

CREATING AN INTERNATIONAL NETWORK OF INNOVATIVE EDUCATIONAL LABS IN MINING ENGINEERING

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ABSTRACT

This paper describes the motivation and procedure for the creation of an international network of Innovative Educational Labs in Mining Engineering. The network is primarily designed for university lecturers in mining engineering to foster a broader exchange and stimulate discussion on best practices for innovative educational lab environments. The objective is to contribute to continuous development and improvement in mining engineering education by encouraging stronger international networking, exchange and discussion among lecturers in mining engineering education.

Mining engineering, just like the mining industry, is a comparatively broad, complex and interdisciplinary as well as international field of study. In addition, mines are enormous plants which are hard to grasp and often exist out of sight of young engineers. Therefore, labs and authentic learning environments already are playing a key role in mining engineering education. In addition, due to the distinctively international nature of the mining industry, there already exists a strong network, especially among professors, in the mining engineering discipline. Both of these factors can provide valuable insights for other engineering disciplines. At the same time, the mining engineering discipline itself needs to remain contemporary and competitive, constantly developing and adapting to changing industry requirements and the international network aims to contribute to and support this continuous improvement process.

The creation of this network of Innovative Educational labs in Mining Engineering is part of an ongoing project titled “CDIO II – Implementing CDIO in Raw Materials Sector”, funded by EIT Raw Materials (2018/2019). The objective of the project is to apply CDIO elements to the raw materials sector in order to drive continuous development in and contribute to a sustainable future for education in the field of Raw Materials. The vision is to create an interactive online platform to visualize this network and to make it accessible for lecturers around the world, thereby contributing to stimulating a dialogue between universities about good practice in mining engineering labs.

KEYWORDS

International Network, Mining Engineering, Laboratory, CDIO Standard 6

INTRODUCTION

To date, aerospace, applied physics, electrical engineering, and mechanical engineering departments at universities all over the world have adopted the CDIO approach. With its open architecture model, it is available to all university engineering programs to adapt to their specific needs (CDIO 2019); however, with respect to mining engineering in particular, the adoption of CDIO principles has been very limited.

Therefore, a project was launched in 2016 that, for the first time, applied the CDIO approach to mining engineering programs. The project “Implementation of Conceive Design Implement and Operate” (2016-2017) focused on the development and delivery of CDIO courses, inspirational lectures and industrial collaboration to bring about the change and awareness needed to modernize the education in the field of raw materials.

The insights from the CDIO I project were shared with the wider CDIO community, for example, through the following papers submitted for 13th International CDIO conference in Calgary:

- CDIO Course Development for Faculty in Raw Materials Programmes
- European Initiative on CDIO in Raw Material Programmes
- Innovative Learning Spaces for Experiential Learning: Underground Mines
- Integrating Sustainability Aspects in Mining Engineering Education

Due to the positive response to the CDIO I project from within the raw materials educational community, and in order to further realize the benefits of CDIO within the field of raw materials, knowing that a lasting implementation of CDIO aspects into a given program can easily take four years, it was decided to continue the efforts within a successor project, “CDIO II – Implementing CDIO in Raw Materials Sector” (2018/2019). CDIO II is being implemented by a consortium consisting of six universities (Chalmers University of Technology, Lulea University of Technology, Delft University of Technology, Technical University of Madrid, University of Limerick and RWTH Aachen University), which are all CDIO partners, as well as two industry partners (LKAB and Auginish Alumina Ltd.) and RISE, the Research Institutes of Sweden.

Both projects, CDIO I and CDIO II, were and, respectively, are funded by EIT Raw Materials. EIT Raw Materials, headquartered in Berlin, is the largest consortium in the raw materials sector worldwide with a vision is to develop raw materials into a major strength for Europe. In accordance with the Horizon2020 framework, its mission is to enable sustainable competitiveness of the European minerals, metals and materials sector along the value chain by driving innovation, education and entrepreneurship (EIT Raw Materials 2019).

Within the field of Raw Materials, Mining Engineering takes a central role and sits at the heart of raw material education. It also constitutes the focus for establishing the international network of innovative labs. Mining engineering is an engineering discipline that involves the science and technology to the extraction of minerals from the earth. Due to the complexity and international nature of mining as an industry, mining engineering is as well a broad and highly interdisciplinary discipline that is associated with many other disciplines, such as mineral processing, exploration, excavation, geology, metallurgy, geotechnical engineering and surveying as well as civil and mechanical engineering, electrical engineering, commerce, economics, management, law and information technology.

Overview of the CDIO II project

The “CDIO II” project focuses on driving the change from traditional educational models focused primarily on conservative teaching methodologies, towards industry driven education

in raw materials incorporating CDIO principles. It thereby addresses the mission statement of EIT Raw Materials as well as the goals of the worldwide CDIO community: To foster innovation and entrepreneurship in raw materials education in order to ensure appropriate adaptation to changing industry requirements. For a comprehensive overview of the CIDO II project, please also refer to a bilingual article published in Mining Report Glückauf 05/2018 titled “Rethinking Engineering Education - Implementation of Conceive-Design-Implement-Operate (CDIO)”.

This paper particularly focuses on the implementation of work package II, “Conceived Innovative labs in Raw Materials”, a key component of the CDIO II project. The work package encompasses a mapping process of international mining engineering labs along with the creation of an international network involving different participating universities and companies. In addition, guidelines for good practice in lab development for mining engineering programs will be developed within the work package. Based on real-world best case examples, the guidelines will exemplify what a good lab in a particular study area may consist of and what new and innovative elements can be included. However, this paper is confined to the mapping process for the international network and does not address the guidelines.

OBJECTIVE FOR A NETWORK OF EDUCATIONAL LABS IN MINING ENGINEERING

The creation of the network is aimed at contributing to the transformation of the teaching paradigm in mining engineering in accordance with the CDIO framework. This transformation is necessary in order to better prepare the engineers of tomorrow for the job market with its changing requirements, largely due to continuous advances in automation and digitization.

We believe that labs are an integral part of the success of this transformation. As Auer and Pester stated, „the use of laboratories is essential for the education in engineering and science related fields at a high qualitative level. Laboratories allow the application and testing of theoretical knowledge in practical learning situations. Active working with experiments and problem solving does help learners to acquire applicable knowledge that can be used in practical situations” (Auer & Pester 2007).

Standard No 6¹ particularly emphasizes laboratories to support the learning of product, process, and system building skills concurrently with disciplinary knowledge and encourages hands-on learning in which students are directly engaged in their own learning, and where students can learn from each other and interact with several groups.

Motivation

The motivation for building such an international network of labs in mining engineering programs is to foster exchange, dialogue, innovation and collaboration among international lecturers in mining engineering.

The reason why this is significant for the mining engineering discipline in particular is threefold. Firstly, a mining engineer may manage any phase of mining operations – from exploration and discovery of the mineral resource, through feasibility study, mine design, development of plans, production and operations to mine closure. Consequently, mining engineering is, more than other engineering disciplines, very broad and touches on or, respectively, includes aspects of other engineering disciplines, such as civil, mechanical, electrical and computer engineering. It is also associated with many other disciplines, such as exploration, geology, metallurgy, mineral processing, geotechnical engineering and surveying. It is due to the complexity of the field and its international and interdisciplinary nature that lab environments

¹ <http://cdio.org/implementing-cdio/standards/12-cdio-standards#standard5>

constitute an integral and essential part of the education of mining engineers. Considering the complexity of any real-world mining environment, especially in underground locations, it is paramount to include “hands-on” experiences in authentic environments (Clausen, Binder 2017).

To date, considerable effort has been undertaken to introduce CDIO aspects into raw materials education in Europe (C. Edelbro et al 2017a, C. Edelbro et al 2017b, K. Bhadani et al 2017), primarily as part of the CDIO I and CDIO II projects implemented within the EIT Raw Materials funding scheme. Prior to 2016, there are no known implementations of designated CDIO actions and approaches in raw materials education. The activities implemented within these projects have focused primarily on faculty development and collaboration with industry through project courses. However, there has not been a designated initiative dedicated to labs in mining engineering. This presents the starting point for focusing more attention on laboratory environments in mining engineering education in particular.

Secondly, the didactics of labs in engineering, but particularly in mining engineering, has drawn surprisingly little academic attention. In fact, a comprehensive search of various scientific publication platforms (Research Gate, Science Direct, and Google Scholar) showed “0” results for the keywords “mining engineering laboratory”. An in-depth *alcatech* study confirms that laboratory environments are under-researched, especially with respect to their didactical conceptualization and the assessment of learning outcomes (Tekkaya et al 2016). Therefore, an international network of mining engineering labs can foster an exchange but also academic attention on the laboratory as one of the key elements of engineering education. In conjunction with the guidelines for best practice labs, which also form an integral part of the project, the outcomes can stimulate further improvement of laboratory experiences for students or at least a discussion thereof. This aligns well with the continued transformation envisioned by the CDIO framework.

Thirdly, engineering is also becoming an increasingly globalized discipline as engineers often move across several continents throughout their career. It is therefore becoming more important to foster an international exchange among lecturers as well to provide internationally competitive programs and opportunities for international and interdisciplinary team and project work already during the course of study. The platform for international labs can increase the awareness for international benchmarks and innovative approaches in mining engineering labs while also providing easier access to colleagues to develop collaborative programs or share best practices.

MAPPING PROCESS FOR INNOVATIVE EDUCATIONAL LABS IN MINING ENGINEERING

The following paragraphs outline the definition, typology, target group, methodology and timeline for the mapping process and the creation of the international network.

Definition of Laboratory (Lab)

For the purpose of the mapping exercise, the authors chose a narrow definition of “laboratory” that also meets the intent of CDIO standard 6. According to the Merriam Webster Dictionary (Merriam Webster 2019) a “laboratory” is:

- a place equipped for experimental study in a science or for testing and analysis; a research laboratory
- a place providing opportunity for experimentation, observation, or practice in a field of study

Other concepts, such as “project courses” and other types of “learning environments”, which may also include cultural aspects and a variety of “out-of-classroom” spaces², as well as “workspaces” and “learning factories” are not considered for the mapping exercise, keeping in mind the goal to visualize the data in an interactive online platform.

What is included in the mapping are educational hardware as well as software labs along with test or experimental mine environments that serve as labs in mining engineering programs. The research team included all labs listed with individual departments or institutes or mining engineering programs, which may also include research labs if there was no clear distinction between research and educational labs made by the university.

The research team excluded laboratories that were not primarily used for mining engineering related education such as laboratories for the analysis of geological properties or material science as the scope would have been too broad. Furthermore, laboratories that are sponsored by companies and are not destined for educational purposes but exclusively for research were also excluded from the survey.

For the purpose of the mapping process, the goal is to create an interactive online overview of “who has what” that is, which university has what kind of lab environments. However, the survey is not a qualitative assessment of the labs with respect to how (well) they are equipped or if learning outcomes are adequately defined for particular courses taught in the lab. Furthermore, in the first phase of the mapping process, specific competencies trained in conjunction with lab capacity will not be considered. These qualitative aspects will be addressed with the guidelines for best practice labs.

Typology of Labs

Based on the definition above, the research team created a typology of labs covering all common labs associated with the various study areas within mining engineering programs. The research team developed the typology based on expert interviews and a preliminary web-based research of mining engineering labs at some of the top-ranking universities. Based on the typology it is possible to later on visualize that data in a meaningful way on the platform, allowing the user to filter or search specific types of labs worldwide. The research team created the following categories for lab types that will be distinguished within the database:

- Computer based (Simulation) Labs
- Experimental Labs
- Experimental Test Mines
- Educational Mines
- Mines in Production

Furthermore, these lab types will correspond with study areas, which were defined as, for example: rock mechanics, mine design, mine surveying, drilling and blasting, health and safety, mine economics etc.

² According to the Glossary of Educational Reform, the term learning environment “refers to the diverse physical locations, contexts, and cultures in which students learn. Since students may learn in a wide variety of settings, such as outside-of-school locations and outdoor environments, the term is often used as a more accurate or preferred alternative to classroom, which has more limited and traditional connotations—a room with rows of desks and a chalkboard, for example. The term also encompasses the culture of a school or class—its presiding ethos and characteristics, including how individuals interact with and treat one another—as well as the ways in which teachers may organize an educational setting to facilitate learning”. (Glossary 2014)

The primary objective is to map and visualize “who does what” or “who has what” with respect to lab environments. This will be assessed at university level and based on study areas and lab types. This is because mining engineering programs are sometimes associated with a specific department, or with a research institute (North America), however, they can also be associated with civil engineering or other programs (Europe) or, such as at RWTH Aachen University, a number of institutes exist as part of a faculty that all partake in lecturing different study areas within several mining engineering related programs.

For the purpose of managing the scope of the survey, the team decided to exclude universities from the survey that do not have mining engineering programmes or lab specifically related to mining engineering education at this stage of the project. They may be included at a later stage if it can be clearly delineated what criteria are applied for the selection.

The variables for the database include:

- Name of University
- Location
- Website
- Study Area
- Type of Lab
- Name of Lab
- Lab Properties Description

Target Group

The mapping process is focused on international universities and does not include colleges and other institutions for higher education. A list of international universities was compiled by the research team from two sources:

- a) The 50 top-ranked universities of the 2018 university ranking of QS (Quacquarelli Symonds) for Engineering - Mineral & Mining (Master) programs worldwide. While potentially biased towards North American universities, the QS ranking is widely accepted as one of the leading and most influential rankings and it is one of the few rankings that allows for a filter for mining and mineral engineering programs
- b) 60 additional European universities with mining engineering programs for the following reasons: CDIO II is funded by EIT Raw Materials and therefore has a natural focus on the European geography. To comply with the focus of the EIT Raw Materials, nearly all European universities with mining engineering programs are included in the mapping and the network building

Even though the QS ranking does not factor in the existence of labs or the quality of labs environments the research team chose the QS ranking with the preliminary assumption that an overall excellent quality of study programs in mining engineering also correlate to some extent with the existence of good lab environments and generally relatively well equipped departments or institutes that contribute to student satisfaction. Combined with a more exhaustive look at the European university landscape, the two lists allow for a good representation of high quality mining engineering programs worldwide with a focus on European programs for building the desired network. However, the research team is aware that the mapping represents a selection and it does not claim to encompass all existing universities with mining engineering programs.

Methodology

The mapping process will focus on a systematic research of the websites of all selected universities. Whenever web research does not prove sufficient, the team will directly contact the respective department, school, or institute to ask for the missing information also making use of existing academic networks from all project partners.

Preliminary data gathering has already proven that web based research has limitations: In more than some cases, websites are only in the native language of the university and not available in English (such as Spanish, Chinese for example). Secondly, limited information is presented on the website about laboratories posing difficulties with respect to confirming the lab type or related study areas. Responses to email requests have been limited as well. Therefore, the second stage of the project will involve telephone calls and inclusion of professors who are interested in the project and willing to access their professional networks.

All data is being gathered and entered into a generic database and later formatted according to the requirements of the visualization software. To visualize the data, the team will chose a suitable software, most likely at this stage the decision will be for "Tableau public". Tableau public is free of charge and easily accessible. Other advantages of the software are that the interactive visualizations can be easily embedded into any other website using an html code provided by Tableau. This makes it possible to distribute the database by email or social media. EIT Raw Materials as well as CDIO could embed the interactive map on their website to ensure broad access to the results. However, should a more suitable software tool be identified during the implementation process, the research team may select a different tool for the final implementation.

The objective for the visualized database is to allow for the following search and filter options:

- Showing all universities with labs worldwide by location (country/city) on a world map
- Filtering for any type of lab resulting in showing only a selection of universities
- Displaying additional information about special capacities or equipment of individual labs along with the website of the department/institute upon selection of a specific university
- Filtering for countries displaying universities in a particular country
- Search for any particular university of lab by name

Data protection is not an issue with Tableau Public since no personalized data is collected during the survey. All data is publicly available data from the internet and gathered on university level. This was also confirmed by the RWTH Aachen privacy officer.

Timeline

The research team will implement and complete the mapping process over the course of 2019. The data collection will start in March 2019 and the target for the first phase (web-based research) of the mapping to be completed is June 2019.

CONCLUSION

We believe that the outcome of the mapping procedure is relevant to the CDIO community for at least three reasons. On the one hand, the assessment of learning outcomes as well as didactic concepts for lab courses have drawn little academic attention. The creation of such a network can therefore expand the discussion on the importance of labs for (mining) engineering education and bring forward innovative (didactic) concepts for educational lab

environments as well as contribute to continuous development among mining engineering faculty. On the other hand, the methodology and idea for creating such a network can be transferred to other engineering disciplines, thereby contributing to fostering international exchange on best practices. Thirdly, the creation of such an international network is closely aligned with the CDIO objectives of continuously improving engineering programs to include more real-world problem solving and produce engineers that can conceive-design-implement-operate. The lab is an integral part to develop the skillsets envisioned by the CDIO framework.

Therefore, the research team would like to use the opportunity to present the findings as part of CDIO projects in progress at the 15th International CDIO conference. This would allow receiving valuable input for the finalization of the platform as well as making the idea and implementation available for a broader audience to transfer the idea of an interactive map as part of network development to other disciplines as well.

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BIOGRAPHICAL INFORMATION

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Elisabeth Clausen is the Director of the Institute for Advanced Mining Technologies at RWTH Aachen University in Germany. Already in her previous role as senior academic counselor at the Technical University Clausthal she has been actively engaged within the CDIO community by implementing the CDIO approach for the first time in Mining Engineering education.

Erik Hulthén is an Associate Professor in Product Development and Head of program in Mechanical Engineering at the Department of Industrial and Materials Science, Chalmers University of Technology. His research is focused on production of rock material, especially process optimization.

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Juan Herrera Herbert is Professor of Mining Technology at the School of Mines and Energy of Universidad Politécnica de Madrid (Technical University of Madrid), Spain. His current research is in integration of different technologies for education in mining disciplines and has been actively involved in the implementation of the CDIO methodology in undergraduate and MSc programs in Mining Engineering in Spain.

David Tanner is a Senior lecturer in Manufacturing Process Technology at the University of Limerick and Assistant Dean of Internationalization in the Faculty of Science and Engineering. He is a member of the Bernal Institute and undertakes research in the areas finite element analysis of metal working processes, additive manufacturing and investment casting. Dr Tanner has been a member of CDIO since 2009 and has developed engineering modules based on the principles of CDIO.

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