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EUROPEAN INITIATIVE ON CDIO IN RAW MATERIAL PROGRAMMES

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ABSTRACT

One of five Knowledge and Innovation Communities (KICs), was launched in Europe in 2014 and has its focus on exploration, extraction, mineral processing, metallurgy, recycling and material substitution of raw materials. To reach the vision, where the European Union's industrial strength is based on a cost-efficient, secure, sustainable supply and use of raw materials, a new generation of skilled people entering industry, universities and research needs to be developed. Today's technical MSc graduates in raw materials and especially primary resources (i.e. exploration, extraction, mining and mineral processing and metallurgy) best suits large companies where they often act as specialists and experts. For small to medium enterprises as well as for our future engineers other skills than technical are necessary. As a part of the KIC Raw Materials, the education project "The implementation of CDIO in raw material programmes" started in 2016. The project focuses, during 2016-2017, on (WP1) faculty- and (WP2) pilot case development. There are no academic institutes in Europe that have yet applied CDIO for primary resource related MSc programmes. This paper describes an education project within the KIC Raw material and presents key outputs with implementing CDIO in mining and metallurgy related programmes.

KEYWORDS

Faculty development, program development, raw materials, Standards: 1, 2, 9, 10

THE KIC IN RAW MATERIALS

The mission of the European Institute of Innovation & Technology (EIT) is to foster entrepreneurship and innovation across Europe. To fullfill the mission, EIT have until 2016 brought together five Knowledge and Innovation Communities (KICs). One of these KICs, was launched in 2014 and had a focus on the raw material chain, i.e. exploration, extraction, mineral processing, recycling and material substitution. The KIC named EIT Raw Materials is supported by more than 100 partners from industry, research and universities. To reach the vision, where the European Union's industrial strength is based on a cost-efficient, secure,

sustainable supply and use of raw materials, a new generation of skilled people entering industry, universities and research needs to be developed (EIT Raw Materials, 2017). All learning and education activities in the KIC Raw Materials are under the umbrella of the Raw Materials Academy. The Academy was created in order to stimulate education and lifelong learning activities and foster new ways of learning and teaching with special focus on the strengthening of innovation and entrepreneurship in the whole raw material chain. The expression “T-shaped” student (Word spy, 2017) is used by the academy and means to educate professionals with an understanding of the full raw materials value chain and with a mind-set for innovation, and entrepreneurship focusing on sustainability. For a schematic view of a T-shaped professional in raw materials, see Figure 1.

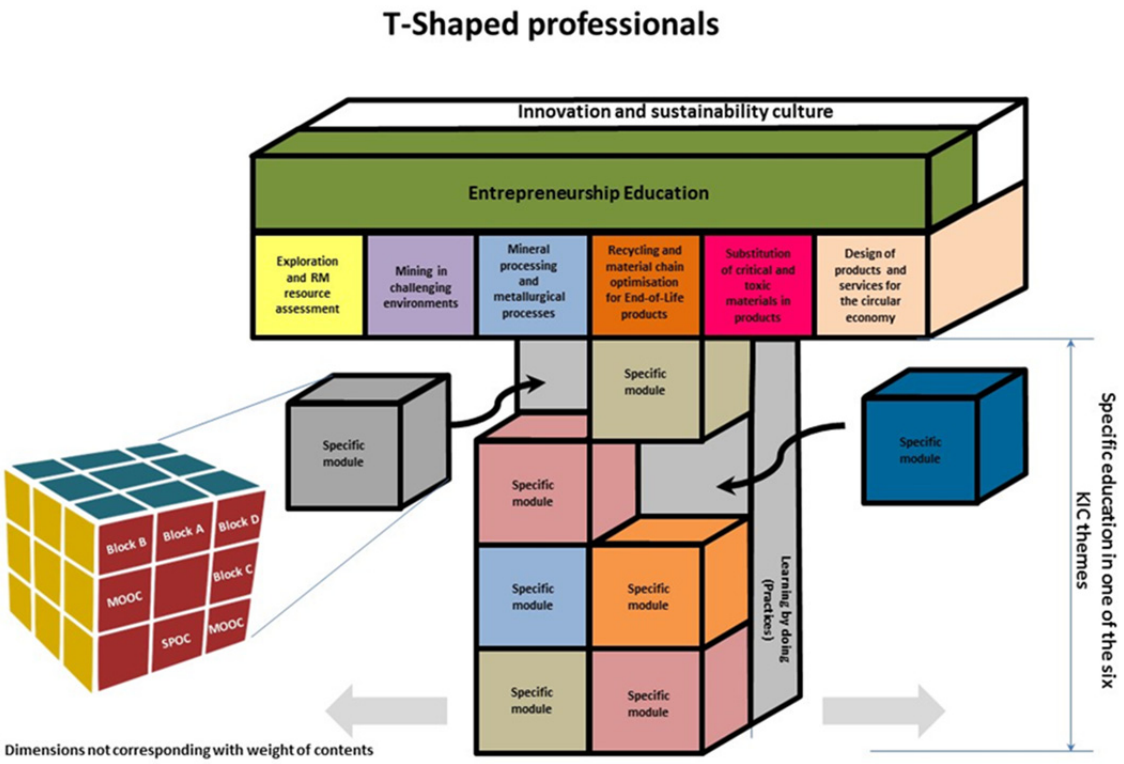

Figure 1. Example of T-shaped students in raw material (by Juan Herrera (UPM) in 2015).

EIT Raw Materials have announced for calls since 2015 and within learning and education the calls have had a focus on PhD-, MSc- and Lifelong education as well as wider society learning. One of the six on-going MSc projects is the implementation of CDIO in raw material programmes (Master Education projects at EIT Raw materials, 2017). There are no academic institutes in Europe that have yet applied CDIO for raw material related MSc programmes. To successfully implement CDIO the university itself, programme responsible and the teaching faculty need to be committed (Chuchalin et al., 2015). Once you have committed staff, the mobility and collaboration between universities and exchange of past experience is likely to drive the CDIO implementation (Loyer et al., 2011, McCartan et al., 2016). By EIT Raw materials funding the partners in the project will have a great opportunity to get the university committed and faculty involved to discuss and cooperate during the implementation of CDIO.

PROJECT DESCRIPTION

The raw material chain can be subdivided into primary (exploration, extraction, mineral processing and metallurgy) and secondary (recycling and material substitution) resources. The main thematic content in this project is primary resources where the stages in the life of a mine are expressed in Figure 2. The exploration phase can be subdivided into reconnaissance and detailed exploration where each of these steps takes between one and five years. Hence often the establishment of a mine does not start until three to eight years after finding a mineralization. The development work, which often takes two to five years, concerns mining rights, financing, roads and transport systems, surface plants, shafts etc. The mining production, which is a process itself, needs to last more than 10-30 years in order to be economically sustainable. The final stage, which often takes one to ten years, is mine closure and restoring the mining area to an acceptable state of safety and environment. In each stage in the life of a mine it is important to simultaneously be aware of all the other stages in order to be an entrepreneurial and innovative engineer.

Figure 2. Stages in the life of mine.

Existing MSc programmes which are linked to the thematic Raw Material content are often very technical and students graduate as professional engineers who know how to solve pre-defined and often non-realistic problems. The students are not fully aware of the stages in the life of a mine and how their work will be affected by other parts in the raw material chain. These technical MSc graduates best suit large companies where they often act as specialists and experts. For SMEs other skills than technical are necessary and warranted in order to be productive from the first day. In addition new smart technologies require a change in the traditional skill-set. Students in such programmes seldom (or never) practice entrepreneurial, communication and innovation skills.

The project focuses on faculty and program development. The project has two work packages on-going, since April 2016, with focus on i) teaching the “technical” faculty through CDIO linked courses (entrepreneurship, business etc.), communicative work-shops, inspiration guest lectures and on ii) curriculum, program and course developed together with the industry.

The consortium for the project covers the whole knowledge triangle with one partner from a research institute, two from industry and five from academia. Looking at mobility, the partners

cover a large part of Europe, from Sweden, Germany, Ireland and Spain. Luleå University of Technology (LTU) is the coordinator of the project and has a long track record as a complete mining university covering all aspects of the raw material value chain including non-technical issues. Research and study programs for the whole range from Raw Materials to Material Sciences is also covered by Clausthal University of Technology (CUT) and Technical University of Madrid (Universidad Politécnica de Madrid - UPM). At both UPM and Delft University of Technology (TU Delft), some engineering programmes have already implemented CDIO and can therefore act as a supporter when implementing CDIO in the resource and mining engineering field. Chalmers University of Technology (Chalmers) was one of the four original universities behind the CDIO initiative. In this project, Chalmers has a role as developer of CDIO courses for the faculty as well as course development within processes around production of rock materials. The University of Limerick (UL) will have almost the same role as Chalmers in this project, as material and processes are one of their specializations. The industry as well as research institute partners (i.e. Luossavaara-Kiirunavaara Aktiebolag (LKAB), RUSAL Aughinish Alumina and SP Technical Research Institute of Sweden) will bring in real cases from the industry and act as advisors for WP1 and WP2.

Work package 1 – Faculty development

WP1 has been focused on faculty development (CDIO Standard 9 and 10) with faculty courses developed and given by the Chalmers and Limerick universities during 2016 and will be given at Delft in May 2017 (Bhadani et al., 2017). The aim of WP1 is to create a faculty course both containing the CDIO approach as well as examples and cases from the raw material sector. Hence in the final faculty course in October 2017, the programmes and courses that have been developed in WP2 will be presented.

Inspirational lectures linked to CDIO have been included in WP1 in order to get the work started and faculty interested in the subject. The first inspirational lecture was given in Madrid in May 2016 and the second in the end of September 2016 in Clausthal. After each inspiration lecture, the project coordinator at LTU briefed the audience on how this can be implemented in our raw material programmes. The major inspirations from the lectures and the inputs that the partners thought they should use in their continued work was to focus on the student contribution instead of the teacher contribution and to use a variation in assessment methods instead of only written exams in the whole program.

Participation at the EIT Academy driven workshops, such as the entrepreneurial workshop at Uppsala University in March 2016, has been a part of WP1 as well. In entrepreneurial schools it was obvious to have a lab for students to foster creativity and innovativeness. The discussions at the workshop regarded lab for raw material students as well as how to engage SME and start-ups in our programmes. To add the possibility for networking and see how others are working with CDIO, programmes and courses, the participation at international CDIO conferences has also been included in WP1.

A transfer from “a standard package” from business and entrepreneurial schools to a content that is specific for our sector is warranted by the RM Academy and made possible by this project. Business and entrepreneurial schools exist at most universities, but these often deliver a "standard package" of project and courses that are not specific for the Raw Materials sector. The universities offering programmes and courses in the RM sector are, as part of EIT Raw Materials, expected to include innovation, entrepreneurship and business

skills, in their MSc programmes. The win-win situation of this work package is that the "technical engineering" faculty will be taught CDIO linked courses and that the "entrepreneurial" faculty will be taught exploration, mining, mineral processing and metallurgy related issues.

Work package 2 – Pilot case development

As the vision is that the university partners include entrepreneurship and innovation in their typical technical engineering programmes, it is important to begin with creating a few EIT RM CDIO pilot cases. For each and every partner the situation and possibilities for CDIO-implementation is unique. Therefore the pilot case development in WP2 will be both on programme and course level.

Since all partners have had a unique prerequisite and starting point the development work has been different. MSc programmes with focus on primary resources and mining are given at LTU, CUT and UPM. The development of the first pilot case with focus on mining started at LTU and will be based upon the industry needs and practical problems and real cases with input from LKAB. Hence at LTU the work during 2016 focused on engaging industry (Standard 2) in program objective and development work (Edelbro et al., 2017) as well as on constructive alignment (Biggs & Tang, 2011) in courses. The result of the work will help to set the context of the programme (Standard 1).

The focus at CUT has been and is on course development within the international MSc Mining Engineering. The main focus has been on courses in mine ventilation (Clausen, 2017), the integration of sustainability aspects in Mining Engineering Education (Binder et. al., 2017) and the implementation of underground mines as innovative learning spaces (Clausen et al., 2017). The focus at UPM has also been on course development at the School of Mines, with the collaboration of professors of the School of Industrial Engineering as advisors. For the course development at UPM, the participation of an external institution for student practices on machinery has also been scheduled. Courses within primary resources are also given at Chalmers, UL and at Delft and are under development work.

DISCUSSION

The CDIO Initiative was based on mechanical and design engineering but is suitable for programs in all fields of engineering (Crawley, 2001). However the acronym does not fully connect to raw material related programmes if it symbolizes what engineers do in raw materials. To explain the acronym to people working in raw materials might require time and effort without conveying the message that CDIO is meant to strengthen the professional side of engineering education. Mining engineers do not talk about products, they talk about processes. Mechanical and design engineers determine stress and load and select material with well-known properties based on strength, weight and price. In mining the stresses are already there and they, as well as the material properties, need to be determined. Hence the different disciplines deal with material from different perspectives. It is also worth mentioning that people working with exploration often has a geoscience background and are not so often engineers. These might be reasons why CDIO has not been implemented in primary resource programmes before.

The primary resource industry is not the number one and most attractive sector for an 18 year old student. With another attitude regarding the context of the programmes and by

having programme development work validated by stakeholders the programmes might get more attractive. Since this project has partners within the whole knowledge triangle (industry, research and academia) the programmes have the possibility to include more real and complex problems. Therefore, it is positive that students and teachers can act as ambassadors of the programmes and with new ambassadors trained every year.

OUTPUTS BY THE PROJECT

Four different events for the faculty, with in total more than 110 registrants, have already been created in the project. The events took place at different countries and locations which made it possible for many partners to attend. For the pilot case development 11 stakeholders from the industry were involved as well as faculty at the different universities. Hence more than 30 people were directly involved in programme and course development.

Through WP 1 and WP2 new teaching methods and pedagogic tools have started to be used in the raw material MSc programmes. The inspiration comes from lectures, CDIO conferences, the developed CDIO cases and faculty courses. The faculties at the universities are now a part of a large pedagogic network through CDIO as well as a large network within the discipline. As a result we will see modified courses and programmes and new developed curriculum with clearer learning outcomes. In total the implementation of CDIO will influence and inspire more than 150 students within primary resources programmes and it will also involve more than 50 faculty members.

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BIOGRAPHICAL INFORMATION

Catrin Edelbro is a Senior Lecturer in Mining and Rock Engineering at the Department of Civil, Environmental and Natural Resources Engineering, Luleå University of Technology. Since January 2015 she also serves as the head of undergraduate education as well as deputy head at the Department of Civil, Environmental and Natural Resources Engineering. In this role she is responsible for the performance, quality and development of more than 20 degree programmes.

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Elisabeth Clausen graduated in Mining Engineering at Clausthal University of Technology and obtained her PhD degree in the area of Underground Mine Planning from the same university. Since 2013 she is working as Akademische Rätin at the Institute of Mining as Clausthal University of Technology. Dr. Clausen is deputy head of the Department for Underground Mining Methods and Machinery as well as lecturer in the field of Mine Ventilation and Climatisation as well as Software for Underground Mine Planning at Clausthal University of Technology. She was awarded by CUT in 2014 and the Society of Mining Professors in 2016 for Innovation in Teaching and Learning.

David Tanner is a Senior lecturer in Manufacturing Process Technology at the University of Limerick and was recently appointed as Assistant Dean of Internationalization in the Faculty of Science and Engineering. Dr Tanner has been a member of CDIO since 2009.

Juan Herrera Herbert is Professor in Mining Technology, Mine Planning and Design and Drilling Technologies at the Department of Geological and Mining Engineering of the Universidad Politécnica de Madrid, where he has served in different positions. He also holds actually the position of Coordinator of the Confedem Industry Chair, dedicated to promote the participation and collaboration of the Spanish mining industry in education programs and activities.

Kristina Jonsson is a Research Engineer at the Department of Mining Technology at LKAB (Luossavaara-Kiirunavaara AB) and a graduate from LTU. She works with projects aiming to improve the production process, both from a rock mechanics perspective as well as a mining engineering perspective.

Stephan Bealieu is chemical engineer working at Rusal Aughinish Alumina Refinery based in Ireland. He has worked in all process areas of processing bauxite ore to produce alumina which is primary raw material for aluminium production. He is also collaborates with universities and research institutes within Europe to develop new technology for bauxite re-use and to innovate in the development education and knowledge management.

Aldert Kamp is the Director of Education for the Faculty of Aerospace Engineering at TU Delft. He is deeply involved in the rethinking of engineering education at university level with a horizon of 2030, as a response to the rapidly changing world. He has been involved in university-level education policy development, renovations of engineering curricula and audits of national and international academic programmes. He is a member of the Council of the CDIO Initiative and Leader of the 4TU Centre of Engineering Education in the Netherlands.

Michael Försth is research manager at the Department of Safety at SP Technical Research Institute of Sweden. He also has a position as professor at Luleå University of Technology where he is faculty program director for the fire protection engineering bachelor and master programs. His main research interests are radiative heat transfer and two phase flows related to fires.

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