Requirements and Learning Modules for Implementing a Hologram Table in University Lectures

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Abstract: Holograms are relatively new technologies that can be used in university lectures. They enhance the learning experience by adding highly detailed three-dimensional (3D) visualization of objects and environments, which leads to more engagement of students and teachers. Particularly in mining engineering education, holograms have great potential to achieve learning goals, where students often struggle with understanding complex 3D concepts. When implementing new technologies in lectures, there is a must to consider the perception of students and teachers, as well as the didactical and technical requirements of courses. The consideration of these aspects ensures an effective learning environment. This paper presents the concept of three holo-modules with gamification features designed with the main goal of supporting the learning and understanding of mining engineering content. The different conceptual modules have been developed based on different learning objectives extracted from teaching requirements and technical aspects of the lectures. The results show a requirements analysis performed and the prototypes designed to integrate a hologram table in different teaching setups, such as seminars, group work, and frontal lectures.

Key words: Requirements analysis, Hologram table, Three-Dimensional displays, Education.

1. Introduction

In educational contexts, holograms have great potential to support the achievement of learning goals of courses and the students' comprehension of content. In comparison to traditional courses, the use of holographic technologies leads to less frontal teaching and more student-centered lectures. Thus, students can create content independently, exchange ideas and possibly apply the theoretical knowledge from courses' learnings in a real-world setting (Kalkofen et al, 2020). The Partnership for 21st Century Skills identified the new skills of creativity, innovation, problem-solving, communication, and collaboration as "separating students who are prepared for increasingly complex life and work environments in today's world and those who are not" (Partnership for 21st Century Learning, 2019b). The use of holograms can encourage the development of such skills as well as the creation of an engaging learning environment, which leads to more collaboration between students and higher learning motivation (Sattar et al, 2019; Stepan et al, 2017).

The case of a hologram table is an innovation in university lectures and is still not widespread. The hologram technology displays highly detailed three-dimensional (3D) objects, structures, and environments from the table center to approximately 0.7 meters of height in a hemispherical volume (Bolognesi et al, 2022). By using lightweight goggles and control wands, users visualize and interact with the holograms, while seeing each other. In contrast, other Mixed-Reality (MR) technologies, such as Augmented Reality (AR) and Virtual Reality (VR), may have limited communication between users due to head-mounted displays that constrain potential interactions (Daling et al, 2020; Kalkofen et al, 2020). In addition, AR and VR can also create motion sickness for users (Allcoat et al, 2021). Therefore, a hologram table can overcome these limitations as they enrich learning experiences, do not restrict the field of view nor inflict motion sickness.

When implementing MR technologies in university lectures, such as a hologram table, it is necessary to consider the perception of students and teachers, as well as the didactical and technical requirements of courses. The consideration of these aspects will potentially avoid misunderstandings and can ensure the application of the technology in a useful way for the educational setup (Lowdermilk, 2013). Therefore, this paper presents the results of a requirements analysis performed as a first step in the introduction of a hologram table to support mining engineering education. Particularly in this field of studies, students often struggle to envision complex 3D concepts and field visits are mandatory in the curriculum but demanding to organize and manage. The hologram table can contribute to this context by supporting the visualization of different aspects of fields and mines in detail, promoting interaction between students and with the holograms, and allowing the creation of gamified lectures to support the learning process of students.

The insights collected were transferred into three conceptual learning modules with gamification features that support the learning and understanding of mining engineering content. In the following sections, it will be presented scientific work, the methods applied in the requirements analysis and results obtained, and the concept of three hologram modules designed. The possible applications of the hologram table and the holomodules in lectures, benefits, and challenges will also be discussed.

2. Related Work

Holographic technologies have been already explored in different educational contexts. Barkhaya and Abd Halim (2016) identified the use in the fields of medicine, business training, engineering, pharmacology, astronautical engineering, archaeology, and early childhood education. In medicine, literature shows that holograms have been adopted for medical training (Sadeghi et al., 2022), procedure planning (Brun et al, 2019), to teach anatomical structures (Ramesh et al, 2022), and medical terminologies in English as a foreign language (Ja'ashan et al, 2022). In the field of control applications, Matišák et al. (2020, 2022) developed an online application that uses holograms to illustrate abstract mathematical models of control theory as physical meaning. The authors highlight the benefits that students can design their controllers and test them with the hologram before going on real controlling plants. Quin et al (2021) described a prototype that applies holograms in online classes at TU Delft in the Netherlands. The study focused on technical aspects and intended to improve video conferences through holo-presence and face-to-face interactions between students and teachers. More recently, Chatar et al (2023) presented applications of holograms in data visualization of drills in real space and for mixed-reality tours in well sites. The authors also highlighted the possibilities to improve users' interactions by collaborating in remote teams and voice communication between users.

Considering the use of holograms in different levels of education, it was found on Rehman et al (2021) that students and teachers from secondary education in science in Pakistan had a positive perception of holograms as a tool to increase students' interest, their long-term memory of contents and engagement in lectures. However, they also highlighted as barriers to implementing the technology the internet speed, the costs, and the lack of technical expertise from teachers. Leonard and Fitzgerald (2018) analysed the usage of MR technologies and, mainly, Microsoft HoloLens© within a secondary school in Australia. The authors identified critical points for the implementation, such as training and support for teachers and the importance of applying the technology with a focus on learning goals. They also argued that teachers and students did not engage with the hologram technology at first contact and therefore did not explore all its functionalities due to the lack of experience with these new technologies. On a gamified setup, Liesatyadharma et al (2023) used a hologram pyramid to teach analytical chemistry to students of senior high school in Indonesia. They evaluated students' performance in chemistry exercises by pre and post-tests and the satisfaction of experts with the learning game. The results showed improvement in the students' correct answers in the test and experts in chemistry approved the game as a learning tool.

The literature presented some areas of study, technologies, and educational contexts where holograms have been used to support innovative teaching. Based on this research, it was identified opportunities to further explore research in hologram tables for university lectures purpose and how it can support mining engineering curriculum.

3. Methodology

This section presents the methods used for the requirements analysis based on design thinking workshops and the Daling Decision Making Matrix (Daling et al, 2021). The analysis was developed based on qualitative research, where important factors were collected from focus groups of students and teachers to implement the hologram table in mining engineering lectures.

3.1 Focus Group Workshops

For the collection of the users' requirements, Design Thinking (DT) methods were applied as a recognized and innovative approach in requirements engineering to solve problems in a structured, agile, team-focused, and interdisciplinary way (Hehn and Uebernickel, 2018). DT is also a collaborative and iterative approach to look at complex problems from a user-centric perspective. The method is usually used for the development of products considering the needs of users, rapid prototyping, and learning cycles (Pereira et al, 2021). It consists of five phases Empathizing, Definition, Ideation, Prototyping, and Testing (Freudenthaler-Mayerhofer and Wagner, 2022), further described below:

- Empathizing is the first stage in human-centered design solutions. It is part of understanding the big
 picture of a problem by getting to know the user deeper, to understand values, experiences, and
 needs.
- In the *Definition* step, the problem statement is determined as well as the users' point-of-view on what challenge is most important to focus on.
- The goal of *Ideation* is to use creativity and generate as many solutions as possible for the defined challenge. From this phase, innovative ideas are created, they are combined, different perspectives are addressed and synergy within the group is created.
- In *Prototyping* users quickly develop the selected solution in a way that it can be tested and receive feedback for further improvement. In this final phase, the prototype is *tested* within the group to refine the solution on user interaction, problem understating, and getting to know the user.

Therefore, two DT workshops were performed with students and teachers from mining engineering courses. The first workshop session was held in October of 2022 with eight participants, four teachers (two from mining engineering) and four students from mining engineering bachelor's and master's programs. The first workshop focused on the Empathize and Definition phases. Students and teachers reflected on the current situation of lectures of one semester and identified potential for using the hologram table to improve the courses and tackle the challenges. In the Empathize phase, the participants defined Personas, which means fictional profiles that represent types of users of a product, having their own characteristics, goals, and needs according to different points of view (Siricharoen, 2021). After it, in the Definition step, they defined the main problem of the Persona, bringing clarity and focus for a final problem to be solved. Then, the participants described their Learning Journey by highlighting the main points of difficulty and achievements during one university semester.

The second workshop happened in December of 2022 with eleven participants including teachers, students, and the representative board of students from mining engineering. This constellation was developed to ensure that students are represented in the final solutions and that the opinion of all the users is considered in the final setups for the teaching concepts with the hologram table. In this session, the Ideation and Prototyping phases were performed. In the Ideation phase, the participants discussed ideas that would improve their current lecture contexts and created together prototypes for teaching concepts, based on the feasible ideas selected. The prototypes resultant of this phase were used as a basis for the conceptual hologram modules developed, which are in development and will still be tested in the future on the hologram table with all the users.

3.2 Daling Decision Making Matrix

In the next step, the Daling Decision Making matrix was applied to gather technical requirements related to the courses and teachers' experiences with MR technologies that could be addressed in the teaching concept with the hologram table. This matrix was developed for supporting teachers' decisions in the design and development of MR technologies in university courses. It differentiates between methodological aspects of teaching, infrastructural factors, individual prerequisites, and the teachers' knowledge, all of which influence the selection of the best MR technology (Daling et al, 2021). The matrix is shown in Figure 1.

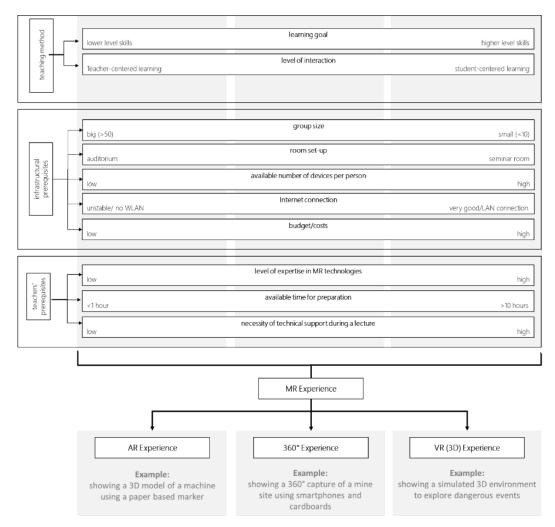


Figure 1: Daling Decision Making Matrix for Mixed Reality based courses (Daling et al, 2021).

Therefore, two teachers with previous knowledge of MR technologies filled up the matrix for selected six mining engineering courses of bachelor's and master's programs, presented in Table 1. In addition, they described in detail the courses' contents, learning goals, existent 3D models on mining structures, and options for creating new 3D data. The information collected provided input to assess technical opportunities and possible limitations in the teaching concepts with the table.

Table 1: Mining engineering lectures selected for the requirements' analysis.

Courses categories	Mining Engineering lectures
Open pit mine	Mining and Energy
	Applied Surface mining
Mine	Applied Underground Mining
	Mine Design and Simulation
Stockpiles	Reserve Modelling and Estimation
	Primary raw material economics and mineral resources

4. Results

4.1 Didactical Requirements

The requirements analysis was performed with the goal of collecting aspects that should be considered in the hologram modules concept and in the overall integration of the hologram table in the mining engineering lectures.

The students' requirements collected from the DT workshops were mainly classified into three categories: teaching methods, social interaction, and evaluation methods of courses. These were perceived as the needs and wishes of students who had already some contact with MR technologies and would like to improve learning and experiences in the courses. Regarding the teaching methods, the students wished for the use of new, innovative, and diverse methods to visualize and understand the contents. They would prefer practical activities and training, such as excursions, problem-detection games, or the planning of a mining site. In addition, they would like to use different types of media during the lectures, for example, online quizzes, MR technologies, and online exercises. In relation to social interactions, the students called for greater use of collaborative projects and more student-student interaction, where they are able to develop projects independently and use their creativity. For the evaluation methods, they reported a preference for mid-term activities or projects during the semester that could support their final exams and grades.

For teachers, the requirements gathered were categorized into modern media and social interaction. For the first category, the use of modern media, such as the hologram table, during lectures could help with the visualization of processes, and mining sites and with teaching structural models. On the other hand, it should be ensured for teachers that they would have the necessary technical support for the use of new technologies. In the second respective category, it is important for teachers the improvement in social interactions between the students themselves and the relationship between students-teachers. More collaboration, participation, and discussion are important points to be changed in lectures. They also wished for enabling experience-based learning for all students while improving collaborations.

4.2 Technical and Structural Requirements

The matrix developed by Daling et al (2021) was used to identify important aspects of the learning goals and the infrastructure of the courses, as well as teachers' requirements on MR media. All the lectures are intended for high-level skills as learning goals. It means that students should be able to understand and reproduce the content taught, which can be supported by the hologram table. Five of the courses lean towards teacher-centered learning, while the lecture reserve modeling and estimation is the only one based on a student-centered learning approach.

Regarding the structural prerequisites, the lectures vary in group size. While the Applied surface mining and Applied underground mining courses have a small group size, the Reserve Modelling and Estimation and Mine Design and Simulation have a medium to small group size. The Mining and Energy course has a medium group size and the Primary raw material economics and mineral resources course has a large group size. Accordingly, five of the courses take place in seminar rooms and the Primary raw material economics and mineral resources takes place in an auditorium. For the six lectures, there is a high number of MR devices available and the internet or LAN connection is considered as very good.

Regarding the teachers' technical experience with MR technologies, in four lectures there is a high level of expertise (Reserve Modelling and Estimation, Applied surface mining, Mining and Energy, Mine Design and Simulation), while for two (Primary raw material economics and mineral resources, and Applied underground mining) there is a medium level of expertise. For all lectures, there is relatively little time available for preparation and the necessity of technical support during a lecture is low to medium-low.

In summary, from the matrix results, the hologram modules applications need to maintain high learning goals for the lectures. It is also a requirement that the teaching concepts for the hologram table should be adapted to lectures in groups from small (less than 10 students), medium (around 25 students), and large groups (higher than 50 students), depending on the courses, as well as the different room types. In addition, while the table itself promotes a more student-centered experience, there is a need to have applications that encourage students to participate in teacher-centered courses. In all courses, teachers have relatively little to medium time available for preparation, and depending on the lecture, teachers might need technical support to use the modules.

4.3 Conceptual Hologram Modules for Teaching in Mining Engineering

Based on the described requirements, three conceptual hologram modules were created to introduce different practical experiences in lectures and to improve the current interaction between students and teachers. In addition, hybrid teaching, students self-learning in small groups, and frontal lectures were characteristics defined by the teachers as necessary for the teaching concepts. The hologram modules will be further technically developed and tested with users in lectures as the next step.

3D Whiteboard

The 3D whiteboard is an extension of traditional teaching methods with interactive features between teachers and students. The goal of this module is to enable the visualization and presentation of complex models or abstract figures in 3D space that usually students from mining engineering have difficulties understanding in 2D images. It also aims to improve interactions face-to-face and in online lectures. Teachers can upload static or dynamic 3D models to the hologram table and manipulate them on the table or via desktop. Some features of this module are the possibility of asking questions and sending answers between students and teachers on a chat, and the creation of comments, videos, or images that appear on the table display for users. Students can also visualize the contents that are presented on the hologram table, on their devices, such as smartphones, which creates more flexibility for different group sizes. On a gamified scenario, teachers can, for example, create questions on specific locations to place renewable energy systems in mining sites and reward students that answer correctly and in a determined time. Students are also able to interact with the 3D objects and can place objects on the table themselves, though the teacher can lock this function. This allows the teacher to create a competitive atmosphere between students by allowing them to place components or objects of mines planning in the most accurate position.

Building game

The building game is a learning module that promotes group work through project development, collaboration between students, and free learning. The teachers should create different scenarios, define specific tasks for the students and evaluate their intermediate progress and results during one university semester. Students can place, move, remove, or connect items, buildings, or equipment and make decisions on their choices. Points can be attributed according to the decisions made and the explanations. This module would be used to accompany projects from lectures and provide students the opportunity to apply theoretical knowledge or to self-learn new concepts through experimentation. It is perceived that students could, for example, evaluate the pros and cons of different decisions and create new mining setups based on a realistic context.

• Game as a reward

The concept for this module is to connect the knowledge gained from other learning platforms such as quizzes, online tests, or exercise classes with the hologram table and to reward students for their participation. Depending on their involvement, students would receive prizes on the hologram table such as 3D materials or resources, which could be used to explore a mining site together as a group. The points that would be gained from the performance in the other learning platforms would be used as a budget for buying the materials, possibly bringing more motivation to students. It is also intended to enhance connections between students, to promote team spirit and collaboration. This module is also planned to be used as a chance to improve students' final grades in courses.

5. Discussion

In this study, three conceptual hologram modules were developed to support current teaching in mining engineering university lectures. Based on a requirements analysis, students' and teachers' perspectives and the technical parameters of courses were collected and translated into the hologram modules. It was observed that the hologram table is a great innovation with many functionalities that can improve teaching methods, interactions, and possibility learning results. Similar to other MR technologies, it would provide a new way to present complex 3D objects and realistic environments with more flexibility, enhancing students' engagement and learning motivation (Sattar et al, 2019; Stepan et al, 2017).

On one hand, in agreement with the literature (Leonard and Fitzgerald, 2018), the collected requirements showed that teachers' training and technical support are important aspects depending on the course. On the other hand, teachers participating in our research have vast experience with MR technologies, and the infrastructure is already set, facilitating the implementation of the modules and use of the hologram table. Another point highlighted in the analysis was that students and teachers are wishing for using innovative technologies in the lectures, to have more flexibility for teaching, learning, and working with real content, instead of abstractions.

Regarding the three conceptual modules, there were opportunities to support the lectures with game-based exercises varying from the presentation of content to team work. It would allow the direct participation of the students and improve social interaction. Advantages and challenges are also foreseen for the implementation of the modules. The 3D whiteboard can support a teacher-centered lesson and visualize complex models and

environments. It can be applied to larger groups of students and would connect with traditional teaching concepts. However, student-student interactions and collaboration may be relatively limited due to its visualization character. The application would also not be suited to train high-level skills such as evaluating or creating content. In the building game, the benefits of the module lie in the promotion of high-level skills like analyzing, evaluating information, and being able to create content independently. In this case, one requirement is the application of small-size groups to solve problems and create scenarios more efficiently, which could improve collaboration and student-student interactions. Finally, the game as a reward would require extra preparation from the teachers, demanding time, since they would need to cope with additional learning platforms. On the contrary, this module could reinforce the content learned and promote teamwork.

6. Conclusion and Outlook

A hologram table is a relatively new technology to explore courses' contents in an innovative way within university lectures. It should be implemented by taking teachers' and students' requirements into account while maintaining an effective learning environment. This study presented the concepts for three teaching modules to integrate a hologram table in mining engineering courses in agreement with users' needs and lectures' technical requirements. As the next steps of this research, the game-based exercises of each module will be defined together with teachers, the conceptual modules will be technically developed, and firstly tested in the courses of Applied Underground Mining and Applied Surface Mining. In addition, it is planned to adapt the teaching modules for use in medicine and dentistry courses, considering specific learning goals. Finally, some limitations on the hologram modules application are already foreseen, such as the adaptation to lectures with more than fifty students, the adjustment of the preparation time of projects, and gamified exercises according to the availability of teachers and the necessary technical support.

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