

# INTEGRATING SUSTAINABILITY ASPECTS IN MINING ENGINEERING EDUCATION

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## **ABSTRACT**

Providing higher education in the field of Mining Engineering means having the responsibility to provide the necessary competences for the next generations of decision makers in the field of raw material supply. These competences are the basis for solving future problems. A significant issue in the future of mining is Sustainable Development. It comprises the main future challenges in the conflict area between economics, environmental and social matters. The alumni of our study program should be aware of these and prepared for upcoming tasks. Therefore, a continuous integration of Sustainable Development aspects into the curriculum of the international Master of Science Program Mining Engineering at Clausthal University of Technology has been undertaken.

The objective is to prepare graduates at best for their future as professionals in Mining. For the integration of Sustainability two approaches were followed simultaneously. On the one hand, aspects of Sustainable Development were integrated in the usual technical oriented lectures. On the other hand, a compulsory lecture was installed to give the opportunity to develop an own view of Sustainable Development in Mining.

The lecture titled Advanced Underground Mining combines project-based learning with the approach of just-in-time teaching. The objectives are to link the existent knowledge from other lectures, in order that the student can act as an expert and communicate adequately with different stakeholders. The objective of the lecture titled Sustainability in Underground Mining is to encourage students to develop and express their own opinion. To this end, students elaborate first together in an active atmosphere the Basics and Methods of Sustainable Development, using fictional and real life examples and discuss them. In the second part, different stakeholders give presentation on their field of action. The students get the opportunity to discuss their action and approaches with regard to Sustainability.

The paper presents the mentioned lectures as non-traditional teaching and learning activities. It focuses on frame condition, learning objectives, realization and results.

## **KEYWORDS**

Sustainability, Mining Engineering Education, Lecture Design, Innovative Teaching and Learning, Standard: 2, 3, 7, 8, 11

## **INTRODUCTION**

Mining is the backbone of economy. The supply with mineral raw materials is directed to their extraction in underground and surface mines. It provides welfare and growth of economy and society. An average American born in 2016 will need more than 1.417 tons of minerals, metals and fuels in their life. (Minerals Education Coalition, 2016). Taking this as a basis and considering the increasing world population and prosperity level, it can be concluded that the demand for raw materials will increase in the future as well.

Meanwhile, the complexity of mineral deposits, the demand of raw materials and the increase in knowledge are leading to new economically, environmental and societal challenges. The combination of these issues leads to the main future challenge: Performance of Sustainable Mining. Future Mining Engineers act in the conflict area between the requirements from economy, environment and society. Hence, the consideration of Sustainability in their education represents an opportunity as well as responsibility for the future, which are taken by implementing the aspect of Sustainable Development in the master's course Mining Engineering.

### ***Objective***

The objective is to design higher education in Mining Engineering that meets the needs, tasks and working reality of future Mining Engineers in their work life by implementing aspects of Sustainable Development in their study program. Therefore, it is essential to identify correct learning objectives and design a concept which aligns them with the teaching and learning activities as well as the assessment.

### ***Methodology***

To find a correct design for the implementation, already existing approaches were investigated. Appropriate aspects were used and supplemented by already-existing ideas and thoughts for getting a consistent and suitable implementation approach for the higher education of Mining Engineers at Clausthal University of Technology.

## **COMMON WAYS OF IMPLEMENTATION**

In order to find a way of implementation, research was undertaken to find, on the one hand, important aspects to consider in the design and, on the other hand, to revise already implemented approaches.

The United Nations Educational, Scientific and Cultural Organization (UNESCO) declared the time from 2005 to 2014 to be the Decade of Education for Sustainable Development (ESD). Although the topic of Sustainability is diverse, essential characteristics were defined in many forms. (UNESCO, 2005) These can also be found in important aspects (Timpson, 2006) mentioned for successful education in Sustainability:

- Interdisciplinary Content of Learning
- Involvement of Students in the Context of Learning
- Active, experiential, inquiry based Process of Education
- Practice of Sustainability
- Partnerships with local, regional communities.

These aspects should be considered while developing the approach. Therefore, the approach will be evaluated and assessed as regards the level of fulfilment of these topics.

The implementation of Sustainability in the context of CDIO Education was discussed in different conference shares. (Cheah, 2014), (Cheah, Yang, & Sale, 2012), (Yang & Cheah, 2014), (Chua & Cheah, 2013) developed an approach for the chemical Engineering, while (Knutson Wedel, Malmquist, Arehag, & Svanström, 2008) and (Enelund, Knutson Wedel, Lundquist, & Malmquist, 2012) faced the challenge in the field of Mechanical Engineering and (Marasco, Moshirpour, Behjat, & Rosehart, 2016) in the field of Computer Engineering. (Hussmann, Trandum, & Vigild, 2010) and (Miñano et al., 2016) investigated on the arrangement of CDIO and Sustainability. These were taken into consideration while designing an approach for the Mining Engineering Courses at Clausthal University of Technology.

For the implementation in the field of Mining Engineering the University of British Columbia developed an approach for the Integration in Education and Research. Interdisciplinary Sustainability Working Groups have a key function in the approach. (Costa & Scoble, 2006)

One educational approach cannot fit whole situation. Teaching must be authentic and needs to fit to the teacher, student and the learning / teaching situation and environment. Therefore, the approaches referred to were used as an inspiration for the implementation at Clausthal University of Technology.

## **MINING ENGINEERING EDUCATION AT CUT**

As one of the oldest mining universities in Europe, founded in 1775, Clausthal University of Technology has a long history in Engineering Education. Starting as a school for mining engineers with courses in mining, metallurgy and mine surveying, later to be supported by courses in mining related law and economics, CUT concentrated on these fields of research and education for nearly 200 years, before expanding the range of courses in the 1960s. Such new courses as Chemistry, Physics, Process Engineering, Mechanical Engineering and Mathematics led to fast rising numbers of students. Thanks to these structural changes, follow-up measures and offering new courses in the following decades, the student numbers increased from about 1000 in 1965 to about 5000 today (2015).

Bridging the gap between tradition and innovation, today Clausthal University of Technology is still strong in education and research in the field of Raw Material Supply and Resource Efficiency. Besides developing innovative methods for the 21<sup>st</sup> century mine, the aim of the Institute of Mining is to educate engineers who are able to develop and apply up-to-date techniques and to face the challenges of today's and tomorrow's global mining industry.

Mining Engineering is an interdisciplinary field comprising the basics of engineering, economy, law and geoscience as well as the special approaches and techniques in Geology, Mining and Processing. In the field of Bachelor's courses (undergraduate program), CUT offers the Bachelor of Science "Energy and Raw Materials" (German: Energie und Rohstoffe) course. This course is split into the two specializations of "Energy- and Raw Materials Supply" as well as "Petroleum Engineering". It is designed for a regular study period of 6 semesters (3 years), with German as the language of instruction.

At the stage of Master's courses, "Mining Engineering" and "Petroleum Engineering" are two fully separated courses. Whereas the language in the Bachelor's course is German, the

Master's courses are entirely taught in English language, aiming at international students. As it is the case for all Master's courses at CUT, this course is designed for a regular study period of 4 semesters (2 years). The international character of the "Mining Engineering" course, with about 75% international students with diverse backgrounds, makes education very interesting but also challenging. Depending on their country of origin, the students at Clausthal have diverse previous knowledge as well as diverse experiences stemming from diverse education systems and learning cultures.

In both the Bachelor's and the Master's courses, the connection between the disciplines and impacts on environment and society are taught as an aside of the mainly technically and economically orientated study contents and not fixed in the course outline.

For a wider integration of Sustainability in the Master's course two ways were followed simultaneously. On the one hand, aspects of Sustainable Development were integrated in the usual technically oriented lectures. On the other hand, a compulsory optional lecture was installed to give the students the opportunity to develop their own view of Sustainable Development in Mining. These two lectures are presented in the following sections.

At Clausthal University of Technology Bachelor's and Master's Courses are structured in modules which consist of compulsory subjects and compulsory optional subjects. "The compulsory subjects are compulsory for all students for whom the respective module is compulsory. The compulsory optional subject can be selected from various modules." (Clausthal University of Technology, 2014)

### ***Advanced Underground Mining – Integration in a technically oriented lecture***

The lecture "Advanced Underground Mining" is a compulsory optional subject located in the third term of the Master's course Mining Engineering. First realized in the winter term 2016/17 it has 3 ECTS and is taught in 28 contact hours complemented with 62 hours of self-study time. The students participating in this lecture already know the basics of Underground Mining and have in-depth knowledge in Material Handling, Ventilation and Climatization, Underground Mine Planning and Equipment.

After the course the student should be able to

- link existing knowledge from the different areas of Underground Mining
- communicate their approaches in an appropriate manner with different stakeholders of Mining (Mining Experts, Society, Economists, Ecologists, ...)
- act as an Expert for Underground Mining.

In order to achieve these learning objectives, a special concept was designed, which compromises different teaching / learning techniques. The course can be structured in four stages, which are represented in Table 1.

The first stage is a half day-long lecture focusing on a getting to know each other in a personal and technical way. Expectations of students and teachers were identified, compared and discussed, learning objectives were presented. The students were introduced to the project situation where they act as one group of mining experts who should design a new mine nearby. The public acceptance was introduced as a main point of the project. The objectives of the stakeholders to communicate with were discussed. In the end the students had to decide if they were part of the project group, by naming the group together.

Table 1: Structure of the Course "Advanced Underground Mining"

Stage	Name	Objectives	Duration
1	Getting Started	<ul style="list-style-type: none"> <li>• Getting to know the group</li> <li>• Understanding the concept</li> <li>• Understanding the project situation</li> <li>• Forming the project group</li> </ul>	4 hours
2	Project work	<ul style="list-style-type: none"> <li>• Planning a new mine</li> <li>• Preparing for presentation</li> </ul>	3 months
3	Presentation	<ul style="list-style-type: none"> <li>• Convincing representatives from civil society of their ideas</li> </ul>	1 hour
4	Assessment	<ul style="list-style-type: none"> <li>• Convincing the technical expert of their ability and skills as an Underground Mining Expert</li> </ul>	20 minutes

The naming and group formation process introduced the project-based learning phase. In the time period of three months the students had the opportunities to get additional information and feedback on set dates every two weeks using just-in-time teaching. The students had to communicate their needs three days in advance. In cases when the teachers were not informed of any needs, no lecture was given. Additionally, the teachers offered support in personal talks and via email. Technically the students planned the mine and prepared a presentation for their talk to the public.

The third stage is the presentation in front of representatives from the community residing next to the planned mine. The students are free to choose their style of presentation. This presentation is mandatory for completing the lecture, but unmarked. The representatives are real persons from the community as well as university staff with a focus on Didactics and/or mining related topics. For preparation a mandatory trial presentation was conducted.

The Assessment in the fourth stage is a presentation of the students' concept in a single oral examination. The students have ten minutes to present their approach. Afterwards, questions are asked for deeper understanding. The performance is assessed by using eight criteria, which are linked to the tasks in the project and the learning objectives.

From the CDIO perspective, the students go through the stages of Conceive-Design-Operate-Implement, which differs in detail in comparison to a "classic" product. In the end of the first and the beginning of the second stage the students develop their understanding of the situation, mainly the presentation of a developed approach for mining. They design a solution for mining the deposit as well as communicate with the different stakeholders while linking the present knowledge and skills from other lectures. By setting a presentation concept they implement their strategy. In the presentation and assessment they need to operate.

Aspects of Sustainability are integrated by focusing on the interdisciplinary topic with a clear emphasis on environmental and social consequences.

### ***Sustainability in Underground Mining – Integration through a compulsory optional subject***

The lecture "Sustainability in Underground Mining" is a compulsory optional subject. The basic characteristics (CP, hours,...) are similar to the above presented lecture. The learning objectives are

- understanding sustainability and the importance of it, Current state of art of sustainability in mining,
- providing the basics to lead the students to critically think about sustainability in the mining industry,
- improving presentation skills.

To sum, the goal of the lecture was defined as the students' having their own critical opinion on Sustainable Development in Underground Mining. For achieving this goal, different concepts and styles were combined and a fitting assessment was developed. These points are presented in the following sequences.

The Learning/Teaching Activities can be structured in three areas as shown in Figure 1.

What?	Basics and Methods of Sustainability	Getting to know views and ideas	Finding own position to given question
Who?	Students / Teacher	Students / Mining Stakeholder	Students
How?	Class room learning	Keynote speeches and discussion	Development of an own approach

Figure 1: Structure of the lecture “Sustainability in Underground Mining”

In the block “Basics and Methods of Sustainability“ a basis for the further course is provided in an active learning atmosphere. Different examples directly related to Mining were discussed in certain points to connect the abstract notions with a specific implementation. This block of nine contact hours is conducted in three meetings. Activating Methods are implemented to motivate and involve the students and foster the professional, practical, social and self-competences. The meetings, which are held close to the beginning of the semester, focus also on sensitization and the discussion in the group.

In the second block key notes are held from different stakeholders from the field of mining. After and during the presentation the presented approaches are discussed to link the basic knowledge with the specific mining situation. The structure is variable and can be adapted to different speakers. Besides direct presentation at the university and videoconference key notes there is the possibility to include the visits for conferences and companies into the second block. The flexibility simplifies the realization. The speakers are chosen from different backgrounds with a special regard on the representation of each stakeholder area as shown in Figure 2.

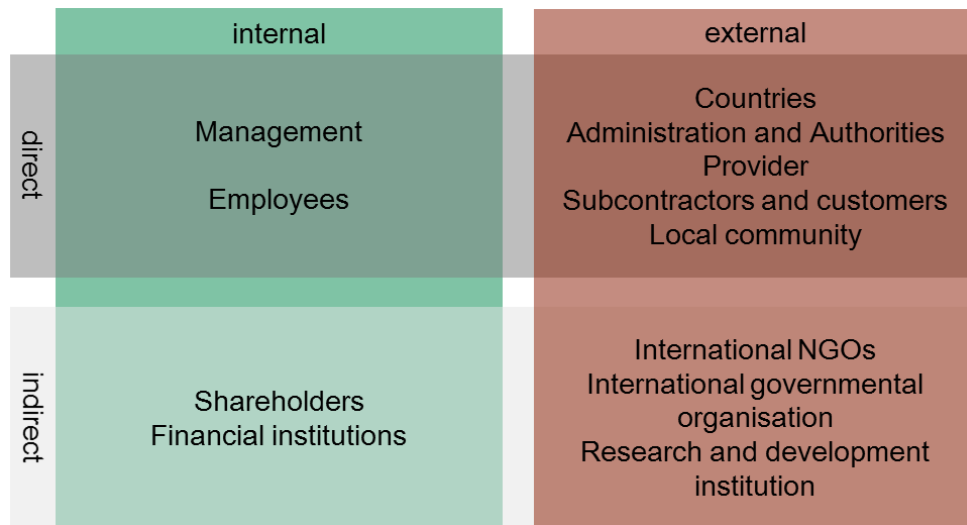


Figure 2: Stakeholders of Mining Activities

The third block focuses on self-study of the student. He/She reflects on the different meetings and presentations and investigates on one's own. In the research the students are free to choose their own way. The investigation is supported by allusion to interesting publications in the relevant field. The objective is to help students develop their own critical opinion on Sustainability in Underground Mining. The teacher acts in this block as a coach who answers questions and gives suggestions. Furthermore, the student gets a peer-to-peer feedback in a private poster session.

The achievement of the learning objectives is assessed in an oral examination, simplifying the competence oriented assessment. The process of the assessment is transparent and announced in the first lecture. The assessment is structured in two parts: in the first ten minutes the student accomplishes the sentence "Sustainability in Underground Mining is for me..." and elaborates his/her statement in following time. A prepared poster can be used as a supplement. In the second half the statement is discussed and further question are asked. The examination is assessed by using five assessment criteria, which are the engagement of audience, the methodology, the quality of arguments used, the usage of examples and the style of presentation. This criteria was developed with the students in a feedback session, when they presented their initial ideas. For each grade (very good, good, satisfying, sufficient, not sufficient) explanation is provided. The table with criteria and grading is accessible for all the students.

With regards to the CDIO approach the action Conceive, Design and Implement are performed by the students. First they need to get an impression of the situation and elaborate their own understanding, which is presented in the assessment. In their future career they will perform the "Operate", acting as a mining engineer with a trained view on Sustainable Development.

### ***Fulfillment of aspects by (Timpson, 2006)***

To approve the fulfillment of the above mentioned aspects by (Timpson, 2006), they are compared with the developed approaches. Results are shown in Table 2. All aspects are covered, but there is also potential of improvement. The success of the concept will be

shown after the first semester is completed and moreover by means of feedback from our alumni in a few years. Until then the courses will continuously be evaluated and improved on the basis of the evaluation results and experience as shown in the next section.

Table 2: Application of aspects by (Timpson, 2006) in the presented lectures

Aspect	Advanced Mining	Underground Mining	Sustainability in Underground Mining
<b>Interdisciplinary Content of Learning</b>	Connection of known topics		Diversity of Keynote Speakers
<b>Involvement of Students in the Context of Learning</b>	Student centered Teaching, Transparency, Constructive Aligned Teaching		
<b>Active, experiential, inquiry based Process of Education</b>	Student centered activating Teaching		
	Experiential learning in group and presentation situations	Development of an own view	
<b>Practice of Sustainability</b>	Self-critical development and presentation of an idea		
<b>Partnerships with local, regional communities</b>	Local project framework and audience	Regional Key Note Speakers and Field Trip Targets	

## EXPERIENCES AND PERSPECTIVES

Both lectures were held the first time with the explained concept in the winter term 2017/2017, which ended in March 2017. Most of the participants have already taken the examination. In the oral examination the students showed constantly a good to very good achievement of the learning objectives.

Different evaluations have been undertaken during and after the lecture. The evaluation of the lecture titled Advanced Underground Mining is mainly based on personal interviews with students and participants of the community talk. During the lecture, feedback was often put directly into practice. At the beginning students often commented that they were not learning anything. In the end they came to realize how to deal with the unfamiliar situation of talking to community members. The participants of the community have also responded positively. An important point, which needs to be improved, is the moderation of the event and the preparation of the participants.

During the lecture titled Sustainability in Underground Mining, feedback was given at each lecture to provide continuous improvement. For the feedback DIN A6 sheets with a plus, a minus and a mouthless smiley were distributed. The students indicated the points they liked the most with the plus and the points which need to be improved with the minus. In addition they completed the smiley with their current mood. The students were mainly in a happy mood after the lecture. They liked the open discussion, collaborative nature, the comforting atmosphere and the discussion with external experts in class. They want to have more details about some topics and more colleagues to discuss with. The experts invited to the sessions enjoyed the discussion with the students as well as the critical questions and views. While preparing for the examination, which represents the third area with regard to Figure 1, some students expressed that they were facing a new, unusual situation because they were not focusing on the given content. The variety of topics presented in the oral examination shows the diversity of students and sustainability.



In an overall survey, students who visited the mentioned subjects were more likely to identify social awareness and acceptance as the biggest challenge in Mining than the students in the control group, who focused more on environmental challenges.

In the first runs, the concepts seem successful and effective to students, teachers and involved persons. Therefore, they will be refined and applied again in the next winter term. The collaboration with the different stakeholders will be deepened and relevant topics will be picked up. Different parties have already shown interest in supporting the subjects. The main goal of the procedure is to keep the discussed topics relevant and updated. Consequently, the alumni of the Master's course will be prepared for their role as Mining Engineers of the future.

## **SUMMARY**

The paper shows a possibility of implementation of Sustainability aspects in Mining Engineering education. Sustainability is one of the key future topics not restricted with the field of Mining. Clausthal University of Technology has identified the demand for Mining Engineers who are aware of this aspect. Therefore, the topic was implemented in the curriculum of the Master Program Mining Engineering.

Two course models, which particularly focus on Sustainability, are presented. In the subject titled Advanced Underground Mining, it is integrated in a mainly technically-focused course. The student were asked to achieve the learning objectives within a project, which was accompanied by a just-in-time counseling. The main challenges was the communication with different new stakeholders. The subject titled Sustainability in Underground Mining focuses on the development of an own critical view in the area of Sustainability. In the three stages of the course, the learning format varied. A strong focus is given in an active and collaborative atmosphere.

The first runs in the winter term 2016/17 showed that the students achieved the defined learning objectives very well through the active engagement in the course. Therefore, the concepts will be revised, improved and kept for the following semester.

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**Alexander Hutwalker** is a Scientific Research Assistant at the Department for Underground Mining Methods and Machinery at the Institute of Mining of Clausthal University of Technology. His field of research is occupational safety and health, focusing on toxic fumes occurring in underground mining activities. When it comes to Mining Engineering Education he focuses on the implementation of methods to activate the participants in the lecture and to encourage them to link their knowledge gained in their studies by the design and methodology of the lectures. Furthermore, he is the contact person for all questions regarding the Master course "Mining Engineering" at Clausthal University of Technology.

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