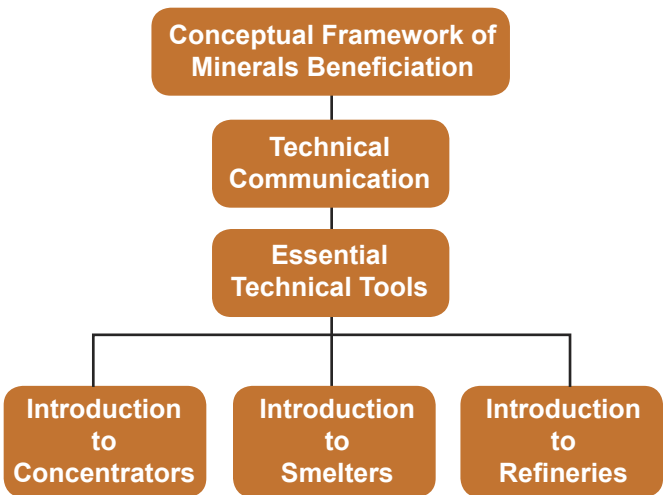
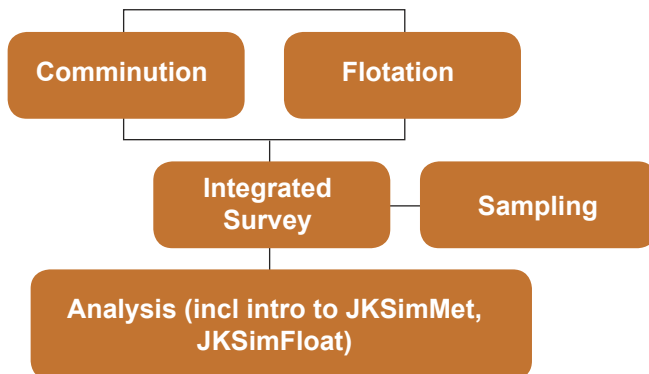


Figure 5: Technical courses in 2012/2013



Course Outlines

Foundation courses

The structure shown in Figure 4 incorporates generic foundation courses – Essential Technical Tools (statistics – presented by Professor Tim Napier-Munn of JKTech, the scientific method, sampling theory and practice), Technical Communication (written and verbal) and a Conceptual Framework of Minerals Beneficiation. The latter course is intended to introduce the graduates to the company, in the context of the broader mineral processing industry nationally and globally. The specific drivers and constraints of platinum production from exploration and mining through to marketing and sale of final products are examined in a series of focussed contact sessions and assignments. The graduates visit an underground mine, a concentrator, a smelter and the base and precious metals refineries and these visits, in conjunction with written material such as the Amplats annual report and the Johnson Matthey Platinum Metals Review (2012), form the research material for their assignments.

In 2012, the ninth cohort of graduates will all be exposed to generic courses related to the three primary processing steps – concentrating, smelting and refining of metals. The aim of these modules is to ensure that every graduate metallurgist has a basic working knowledge of each process unit so that they are not prematurely consigned to a particular process but can be utilized where the operational needs are greatest.

Basic Technical Courses

Basic technical courses build on the foundation laid by the introductory modules. Technical courses were initially limited to comminution and flotation; hydrometallurgy was introduced in 2008. The technical courses offered in 2012 are shown in Figure 5. In addition to these, Amplats provides the graduates with in-house technical courses on topics such as process mineralogy and pyrometallurgy (presented by the University of Pretoria).

Progression of technical courses

The standard technical content as described in Sweet et al. (2006) has evolved from year to year to suit the dynamics of each cohort and the operational needs of the company. In 2004 and 2005 the program was structured to include site visits and other practical experiments in combination with classroom time. However, the large numbers of graduates in cohort the 2005 cohort drove the convenors to consider alternative options for the practical aspects of the training. From 2007 onwards an integrated site survey is conducted during the month of July of the first year. Each year a site is nominated by Amplats and a specific set of objectives and goals is set by the site operations management. A survey protocol and work program is then designed by the graduates to meet these objectives. The work program is interspersed with seminars on material coherent with the objectives, or related to technical constraints and drivers of the specific operation. Each graduate is trained to understand and use the latest generation of state-of-the-art measurement devices and sensors. They also process all samples generated by the survey campaigns themselves – filtering, drying, splitting, bagging and labelling all samples for dispatch to the analytical laboratories. This “Winter School” approach has proved very successful in terms of maintaining engagement of a large group for a sustained period while addressing real plant issues.

Up to 2009, preliminary analysis of the data obtained from the Winter School surveys was conducted during the latter modules of the first year Comminution and Flotation courses. Graduates who progressed to the second year in the “Concentrator” stream were able to engage with the data again in the context of a more in-depth analysis of the operating parameters of the equipment and the efficiencies of the various parts of the circuit, as described in the next section.

Integrated Analysis of Mineral Beneficiation

Until 2010, the second year Comminution and Flotation courses were followed by an integrated analysis of the comminution and flotation circuits. The integrated analysis course was comprised of a series of workshops concentrating on analysing data collected during the course of the program in order to address the specific issue raised by the Winter School site. For example, one site wanted to increase throughput by 20 % and the task of the AGDP graduates was to recommend how the plant should be configured to maximize the returns from this increase. The design capacity of all parts of the circuit was considered, and survey data was used in conjunction with simulation and historic operating data to determine where the bottlenecks were likely to be and what mitigating factors could be employed. Feedback to the site was in the form of written reports and oral presentations – either done as a pair or individually.

As this module was the culmination of two years of intensive training, the graduates were expected to rise to the challenge and use all the tools at their disposal effectively. The integrated analysis was designed to test not only their technical skills but also their ability to work under pressure and in groups, and to use the communication skills taught throughout the program. The final deliverable was a presentation to the Amplats executive on the findings and recommendations for improvements based on the challenges set at the time of the survey.

Owing to the adaptation of the program to allow the first year graduates more time on the operations, the basic technical content and the advanced second year material have been re-evaluated in order to have fit-for-purpose comminution and flotation courses that cover the basics as well as some

advanced material. Therefore a hybrid second year is currently presented (Figure 5) that does not include a stand-alone integrated analysis course. Instead, the distillation of integrated outcomes from the data gathered during the program is now undertaken as a more abbreviated exercise within the individual comminution and flotation courses. This compromise was necessary to ensure the sustainability of the program, effectively halving the time devoted to this outcome of the course. It remains to be seen whether this change can meet the high expectation of management created by the previous model, but the performance of the first cohort under the new program in 2011 has been very encouraging.

Benefits to Anglo American Platinum

Amplats instigated the AGDP to provide their operations with skilled technical staff with a consistent and sound approach to optimisation and daily production management using industry best practice. It was clearly recognized that the benefits to the company would be felt tangibly as the plants became staffed with more and more AGDP alumni. Further, the close attention paid by a cohort to their Winter School site – from the survey itself through the preliminary data analysis stage and finally the recommendations presented to the executive – were practically guaranteed to highlight strategies for improvement of that particular site. A less obvious but equally important benefit has been the effect of the AGDP on the retention of graduates at Anglo American Platinum, which is discussed below.

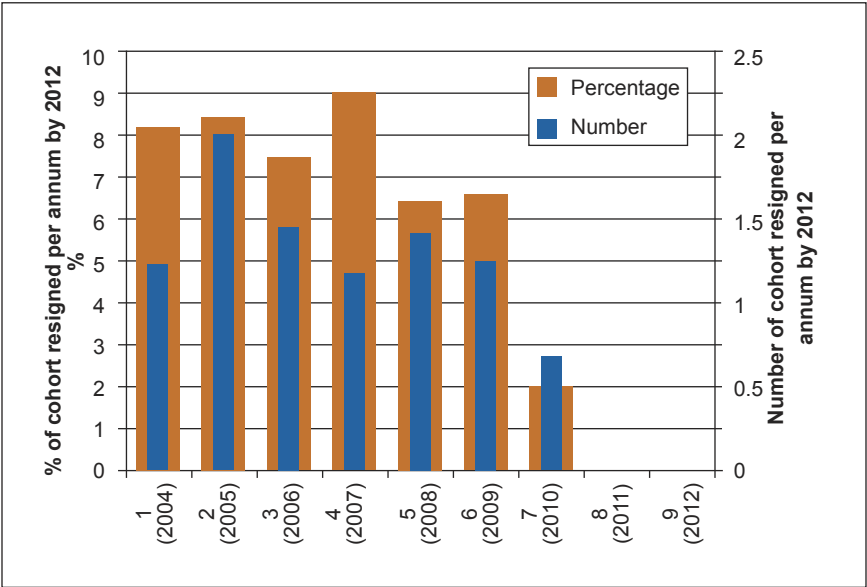
Retention of Graduates

The number of graduates who leave the company has steadily been decreasing, as can be seen in Figure 6 which presents the percentage and number of each cohort who have resigned from the company as of March 2012. It can be argued that the trend is purely time based – the longer the graduates have been in the company the greater the chance that they would leave. Certainly the commodities boom of 2007 and early 2008 played an important role, with several graduates moving to Australia to take up positions in the mining industry there. However, the graph does not show that, of the first two cohorts in 2004 and 2005, the majority of graduates who left the company

did so either before completion or in the year directly after completion of the program. Therefore the reduction from 67% of Cohort 1 to 27% of Cohort 5 – who have been alumni for just over two years now – is highly significant. In terms of total numbers, 72% of the 177 graduate metallurgists employed by Amplats since 2004 remain in the company. 18 of the 177 did not complete the program, and 13 of these have left the company.

It is also interesting to note that in 2006 and 2007 when the industry globally was experiencing a major commodity boom, the percentage of graduates who left was still lower than in the preceding two years. The Global Financial Crisis of 2008/2009 certainly had the effect of slowing down the rate of attrition, almost to a standstill in 2010 although with a slight increase in 2011, but is hard to state with any certainty what the real effect has been. The creation of the AGDP in 2004 and the absorption by the company of 125 graduate metallurgists that remain employed by the company has done at least two things:

Figure 6: Percentage and number of graduates from each cohort that have resigned per annum to September 2012



- (a) It has created a very young junior and middle management team in the Amplats Process Division
- (b) It has, as a consequence of (a) created a sense of frustration among the AGDP alumni who have yet to achieve a promotion – 12 of 31 graduates that exited AGDP between 2006 and 2009 (cohorts 1 to 4) have yet to be promoted above their entry level of Patterson D2.

Simultaneously, Amplats undertook minor restructuring in its process operations to maximize the benefits to be derived from employing a significant number of metallurgists. This restructuring led to the creation of several technical and operational management positions and allowed AGDP alumni from the early cohorts to apply and be appointed. This almost certainly has a positive effect on retention as graduates saw promotional prospects that were previously missing, but also added frustration as graduates from later cohorts overtook those from earlier cohorts. While decisions to promote are merit based, the effect of being overtaken cannot be underestimated especially in a population of AGDP alumni that rightfully has high expectations for success.

The global economic slowdown has prevented many of the frustrated individuals from leaving the company – Amplats pays well and matching or improved offers are few and far between. Most of the thus far unpromoted metallurgists are also not candidates for emigration which has been an option for several of their peers. It remains to be seen what happens when the global economy shows real signs of recovery but it seems inevitable that there will be a spike in the attrition rate as dis-spirited individuals seek out better prospects elsewhere, inside or outside of the mining industry. It is not known how many of the graduates who have left Amplats are still working in the metallurgical industry in South Africa. However, the authors often come into contact with alumni working in the industry for other mining houses or for one of the many engineering design firms based in Johannesburg. Therefore the substantial investment in training by Anglo American Platinum has benefited the industry in the country as a whole.

At Amplats the graduate training program (AGDP) is funded and administrator through the R&D department, not via the training or human

resources development structures. This conscious decision ensures that the program can be influenced directly by operational needs while delivering relevant, topical research outcomes which offer the potential to become part of industry best practice.

Improvements to Operations

Several significant interventions have been possible owing to the concentrated efforts of the AGDP graduates and UCT trainers, the goodwill and assistance of the Winter School sites and the beneficence of the Amplats program managers. Indirect benefits have also been realized, and these will be discussed first.

Survey sampling protocol

The first integrated surveys with cohorts 1 and 2 were planned and executed by UCT and the graduates in accordance with the Amplats standard survey protocol. This protocol had evolved to performing triplicate surveys in as short a time frame as possible in order to be able to quantify the standard deviation of each process stream sampled. For a reasonably steady plant, this is possible to achieve without too much difficulty. However, triplicate surveys mean three times the number of samples to be prepared and assayed (the survey done with cohort 1 generated nearly 2000 samples for further analysis). In addition, for a plant that is in constant flux it is impossible to find a window of opportunity that complies with the underlying requirements of steady state. Cohort 2 were not able to complete a full survey of the nominated site as variations in operating conditions were too great at any given time to meet the steady state requirements.

The learnings from these two surveys were taken back to the Amplats technical management team and led to their adjusting the standard survey protocol to suit the conditions found on site, while still complying with the basic statistical sampling requirements. This has led in turn to the financial cost of surveys being substantially reduced, the turn-around time of assays from the analytical laboratories being reduced and feedback to the site occurring in a time frame that allows the findings to still be relevant, without compromising the integrity of the data collected.

This outcome has massively influenced the buy-in of the operations to the value of the program (beyond its obvious training objectives), and has led to competition between sites to host the AGDP Winter School, rather than seeing it as an intrusion to their day-to-day operation (which is often the case when site work is primarily motivated and managed by head office). This buy-in and support from the site in turn amplifies the quality of both the training and outcomes, in a virtuous feed-back loop.

Mass pull control

Cohorts 3 and 4 conducted surveys six months apart on an operation that had recently been commissioned, treating a new ore from a different part of the reef. From the complete circuit survey and subsequent mass balance done by cohort 3, it was possible to determine the volumetric flows in all parts of the flotation circuit. It became evident that the rougher concentrate sumps, pumps and pipe lines were oversized for the mass pull of the rougher circuit. This led to the pumps cavitating, causing unstable feed to the cleaner circuit, reduced mineral recoveries and inconsistent product quality.

Based on the evidence of the graduates' survey, the oversized equipment was replaced prior to the visit to site by the fourth cohort. Improved plant stability allowed cohort 4 to conduct tests on both the rougher and cleaner circuits in order to quantify how the mass pull changed as the operators adjusted the air flow rates and pulp levels. This information was fed back to the process control department who worked together with the site metallurgists to implement a robust mass pull control strategy to maximize mineral recovery without impacting on product quality.

Reduced steel ball consumption

Cohort 5 performed their integrated Winter School surveys on the same operation as cohort 1. The concentrator plant consists of a primary Run-of-Mine (RoM) ball mill followed by rougher flotation. Rougher tailings are reground in a secondary ball mill, which is followed by another flotation stage. The survey data was analyzed on a size by size basis, and detailed mineralogical information was collected on selected streams in the milling

and flotation circuits. In addition, all the necessary equipment parameters were measured in order to develop a full circuit model of the comminution and flotation circuits.

The comminution circuit models were implemented in JKSimMet which allowed the graduates to simulate the circuits under varying operating conditions. As part of the integrated analysis they analyzed historic plant data which they used in conjunction with the JKSimMet models to conclude that the plant could reduce the ball load in the primary RoM mill without affecting the downstream flotation response. This would not only reduce the energy consumption of the RoM mill but would also result in a significant reduction in steel media wear. Steel balls and power represent two of the largest expenses for a concentrator plant, in addition to being the largest contributors to the carbon footprint of the operation (Le Nauze and Temos, 2002); therefore the savings that the site achieved when this recommendation was implemented successfully contributed to the sustainability of the operation as a whole.

Improved mineral recovery

The largest single stream platinum concentrator in the world was surveyed by cohorts 6 and 7, 18 months apart. The first survey was conducted soon after the plant was commissioned and laid the foundation for post-commissioning optimisation, including the installation of IsaMill™ technology in both Mainstream Inert Grinding (MIG) and Ultrafine Concentrate Grinding (UFG) applications (Rule, 2011). The full circuit survey was used as a basis for the subsequent work done by cohort seven, who were tasked with improving the flotation recovery of the circuit by at least five percent.

Measurements done on the primary rougher cells using the Anglo Platinum Bubble Sizer indicated that the gas dispersion of the cells was poor. Further investigation revealed that the ore possessed some altered silicate minerals which affected the rheological properties of the slurry causing it to become very viscous at relatively low solids concentrations. This was hampering the ability of the cell mechanisms to disperse gas, and subsequently reducing the flotation recovery. Diluting the feed slurry

with water dropped the viscosity sufficiently to improve gas dispersion, and the flotation recovery increased by over 10%.

Conclusions

In the nine years of its existence the technical graduate training program at Anglo American Platinum has earned its reputation for delivery of confident and competent metallurgists for their operations. It has adapted to the local and global environment to remain relevant and to ensure its sustainability for the future. Finally, the rapid technology transfer of industry best practice through the training program has led to measureable improvements to the operations, which more than support the substantial investment of time, effort and funding made by Anglo American Platinum.

Acknowledgements

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