INNOVATIVE LEARNING SPACES FOR EXPERIENTIAL LEARNING: UNDERGROUND MINES

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ABSTRACT

Underground Mining is characterized by a high degree of complexity and singularity due to specific deposit conditions and complex interactions with the environment. To gain a deep understanding of underground processes and its influencing factors traditional abstract teaching approaches mainly do not cover theses complexities in sufficient detail while at the same time students are lacking of underground experiences and knowledge. To connect the students as early as possible with potential future working environments the understanding of relevant methods and processes could be facilitated by hands-on-teaching situations and/ or in authentic learning spaces.

Facing these challenges the objective is to design, select and integrate authentic learning spaces into underground mining engineering courses and to encourage experiential learning. For a successful course implementation the learning spaces need to be aligned to the intended learning objectives and respective teaching and learning methods.

Therefore, different authentic learning spaces for fostering experiential learning were consequently developed and successfully implemented into existing courses of B.Sc. as well as M.Sc. - Program at the Institute of Mining at Clausthal University of Technology in recent years. Places for these teaching-and-learning activities is for example a research and teaching mine, which was established at the former ore mine and nowadays World Heritage Site Rammelsberg in close distance to the university. Furthermore cooperation with mining companies, manufacturers and other operators of underground facilities were assembled to design learning spaces fitting to the course content, learning situation and lecturer philosophy. In addition the spatial situation at the Institute was revised and working spaces are set up as a flexible learning environment.

The paper will give an overview of the realization of the CDIO Standard 6 in the framework of Underground Mining Education by presenting examples of innovative authentic learning spaces and their implementation into Mining Engineering courses at Clausthal University of Technoloyg.

KEYWORDS

Mining Engineering Education, Learning Spaces, Underground Learning, Experiential Learning, Innovative Spaces, Mine Ventilation and Climatization, Standard: 6

INTRODUCTION

Underground Mining is characterized by a high degree of complexity and singularity due to specific deposit conditions and complex interactions with the environment. The working environment is mainly unique, only partly known and difficult to understand. The influencing factors are diverse and connected to cluster of origin as well as the processes and approaches for mine design and operation are complicated. The connection of aspects makes it difficult for the students who are lacking of underground experiences and knowledge at the same time for understanding and following the course content. Hence traditional teaching approaches are less appropriate to cover and communicate the described complexities. Therefore it is a challenge for lecturers in this field to guide students to gain a deep understanding of underground processes and its influencing factors. Innovation is needed.

Our approach is to familiarize students as soon as possible with the future working environment and potential working situations. Experiential learning is fostered by hands-on-teaching situation. Locating them in authentic learning spaces completes the approach.

The objective is to combine experiential learning with authentic learning spaces to foster a deeper and holistic understanding of the complex area of safe, efficient and sustainable underground production of raw materials. Therefore it is necessary to design, select and integrate authentic learning spaces into underground mining engineering courses and to encourage experiential learning.

For achieving these goals different authentic learning spaces were consequently developed and implemented into existing lectures of B.Sc. as well as the M.Sc.-Course at the Institute of Mining of Clausthal University of Technology (CUT). The papers will give two examples for the implementation focusing on the “Learning Lab” and the “Research and Teaching Mine Rammelsberg”.

SPACES FOR EXPERIENTAL LEARNING / CDIO STANDARD 6

Experiential Learning as introduced by (Kolb & Fry, 1974) analyzes the general natural learning approach of humans to transfer it to the educational background. The experiential learning model is based on four stages, which form a cycle: a concrete experience is followed by observations and reflections in the second stage, where data about the experience are collected by reflecting on the experience. In the third stage the data are analyzed during the formation of abstract concepts and generalization. The concept developed is tested in the fourth stage with implementation and application to a new situation. Individual learning styles are established by the emphasis set and methodology chosen in the different stages. Hence Implementing Experiential Learning means to consider the different learning stages and to offer support at the different stages by designing of tailor-specific course content and environment.

Each learning experience takes places in a multilayered environment. (Bronfenbrenner, 1977; Bronfenbrenner, 1979) defines four systems as levels for the learning Space: Microsystem, Mesosystem, Macrosystem and Exosystem. The immediate setting which can be a classroom is described by the microsystem. The Mesosystem is represented by the closer environment of the learners for example his/her family and life situation. The Exosystem comprises the structures which influences the person’s environment. Examples are formal and informal social structures. The Macrosystem is influenced by the institution and society with their structure, values and culture. As a teacher we can reasonably change the Microsystem by adjusting the style and environment of our lecture. Changes in the other systems can be just partly initiated by teachers. Therefore the paper focusses on the Microsystem with a particular focus on the spatial design.

The sixth Standard of the CDIO Initiative also deals with the physical design of the learning Environment in CDIO based Engineering Education. The Standard is formulated as:

"Engineering workspaces and laboratories that support and encourage hands-on learning of product, process, and system building, disciplinary knowledge and social learning" (CDIO Initiative, 2010)

Hands-on-Learning focuses on the real experience as the event, which starts the learning cycle. The present work also implements the sixth Standard of CDIO.

Besides the chaperonage, appropriate guidance and partly instruction in the stages observation/reflection, concept design and testing emphasis is particularly on the use of Underground Spaces to provide conducive experience. Two of these learning spaces will be described in the following section.

UNDERGROUND LEARNING SPACES FOR MINING ENGINEERING EDUCATION AT CLAUSTHAL UNIVERSITY OF TECHNOLOGY

Today's Clausthal University of Technology (CUT) was founded in 1775 as a mining academy. During its history, the Royal School of Mines (1864) broadened its focus and covers today in research and study programs the whole range from natural sciences and raw materials to material sciences, over mechanical and Process Engineering to Economics, Computer science and advanced Electronic Waste Recycling. CUT main research areas are Sustainable Energy Systems, Raw Material Supply and Efficiency, Materials Science and Processes, Cyber-Physical Systems and Simulation - more than 50% of the professorate are acting in Raw Materials related research areas, coordinated in Clusters for fostering interdisciplinary research. The University runs several students laboratories and a Research and Teaching Mine in cooperation with the World Cultural Heritage Rammelsberg, a former ore mine with more than 1000 years of production and supports a well-established network to regional and nationwide industrial partners. Good teaching with the integration of competence-oriented, students-centered innovative teaching and learning approaches is import for CUT. Therefore the Centre for Higher Education offers a Professional Certificate in Teaching and Learning in Higher Education as well as a variety of different courses in Higher education and personal coaching. CUT is a partner in the project "European Initiative on CDIO in Raw Material Programmes" (Edelbro et al., 2017) with the focus on Faculty Development and hence participation in CDIO- courses as well as design and enhancements of student workspaces, labs and active and experimental learning. Besides developing innovative methods for the 21st century mine of the future, the aim of the Institute of Mining is to educate engineers who are able to develop and apply up-to-date advanced mining technologies and to face the challenges of today's and tomorrow's global mining industry.

For coping with the challenges of the Mine-of-the-Future, future Mining Engineers need besides a deep understanding of fundamentals of engineering and geosciences and the ability to complex systemic thinking well trained competences in the sense of "T-shaped" professionals. Therefore traditional teaching methods focusing on broad transfer of knowledge need to be complemented with innovative teaching and learning approaches. Nevertheless experience made in the tradition of teaching are still considered. A main issue is the involvement of hands-on elements. This papers presents two spaces and their usage mainly in the lecture “Mine Ventilation and Climatization”, which is part of the Bachelor Course B.Sc. Energy and Raw Materials. The general teaching concept in the field of Ventilation and Climatization, which is underlying this lecture is described in (Clausen, 2015). The „Learning Lab“ provides in a two room situation the possibility to go through all steps of product design. In the respective lecture the situated Ventilation Lab is used. The “Rammelsberg Mine” offers a plenty of working spaces in Underground, which are exemplary presented. On the one hand the lab provides a self-learning environment for student research. On the other hand the Rammelsberg Mine represents a mining environment, where students can deal with realistic case studies and szenarios.

Learning Lab

The idea of the “Learning Lab” is to provide appropriate rooms for groups as well as for individual work, which can be used for all lectures during the contact hours or self-learning time. The principle enables teachers as well as learners to use the room in a diverse and modularized manner, which can be adapted easily to different requirements. The development of the room concept started in 2013 with the provision of the room and is still ongoing. Meanwhile different teaching/learning concepts were realized in the room. A considerable change was caused by the modernization of the building and the associated move to new rooms. Taking this change as an opportunity a room concept was developed which is inspired by different presentations at the 12th International CDIO Conference in Turku. The concept is not fully implemented due to ongoing construction works. Figure 1 shows the actual setting in the experiential part of the Learning Lab.

Figure 1: Learning Lab

The objective of the concept is to design a flexible working space which enables students and teachers to establish different flexible teaching and learning settings while minimizing space constraints. Therefore flexible furniture is installed. In the group working room the table as well as the chairs are adjustable in height. For presentation and discussion purposes a central monitor as well as whiteboards and other paper based moderators materials can be used. The experiential room shown in an earlier development stage in Figure 1 is furnished with foldable table and stackable chairs. Therefore different settings can be realized by rearranging these. Different models of mining methods (e.g. hanging from the ceiling), ventilation methods and shaft support are located at the Lab.

The central part of the learning lab with reference to the education in the field of Mine Ventilation is the test stand, which is developed internally at the department. Within tutorials and assignments students develop their understanding of fluid dynamics and its relevance to mine ventilation by using and modifying the test stand. Different settings can be assembled, measured and analyzed with minor support of a student assistant. The room provides the possibility for further discussions so that the student can stay in the room based on their individual pace and learning progree.
In both rooms storage compartments are installed for personal, group and teaching items. The access is realized by a chip-based lock system which allows a flexible entrance for students. The learning lab represents a learning space directly at the facilities of the university, which can be used flexible by students and teachers.

Rammelsberg Mine

The Rammelsberg Mine is a former ore mine situated at the northern edge of the Hercynian mountains in the city of Goslar. The mine production was documented over 1.000 years until it was terminated in 1988. Meanwhile more than 30 million tons of silver, copper and lead ore were extracted. After closure the mine was transformed into a Museum, which welcomes more than 100.000 visitors annually. In 1992 the Rammelsberg became with the historic city of Goslar a UNESCO World Heritage site, which was expanded in 2010 by including the Upper Harz Water Management system.

After establishing an official partnership in 2010 between CUT and the World Heritage Site Rammelsberg the former ore mine became the teaching and research mine of the University at the 16th of January 2013. The partnership was shaped by research projects underground, scientific conferences on montane history and mainly on lectures conducted at the Rammelsberg Mine. The alliance combines the traditional mine site with the innovation of research and education at CUT. The variety of possible uses exceeds the framework of this paper. Therefore typical examples are shown below.

The Rammelsberg Mine offers plenty of rooms, which can be used in a variety of different settings. Besides the surface installation with seminar rooms (e.g. for safety instructions) mostly all open areas in underground can be used. Restrictions are caused by areas with instable conditions and the flooding process. Due to flooding of the lower levels after the termination of production cavities are only usable in the higher area above the “Rathstiefsten Stollen” which is the level of 293 m. Underground learning location can be equipped with chairs and benches as well as with presentation equipment, power supply is available.

Figure 2 shows a common learning situation located in Underground. The main advantage of locating this kind of learning activities underground is the vicinity to the mining environment where effects can be shown and measurements can be undertaken. Additionally the students are more concentrated due to the insufficient mobile network. At the Rammelsberg Mine rooms for different group sizes up to 50 people are available. So the learning space can be adjusted to the situation. These areas are appropriate for group based learning as well as for example for preparing measuring campaigns.

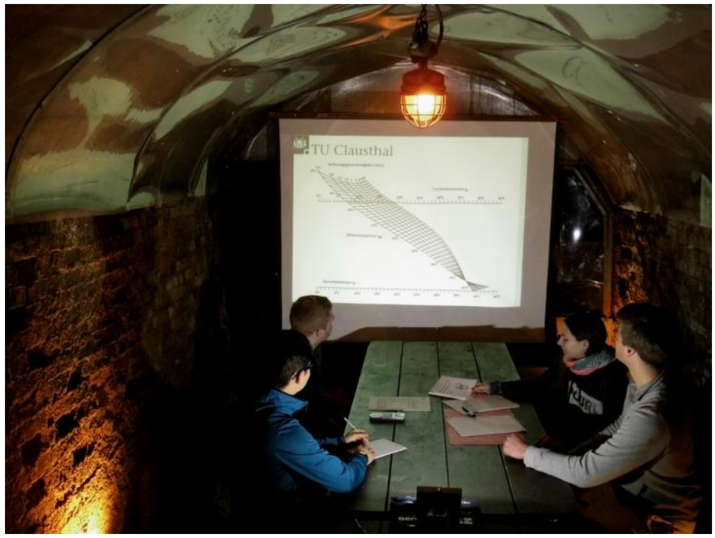

Figure 2: Learning in Underground

The design, conduct and evaluation of a Ventilation survey is an important and major tasks of Mining Engineers working in the field of Ventilation. The students are learning while working on specific tasks how to plan, conduct and analyze a mine ventilation network. They work individually or in a group as shown in Figure 3. Besides the direct tasks the students foster their skills in project management, organisation and documentation and need to show social and self-competences.

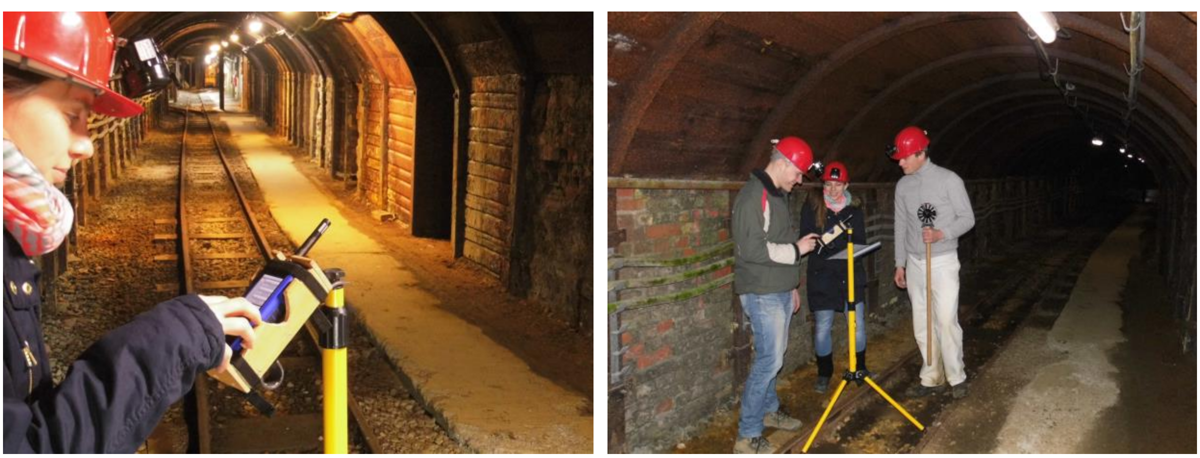

Figure 3: Ventilation survey, individually (left side) and in a group (right side)

By the selection of the settings different levels of difficulty can be realized. Figure 4 shows the comparison of two situations. The left one can be used for the introduction on a basic level. The elements are clear and the drift has no curve. The right situation is more challenging: besides the duct different types of support and intersection of drifts must be considered. Students develop by understanding the simple setting according to the Experiential Learning Approach a procedure for measuring which can be tested and refined by application in more complex situation. For being successful in underground mining operations it is important to get a quick and thorough overview of the environment and the influencing factors and then having the ability and "toolbox" to adapt known procedures to the specific conditions.

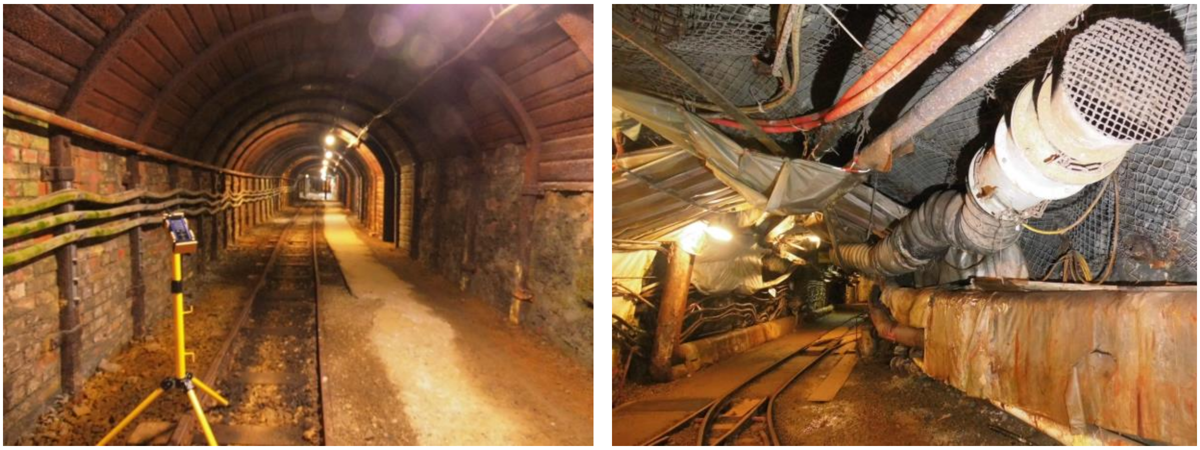

Figure 4: Different settings, simple (left side), more complex (right side)

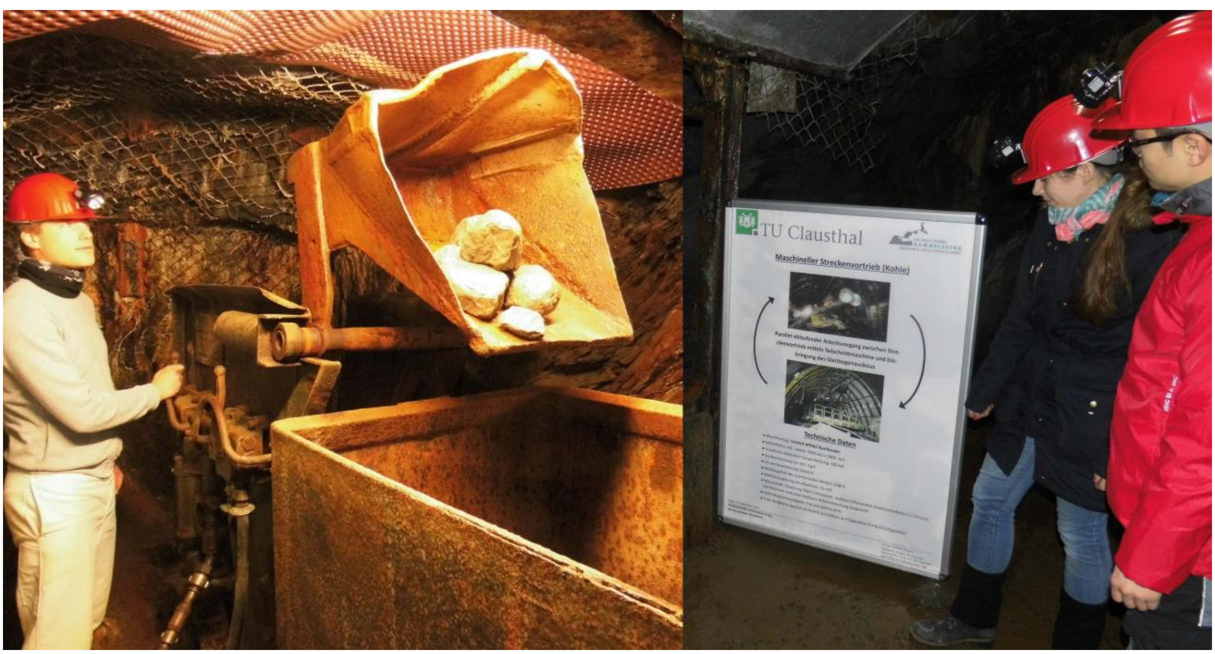

Figure 5: Combination of equipment, information poster and of course students

Another situation is shown in Figure 5, where old equipment nowadays used in an exhibition, and technical information presented as a poster are combined. Using the technical exhibition area, where the drilling and blasting cycle for road development in ore Mining is presented, students for example have the task to calculate the needed amount of fresh air. Therefore they need to analyze and understand the process, filter the given – partly unnecessary - data to get the relevant information and to use appropriate engineering tools for finding the solution. A following task could be the ventilation design for the exhibition area which is directly comparable to an underground mining section. In summary students tend to believe

“understanding” simply is the ability to reproduce knowledge. But reality comes with unexpected challenges. Conducting our ventilation tutorials at the Rammelsberg Mine, they are challenged with tasks and problems that ventilation engineers are facing every day. Questions arise and students start approaching the problems from an all new position, consolidating their knowledge. Most of the students say, they would highly appreciate the practical tutorials as they were a good complement to the lecture. In addition (Clausen, 2015) observed a general positive relationship between a combined teaching and learning approach using lectures in class, hands-on learning in lab and learning in an authentic learning venue on the professional performance, acquisition of competences and student`s motivation.
The following exemplary feedback from students show that they see a direct relationship between the integration of authentic and innovative learning spaces and their individual learning success:

- “In opposite to many other lectures, the mine ventilation course allowed us to demonstrate our theoretical knowledge from the lectures in a practical mine ventilation surveying situation. However, we did not only apply our knowledge, but we were also facing new, unexpected problems that had to be solved on the spot. Conducted like in a real engineer’s life situation, the tutorials at Rammelsberg prepared us best for our future every day job in a mine.”
- "I highly appreciated the practical orientation of Mine Ventilation I. Surveying at Rammelsberg Mine helped me to gain a feeling and practical understanding for the measurements. Leaving the lecture hall and applying my knowledge in a real mine surrounding enhanced my comprehension of the course´s content as well as my interest in the subject itself."

PERSPECTIVES

This paper presents an excerpt of innovative learning spaces, one in underground. Additionally the integration of field trips, underground project work and other authentic and realistic learning / teaching activities lead our students to individual learning experiences which foster a deeper learning and understanding while enhancing at the same time additional relevant key competences.

Involving the feedback and evaluation of students as well as the personal experience and latest scientific findings concepts for experiential learning and appropriate learning spaces and their implementation to the study courses will be further developed and enhanced. The cooperation with already existing and new partners such as the CDIO Initiative opens doors to new ideas and challenges. The primarily goal will always be to prepare and enable our students best to their professional and social life.

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REFERENCE LIST

Bronfenbrenner, U. (1977). Toward an experimental ecology of human development. *American Psychologist, 32*(7), 513–531.

Bronfenbrenner, U. (1979). *The ecology of human development: Experiments by nature and design.* Cambridge, Mass.: Harvard University Press.

CDIO Initiative (2010). *The CDIO Standards v 2.0.* Retrieved January 30, 2017, from http://www.cdio.org/files/standards/CDIOStds&Rubricsv2.0_2010Dec8.pdf.

Clausen, E. (2015): Measuring the effectivity of a combined teaching and learning approach on the professional performance, acquisition of competences and student`s motivation. In: Helmut Mischo und Carsten Drebenstedt (Hg.): Latest Innovations in Mining Education & Research. Proceedings of the 26th Annual General Meeting & Conference of the Society of Mining Professors (SOMP). 26th Annual General Meeting & Conference of the Society of Mining Professors (SOMP). Freiberg, Juni 2015, S. 43–48.

Edelbro, C., Hulthén, E., Clausen, E., O'Donoghue, L., Herrera Herbert, J., Jonsson, K., Beaulieu, St., Kamp, A., Försth, M. (2017). European Initiative on CDIO in Raw Material Programmes

Kolb, D. A., & Fry, R. E. (1974). Toward an Applied Theory of Experiential Learning, 33-57. Retrieved January 27, 2017, from https://books.google.de/books?id=jl72GwAACAAJ.

BIOGRAPHICAL INFORMATION

Dr. 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 Climatization 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.

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