Applying a Logic Model Framework to Mineral Processing Education

IMPC Education Commission Study Update

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Summary

The objective of the IMPC Education Commission is to establish a set of curriculum guidelines for minerals engineering education that meet current industry needs and can be implemented by education providers around the world. The current phase of IMPC Education Commission activity aims to provide sound directives for mineral processing education programs, especially the knowledge and competencies required by graduates and the resources and activities required for their development.

To meet the goal of establishing program guidelines, defined as a series of activities supported by a group of resources intended to achieve specific outcomes among particular target groups, the Education Commission adopted a logic model methodology. Over 100 professionals from various backgrounds, countries and experience took part in semi-structured interviews.

The analysis of the interview responses produced a preliminary definition of Mineral Processing and a logic model that included the activities and outputs for a mineral processing curriculum.

The following are the highlights to be retained from this evaluative process:

- A preliminary definition of Mineral Processing was developed: ***Mineral Processing is the discipline of liberation and concentration of desirable minerals to produce essential products in an economical, efficient and safe manner that is environmentally and socially responsible.***

This definition requires further refinement, input and discussion from a wider group of professionals.

- The logic model provided the guidelines for the course content with some measure of granularity. This included core operation courses from comminution to dewatering, core supplementary material from materials handling to statistics and auxiliary courses such as ethics and health and safety.
- The five major outputs, concepts students should have mastered by graduation, are: process, economic, environmental, social, and personal.

Introduction

IMPC Education Commission work to date represents good progress towards the stated commission objective, but has yet to develop sound directives regarding:

- the quality and currency of existing course content
- the knowledge, skills and behaviors, particularly new knowledge and skills, that graduated mineral processors need to perform their duties
- the learning resources and activities needed to develop the requisite skills and competencies

In order to address these aspects of curriculum design, the education commission has adopted a logic model methodology. Logic models (logic frameworks) not only help evaluate program performance but also help develop them. The application of evaluation methods systematically assesses and improves planning, implementation, and effectiveness of programs.

Project justification

The IMPC is well placed to specify guidelines for mineral processing education at the international level. Some of the arguments to justify that statement are:

1. A move away in University education from specialised to more general undergraduate degrees in science and engineering means that fewer schools are teaching mineral processing and even fewer run programs with sufficient depth to constantly review and update content

2. Funding pressure on universities delivering minerals education, resulting from the cyclic nature of commodity prices, is reducing the number of mineral processing professors in full time employment in universities
3. Many mining companies that once developed and shared technical literature are less able to do so; in addition, many companies have curtailed their mentoring of entry level engineers.

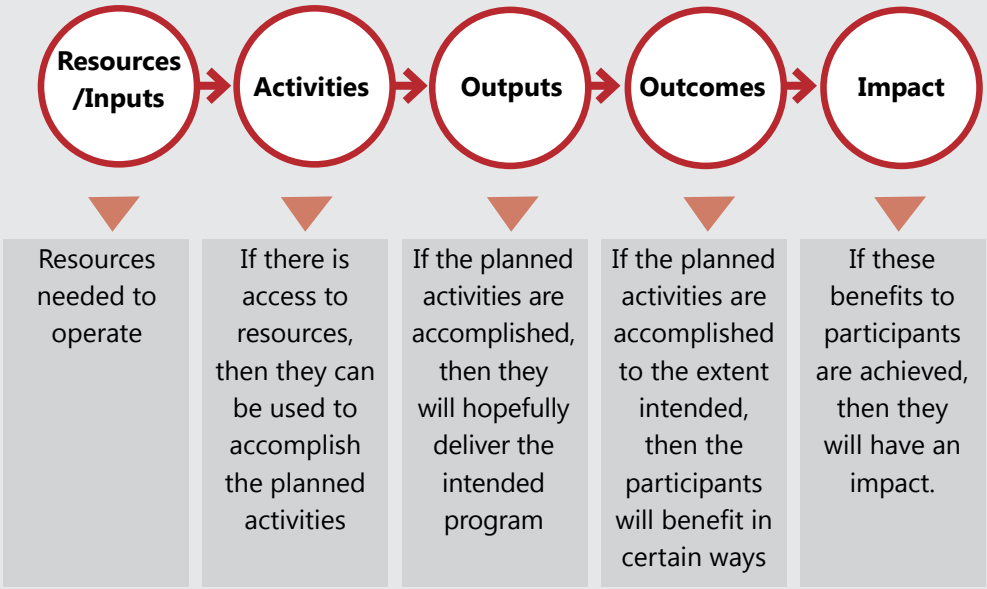
The logic model for the content of Mineral Processing Education

The Education Commission adopted a program evaluation logic model as part of its endeavor to help define educational content for Mineral Processing. Logic models are used, for example, by government to monitor progress towards delivery of target outcomes of a program. The models provide a framework to monitor how the inputs (e.g., budgets, people) are transformed into the outcomes. They are generally developed by a group, aiming for consensus based on the contribution of all stakeholders. Educational programs provide excellent cases for the use of logic models. Applying this framework to Mineral Processing, with the ultimate outcome of identifying the content of a Mineral Processing education program, this report outlines the program content from the perspective of practitioners.

The components of a generic logic model for a program evaluation seen in Figure 1 are:

- **Inputs:** the program's human, financial and material resources, and their organization
- **Activities:** the programs, services, products, transactions that transform the inputs into outputs
- **Outputs:** the direct products of the program, or the transformation of resources into something that is delivered to clients
- **Outcomes:** in the short term, the results of the program and their effects on target groups, stakeholders and their environment, and in the medium to long term their impacts on the overall goals of the program.
- **Impact:** on the system as a whole.

Figure 1: An Example of a Generic Program Logic Model



Based on the generic framework in Figure 1, the components of the Mineral Processing Education Program logic model were determined to be:

- **Inputs:** the program's human, financial and material resources
- **Activities:** the courses granularity, services, transactions that transform the inputs into outputs
- **Outputs:** the direct thematic content of the education program
- **Outcomes:** relate to how well a graduate meets employer and industry sector requirements, and
- **Impact:** relate to the impact of graduate capabilities on industry

Outcomes and Impacts are beyond the current scope of the education committee and require input form a group with a broader remit. These will be the focus of Phase 3 of the Education Commission work.

Method – the Education Commission Study

The program evaluation solicited the input from various stakeholders in mineral processing to assess if there were any gaps between what is taught and what the sector perceives is needed.

Semi-structured interviews were conducted as the first step in the formation of the program logic model.

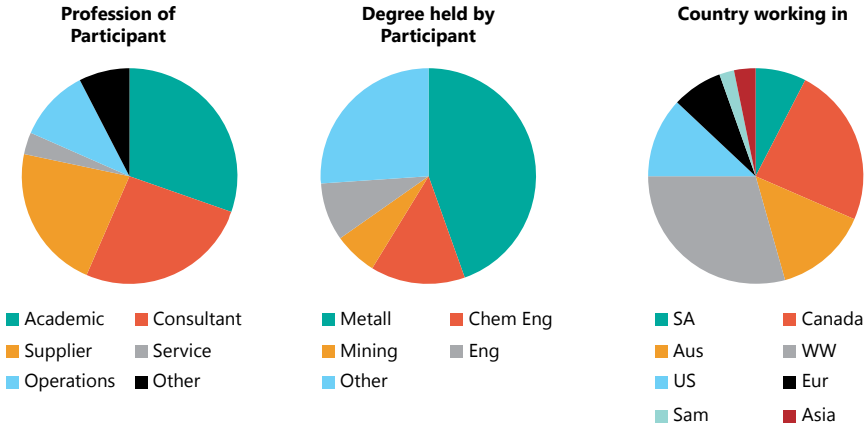
The key questions focused on:

1. What would be the definition of Mineral Processing?
2. What does a mineral processor do? or, What sort of activities are in mineral processing?
3. How would you know if Mineral Processing achieved its goals/did what it was supposed to, met its objectives?

The evaluation was conducted via a semi-structured interview at three conferences: Flotation 15 in Cape Town, South Africa, Canadian Mineral Processors, Ottawa, Canada, and the Society of Mining Engineers, Phoenix, USA. Responses were also solicited from various stakeholders in Australia. The profile of the interviewees is presented in Table 1.

Each individual was asked to comment on the three aforementioned questions. Once the interviews were completed, two experts independently identified common themes from the answers. A consensus was formed about the themes and a unifying preliminary definition of Mineral Processing resulted based on the analysis of these themes.

Table 1: Profile of interviewees*



Country	Number	Males	Age	Experience
South Africa	24	17	52	26
Canada	26	22	48	20
USA	30	24	48	23
Australia	22	16	N/A	23
Total	**102**	**63**	**50**	**23**

Results

The 102 interviewees were from varied backgrounds, countries and professions with on average 23 years of experience in mineral processing. The majority were academics and consultants with metallurgical degrees. The cohort was 38 % female.

Preliminary Definition of the Mineral Processing Discipline

The definition of Mineral Processing was based on the first question, while the logic model was based on the feedback and information obtained through the interviews on the 2nd (activities) and 3rd questions (outcomes). The preliminary definition was presented to a set of senior professionals. Revisions were made until an agreed version emerged.

Analysis of the interview data from the professionals, performed by the 2 experts, yielded several common threads which created the preliminary definition shown below.

Definition: Draft 1
Mineral Processing is the discipline of efficient and safe processing of valuable earth resources in an environmentally and socially responsible manner to produce useable products.

Following several sets of revisions by senior professionals, the draft mission statement was refined to the following:

Definition: Draft 2
Mineral Processing is the discipline of economical, efficient and safe processing of valuable mineral resources in an environmentally and socially responsible manner to produce useable products.

Definition: Draft 3
Mineral Processing is the engineering discipline of liberation and concentration of desirable minerals to produce essential products in an economical, efficient and safe manner that is environmentally and socially responsible.

The final draft version, still subject to further refinement is:

Definition: Draft 4

Mineral Processing is the discipline of liberation and concentration of desirable minerals to produce essential products in an economical, efficient and safe manner that is environmentally and socially responsible.

Several key elements are within the definition:

- *Mineral Processing is a discipline of expert professionals*
- *Mineral Processing is governed by economics*
- *Mineral Processing is done according to best safety practices*
- *Mineral Processing is sustained by balancing social, environmental, and economic demands*
- *Mineral Processing requires efficient use of resources*
- *Mineral Processing requires consistent communication among all stakeholders*
- *Mineral Processing is guided by best evidence*
- *Mineral Processing is improved through the development of a knowledge base along with research and the application and dissemination of new knowledge.*

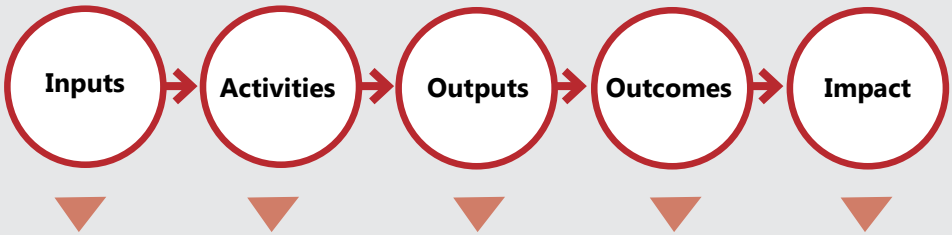
The definition and the answers to the questions from the interviews were used to create the logic model. The specific comments from interviewees on activities and outcomes were integrated into the logic model.

The Logic Model for Mineral Processing Education

Analysis of the 102 survey responses has provided Inputs, Activities and Outputs for the Mineral Processing Education Program logic model, and are represented in Tables 2, 3, 4 and 5.

The last two model segments, Outcomes and Impacts, relate to how well a graduate meets employer and industry sector requirements, and requires input from a group with a broader remit.

Table 2: The logic model



Inputs	Activities	Outputs	Outcomes	Impact
• *See Table 3:* • Institutional Support • Program Support • Personnel • Material • Finance • Space	• See Table 4: • Program content • Core Courses • Operational • Supplem-entary • Auxillary Courses	• See Table 5 : • Process • Economic • Environm-ental • Social • Personal	• Will be developed in Phase 3	• Will be developed in Phase 3

The Logic Model Inputs

Table 3 lists the program's human, material and financial resources. The organization of the inputs will differ from institution to institution. This list is a guide and should not be taken as complete.

Table 3: The Education Logic Model Inputs

INPUTS				
Institutional Support	**Personnel**	**Material Resources**	**Finances**	**Space**
	Administrators Librarian Other teaching staff Health Safety Guidance councilor	Journals and books MOOC and other online resources Software Audio visual equipment	Budget Donations In-kind support	Admin. Library Student building Lecture halls

Program Support	**Personnel**	**Material Resources**	**Finances**	**Space**
	Chairman of program Teaching staff Support staff (Secretarial, Technical, Research) Adjunct teaching staff, practitioners Research staff Student mentors	Internet access Computers Written course material	Budget Research grants Contracts	Classroom Labs Workshop Supply shops

Logic Model Activities

Table 4 includes the activities or the content of a mineral processor's education at the course level. The content of the courses is from many perspectives. Some themes are general and cross all aspects of the education field, such as mineral processing should use best practices, be based on evidence, mineral processors should be lifelong learners and be prepared to learn on the job. The personal characteristics of a mineral processor include patience, and good people skills. The latter are not usually taught at university but are acquired skills.

The activities are divided into core courses (unit operations, supplementary material and auxiliary courses). The table of course contents is organized such that the first column provides the major topic and the subsequent columns the granularity. For example:

The first column of unit operations comprises 4 blocks from comminution to dewatering with some granularity in the second column. In supplemental material 10 blocks are identified, including auxiliary courses. Note, the raw data had more granularity, but for brevity only a summary is provided.

Table 4: The Education Logic Model Activities

Core Courses: Unit Operations	
Comminution	Breakage principles, Crushing, Grinding, Particle size analysis, Liberation analysis
Particle size separation	Screening, Classification
Mineral recovery and separation	Ore Sorting, Density-based separation, Flotation Magnetic, Electrical, Others Chemical processes
Dewatering	Sedimentation, Filtration, Thermal

Core Courses: Supplementary Material	
Materials handling	Transport: conveying, pumping, pipelines; Concentrates: shipment, storage; Tailings: storage + treatment
Applied mineralogy	Instruments and methods; Data presentation and interpretation Ore and mineral properties Geometallurgy
Process control	Instrumentation; Regulatory control to optimization KPI, Targets, Quality Automation
Statistics	Sources of measurement error; Plant sampling & surveying: theory, methods, devices, Modeling
Material balancing	Methods: data reconciliation; Metallurgical accounting, Plant auditing
Testing	Laboratory: methods + instruments, Plant: methods, performance measures, Experimental design, Model building
Measurements	Ore and process parameters; Product specifications, value; Observations, Data collection & mining: interpretation & utilization
Process design	Process and equipment selection, Plant: layout, costing, scheduling; Reporting Case studies
Environment	Regulations: local & national, Energy: minimizing, novel sources; Water: conservation, monitoring & control, treatment, recycling Ecological engineering & recycling
Auxiliary Courses	Health & safety, Personal development, Research management, Economics, Consulting, Engineering ethics

Table 5: The Education Logic Model Outputs

OUTPUTS				
Process	**Economics**	**Environmental**	**Social**	**Personal**
Mineralogy & mineral properties Materials handling Unit operations Equipment selection & sizing Plant & circuit design Sampling & statistics Material (mass) balancing Experimental design Ore testing & geometallurgy Measurements, assaying & instrumentation Control & automation Plant & laboratory testing techniques Performance measurement & auditing Project management Research methods Communication & informatics Marketing Mining basics Extractive metallurgy basics	Metallurgical accounting Mineral economics Taxation & royalties Financial markets Budgeting & forecasting	Local & international standards & requirements Measurements & techniques Control & mitigation technologies Recycle technologies	Indigenous and marginal group rights Impacts of mining Impact benefit agreements Legal and licensing requirements Engineering ethics	Engineering ethics Leadership Mentoring & personnel management Exposure to industry Entrepreneurship Career path options Networking

Logic Model Outputs

Table 5 presents the 5 major outputs expected from a mineral processor's education from the process itself to personal growth and links back to the definition of a mineral processor. These outputs were collated from the interviewers and grouped into the 5 major themes by two experts in the field. The outputs define the specific deliverables resulting from the activities. That is a graduated mineral processor should have mastered the material listed under the first 4 of the 5 themes. The personal growth theme includes material taught (e.g. engineering ethic) as well as elements of life-long learning.

Conclusions

The significant findings were:

- A preliminary definition of Mineral Processing was developed. The definition requires further refinement, input and discussion from a wider group of professionals.
- The logic model provided the guidelines for Mineral Processing Education course content with some measure of granularity and
- Helped identify 5 major outputs of a mineral processing education

Outcomes and Impacts of Mineral Processing Education have yet to be addressed, and completion of the logic model requires consultation with a broader group of stakeholders including mineral processing operators, supply companies and customers. This work will be the focus of Phase 3 of the IMPC Education Commission activities.

The logic model methodology provides a valuable addition to the work of the Education Commission, aiming to provide a robust, practical and relevant set of guidelines for mineral processing that will help the IMPC deliver a consistent message to its stakeholders about the needs of the mineral processing profession in the future.