

Education 4.0: MiReBooks - Development and Usage of Mixed Reality for Teaching Mining in Higher Education

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Abstract

In order to meet workplace demands in relation to Industry 4.0, the MiReBooks project was established in 2019. The main focus of this paper is to present the project's outcomes in the field of Education 4.0 whereby, Mixed Reality (MR) Mining Engineering educational material was developed for teachers, this in order to integrate MR in classroom instruction with the aim to enhance student understanding and application of knowledge to increase their competence in the specific field of the subject. An account of a MR application in a mining lecture is presented, together with student feedback, providing grounds to ascertain that the integration of such technology can improve student learning in the achievement of lesson/course Learning Outcomes.

Keywords: *Mixed Reality; Mining; Education 4.0; Teaching & Learning; Engineering.*

1. Introduction

The economic age of rapidly advancing technology, digital transformation and workforce demands, set exceptional challenges on educational systems to prepare graduates for their future careers (Teo et al. 2021). The advancement of Industry 4.0 requires educational institutes to transform teaching and learning approaches and to conceptualise new learning content to meet the demands of industry now and in the future. This approach further requires the training of transversal skills which permit learners to not only acquire technical knowledge but also with opportunities to train soft skills and promote an adaptive mindset and readiness to flexibly engage with new methods to deal with the intricacies of technological advancements and uncertainty (Ralph et al. 2022).

Ergo, Higher Education Institutes (HEIs) play a pivotal role in contributing to industry required competences by ensuring the workforce readiness of their graduates. Within the discipline of engineering education, with a particular focus in the field of mining, traditional based teaching and learning techniques prevail. Frontal based theory lectures are supplemented, when possible, with onsite mine visits, which limits the student's possibility to interact with the mining operations at a meaningful level.

In 2019, the 'Mixed Reality Handbooks for Mining Education' project was launched (MiReBooks). This being one year after the release of the Digital Education Action Plan 2018-2020, from the European Commission. This action plan laid the foundation for innovative education, setting out the skills, knowledge and attitudes citizens need for life, including digital competence (Eu Comm. 2018).

The MiReBooks was a successfully applied for project funded by the European Institute of Innovation & Technology (EIT), within their Raw Materials Knowledge Innovation Community. In 2019, the project commenced with the aim to create a new digital teaching and learning experience which would enhance and optimise traditional paper-based education by enriching it with virtual and augmented reality-based experience.

The MiReBooks project comprised a consortium of core HEIs, Industry entities and research institutes and was led by the Montanuniversität Leoben in Austria. The other core HEI partners were, Luleå University of Technology (LTU), Rheinisch-Westfaelische Technische Hochschule Aachen (RWTH) in Germany, Tallinn University of Technology in Estonia and the Technische Universität Bergakademie Freiberg (TUBAF) in Germany, Technische Universität Graz (TUGraz) in Austria, Università di Trento (University of Trento). Also, research institutes and companies comprised of core and associated partners connected to the project were, KGHM Cuprum sp. z o.o. Centrum Badawczo-Rozwojowe (KGHM Cuprum Ltd. Research & Development Centre) in Poland, Teknologian tutkimuskeskus VTT (Technical Research Centre of Finland Ltd. VTT) in Finland, Luossavaara-Kiirunavaara AB, LKAB in Sweden and Epiroc AB also in Sweden (MiReBooks 2019).

The main objectives of the MiReBooks project involved the following aspects:

- The development of an instructional ‘Didactical Handbook’ on using/integrating Mixed Reality in lectures
- The development of a Virtual Reality lecturing tool
- The development of Mixed Reality integrated Mining book series

This paper will serve to demonstrate the abovementioned outcomes of the MiReBooks project and provide insight into current/future activities. It will also present an account of the didactical usage of ‘Mixed Reality’ in a Mining lecture, as taught at the Montanuniversität Leoben, Austria within the academic year 2022.

2. Project Objective and Scope

The overall scope of the project was to develop a new digital learning experience that would innovate the teaching, learning and subsequently applying, of mining engineering education at a tertiary level. Combining state-of-the-art pedagogical methods with digitalisation of teaching materials, students are able to maximise and take advantage of new ways of classroom interaction that is more suitable for the needs of their generation as digital natives. The tools and material outcomes from the project are correspondingly designed in such a way that it is also attractive for professional industry application targeted at life-long learners to bring existing employee’s competences in line with the latest developments.

2.1. MiReBooks – Didactical Handbook

One of education’s most important tools is pedagogy and subsequently, the didactics applied for teaching/learning materials (OECD 2019/20). One of the pinnacle outcomes from the project was to develop a didactical handbook for educators to understand and aid them in the use of mixed reality (MR) in lessons. The book was developed and designed by pedagogues in the English language and split into 4 chapters.

Chapter one provides an introduction to the applications of Mixed Reality in connection with Raw Materials in lessons, Education 4.0. It provides deeper understanding and examples of what, and how, MR aspects can benefit teaching and learning. Chapter two provides input on Teaching 4.0. It specifically addresses didactics in education through the understanding and application of Bloom’s Taxonomy to derive appropriate Learning Outcomes for lessons integrating MR technology. It explains in detail Gamification and other methods for teaching and how MR technologies can be applied in Raw Materials related education. Chapter three provides a deeper account/understanding of teaching with Mixed Reality and the various means that can be applied e.g. VR headsets, handheld devices e.g. mobile phone and possible MR content. Finally, chapter four provides the reader with the practical set-up of integrating

MR elements in domain teaching. It offers the reader a MR decision matrix to help guide the lesson development to the appropriate MR tool for the purpose of instruction.

The MiReBooks Didactical Handbook is provided free of charge for all educators who would like to apply these technologies in their lessons with the goal to improve and aid the understanding and application of aspects in relation to e.g. mining engineering education.

2.2. MiReBooks – Virtual Reality Lecturing Tool

MiReBooks VR lecturing tool introduces the use of 3d models and 360° videos and images to the lectures in the classroom as well as online for remote teaching. The MR media contained in the book can be accessed for use in lectures and to enhance comprehension of complex topics. The tool takes over the role of electronic presentation software e.g. PowerPoint, including VR media, while allowing lecturer/student interaction. The VR lecturing tool requires the use of VR headsets, currently Oculus Quest 2 is being used for the students and a tablet, or laptop, for the lecturer to convey the lesson. The lecturer can play 360° videos and images and/or 3D models as part of the presentation. When in a new 360° exciting environment it is easy for the students to get distracted and lose focus on the teaching activity and miss the learning outcomes. To avoid focus diversion, the lecturer has some features available to keep the student's focus. These features allow real-time (RT) drawing on the 360° video/image or 3D model and field of view blocking. The lecturer has also an overview of the connected student's status, to detect any connection issues and even loss of focus from students. The students also have access to features, such as question placement and 3D model manipulation. All these features ensure enough control over the VR environment so that the learning goals can be achieved more efficiently than with traditional methods.

2.3. MiReBooks – Mixed Reality (MR) Integrated Mining Book Series

One other important outcome from the project is the development of a mining book series with integrated MR material. The development of this is a cross collaboration of several Universities in Europe. The overall focus is on sustainability in mining and a total of 7 books are in the series. These have been written by leading experts in the topic field from the Universities' and each book covers the following topics: 1. Sustainability and Mine Planning 2. Safety in Mining 3. Rock Fragmentation 4. Surface Mining 5. Underground Mining 6. Rocks Mechanics and lastly, 7. Mine Closure.

Each mining handbook includes QR codes (Links) which trigger extra learning content. This enhances comprehension of complex topics and provides more material to extend the competence of the students. The platform is based on a webpage. The content linked to the QR codes have different natures:

1. Study cases: are for the student to put into practice what they learn in the books. So, competence on the topic can be tested by solving problems of performing calculations.
2. AR 3D models: can be explored on the platform and also as AR with the help of a smartphone or tablet. The platform has an AR 3D model delivering system that bridges the need for an APP. From the platform, the camera from the student's smartphone is used to show the 3D models as AR. 3D visualization helps to understand the spatial distribution of operations and promotes self-exploration as well as technical discussions in the classroom.
3. 360° videos and photos: can be explored from the browser or with the help of smartphones/tablets and VR headsets (e.g. Oculus Quest 2). By using VR headsets, the student is immersed in a VR environment which helps with understanding the scale and distribution of operations.
4. Links to more content: VR and AR are not always the best tool to enhance comprehension of every topic. Conventional videos, as well as content on other web pages, are shared to promote the students further reading and researching.

While the platform is conceived as a tool to share multimedia content triggered by the books, users must find value in it even if they do not own any of the MiReBooks handbooks. All content shared on the platform will include enough explanation so that it can be understood and useful for all platform users.

3. Learning Pathway

The following section will provide insight into a university lecture, the use of virtual reality to support the understanding and application of knowledge in the classroom and the continuous feedback from students which allows insight for improving the user experience from both the teaching and technological sides.

3.1. Continuous Mining Methods – Surface Mining (held on November 29, 2022)

A total of 15 students studying mining engineering attended a two-hour lecture about surface mining. The didactical set-up was the integration of a MR environment whereby, each student was provided with a VR headset and given instructions on its functionality. This method is used specifically to aid the teaching and learning knowledge transfer. The learning outcomes for the lesson where: upon completion of the lecture the student will be able to 1. Understand the basics of continuous surface mining methods and 2. Explain the different surface mining operations. During the lesson the students used MiReBooks programmed VR headsets and were transported virtually onsite to two running open coal pit mines located in Germany (Hambach and Jänschwalde). This allows the student full access to all operational aspects of the mine that otherwise would not be accessible or difficult to arrange as a site visit. Ergo,

the knowledge transfer goes hand-in-hand with the practical insight into the material being taught and the lecturer is able to explain in detail what they are seeing, how it works and the different surface mining methods that are applied.

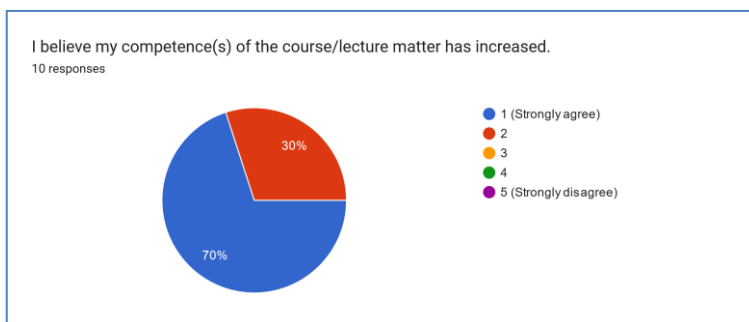
Directly after the lesson, both the students and the lecturer are provided with an extensive online feedback form which they immediately complete. The questions asked provide answers regarding the software usability and lecture didactics, which also includes an assessment of the learning outcomes. This feedback loop is indispensable in providing input to develop the software further and to create a better user experience. In each iteration of the software, bugs are corrected, and also, new features are built in to directly address the user's feedback.

3.2. Lesson Feedback, 'Continuous Mining Methods – Surface Mining'

A total of 15 students attended the lecture, whereby only 10 fully completed the feedback form and could therefore be used. The gender division of the students were 4 females and 6 males. The feedback form is divided into several sections: general information, user ability (VR), system usability, learning outcomes and lastly, open feedback questions to help improve the experience.

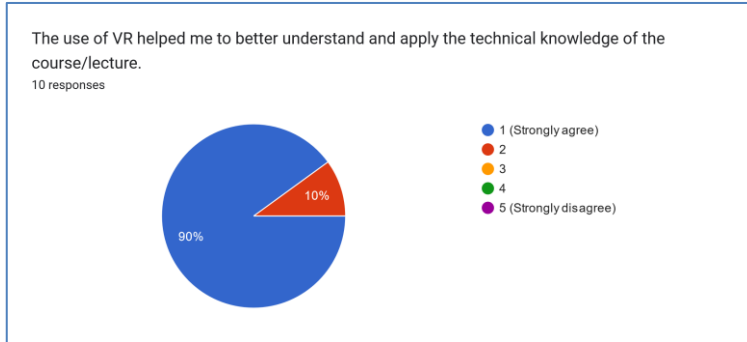
The feedback (self-assessment) provided by the students in direct relation to the Learning Outcomes of the lesson, was addressed by the following two questions and a 5-point Likert scale was used whereby, 1 is strongly agree and 5 is strongly disagree. A total of two questions in this section are provided to the students: 1. 'Post lesson, I believe my competence of the course/lecture subject matter has increased' and 2. 'The use of VR helped me to better understand and apply the technical knowledge of the course/lecture.'

The results of the 10 completed forms will now be presented in relation to the feedback form questions on the lesson LO's: LO 1. Upon completion of the lecture the student will be able to: Understand the basics of continuous surface mining methods. LO 2. Upon completion of the lecture the student will be able to: Explain the different surface mining operations.



Graph 1. Student Feedback Responses.

In relation to the question: 'Post lesson, I believe my competence of the course/lecture subject matter has increased', 70%, respectively 7 of the students indicated that they strongly agreed that their competence(s) of the lecture in relation to surface mining methods had increased, while 30%, respectively 3 agreed with the statement.



Graph 2. Student Feedback Responses.

In relation to the question: 'The use of VR helped me to better understand and apply the technical knowledge of the course/lecture', 90%, respectively 9 of the students indicated that they strongly agreed that the use of VR helped them to better understand and apply the technical knowledge of the lesson, while 10%, respectively 1 agreed with the statement.

The above results give reason to believe that integrating MR within domain curriculum can improve and enhance the students' ability to not only comprehend the lesson material but also in applying it. The Learning Outcomes are reached and tested immediately by the teacher who is not only relaying information but has the possibility to demonstrate the application of this within a classroom environment.

4. Conclusion/Outlook

Digitalisation in education must be part of the future learning pathway to ensure a competent workforce for the mining engineers of tomorrow in Europe. The MiReBooks project has changed the way traditional teaching and learning in mining education takes place. Through the continuous feedback loop the various applications of MR, the platform and the book series are constantly being improved. The feedback from students and teachers in direct relation to the course/lesson Learning Outcomes demonstrate the transfer of knowledge and competence of the participants can be enhanced. As Education 4.0 integrates technologies it also addresses not only the necessary hard skills taught as part of the lessons but also the soft skills needed within the field of digitalisation necessary for Industry 4.0.

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References

- Benjamin James Ralph, Manuel Woschank, Corina Pacher & Mariaelena Murphy. (2022). Evidence-based redesign of engineering education lectures: theoretical framework and preliminary empirical evidence. *European Journal of Engineering Education*, 47(4),636-663. doi: 10.1080/03043797.2021.2025341
- European Commission. (2018). Communication from the Commission to the European Parliament, The Council, The European Economic and Social Committee and the Committee of the Regions on the Digital Action Plan. url: <https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52018DC0022&from=EN>
- MiReBooks. (2019). *Project Official Website*. Retrieved January 19, 2023, from <https://mirebooks.com>
- Organisation for Economic Co-operation and Development (OECD). (2019/20). The relevance of general pedagogical knowledge for successful teaching: Systematic review and meta-analysis of the international evidence from primary to tertiary education. url: [https://www.oecd.org/officialdocuments/publicdisplaydocumentpdf/?cote=EDU/WKP\(2019\)20&docLanguage=En](https://www.oecd.org/officialdocuments/publicdisplaydocumentpdf/?cote=EDU/WKP(2019)20&docLanguage=En)
- Teo, T., S. Unwin, R. Scherer, and V. Gerdiner. (2021). Initial Teacher Training for Twenty-First Century Skills in the Fourth Industrial Revolution (IR 4.0): A Scoping Review. *Computers & Education* 170: 104223. doi: 10.1016/j.compedu.2021.104223