VR GAME FOR IMPROVING SPATIAL UNDERSTANDING

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ABSTRACT

Some engineering students at the TU Dortmund University have trouble with spatial understanding regarding technical drawings in engineering. This is an important skill that is needed for higher education studies and future professions. To support aspiring engineers in higher education to acquire those skillsets, a VR learning tool is being developed. A pretest was conducted with a small group of students to get their first impression. They then filled out a survey which is analyzed in this paper. Overall, this paper is a progress report about the development of this spatial-perception-assistant software. The key finding is that this VR environment is an effective tool to improve the spatial visualization ability. Since the state of the software is still in its early stages, the VR software is still too technical for some students. Therefore, more playful game elements should be implemented to make the game more appealing to students.

KEYWORDS

VR, Educational Game, Pretest Evaluation, Engineering, Technical drawing, Spatial-perception-assistant

1. INTRODUCTION

Engineering students at the TU Dortmund University are trained in a variety of areas from the basics of mathematics to more specific areas such as turbines. The Department of Machine Elements teaches students many disciplines early on, including but not limited to what standard parts exist, how to choose the right parts for different applications, and how to design machines with their acquired knowledge. Engineering students face challenges when trying to match 2D projections with real machine elements, often due to a lack of spatial awareness and limited opportunities to physically interact with machine parts. The Department of Machine Elements continuously seeks out new ways to combat this issue and improve education.

In the field of engineering education more and more VR and AR technologies are being used (Cheng et al., 2018; Scaravetti & François, 2021). At the same time, serious games are attracting more and more interest in the education sector (De Gloria et al., 2014). Serious games are interactive tools designed to educate while providing entertainment. Players engage in these games to enhance their knowledge and practice their skills by overcoming various challenges presented within the gaming environment (Zhonggen, 2019). In response to the increasing digitization of teaching and the potential of VR technology, the Department of Machine Elements has decided to enhance a workshop in which students assemble a ball-sorting machine in small groups by offering it as a serious game in a VR environment named ViSAs (Virtual Sorter Assembly). This decision is based on the findings of Soliman et al. (2021), who demonstrated that VR technology improves students' understanding of engineering topics and offers positive cognitive and pedagogical benefits (Pantelidis, 2009). Additionally, VR incorporates elements of gamification, making the learning experience more engaging and motivating. This approach not only enhances motivation but also accommodates different learning styles, catering to individuals with varied preferences and strengths in their learning process (Laura Freina & Michela Ott, 2015; Rojas Sanchez et al., 2022). By leveraging VR technology, the department aims to provide an immersive and interactive learning experience, which is a preference and requirement of the current generation of engineering freshman (Abulrub et al., 2011; Dinis et al., 2018). The motivation for the creation of a serious game is that a serious game increases the effectiveness of learning (Wouters et al., 2013). In the areas of declarative knowledge, knowledge retention and procedural knowledge, serious games are found to be more advantageous than traditional teaching methods (Riopel et al., 2019).

In the updated workshop, students will be able to assemble the machine as a serious game in a 3D environment. They can interact with the virtual components, examine their functionality, and observe how they fit together, all while gaining a better understanding of how the technical drawing translates into a real machine. Abdelhameed (2013) showed these VR benefits in the context of architectural design. To evaluate the effectiveness of the VR tutorial, students will be interviewed to assess the extent to which the tool has improved their spatial understanding and understanding of engineering drawings. This feedback will help the Department of Machine Elements gauge the impact of VR technology on the learning outcomes of mechanical engineering students and determine its potential as a valuable educational tool in the field. This innovative approach not only enhances students' spatial visualization skills but also prepares them for future engineering challenges in an increasingly digitized world (Salah et al., 2019).

At the beginning of the paper, the VR game is introduced. The students were able to test the current development state of the support tool and filled out an anonymous survey afterwards. According to this, an evaluation is discussed in chapter two, where the students' satisfaction and the rating of the support tool is analyzed. Last but not least, a short conclusion on how the support tool or respectively the VR environment are capable of raising motivation through the innovative software.

2. VR GAME - VISAS

To improve the independent skill training for the assessment of technical drawings, a virtual reality game is being developed as part of the *CrossLab* initiative. The purpose of this game is to incentivize students through the use of VR technology as an innovative tool for higher education. Constructive Alignment, which is a didactic concept developed by John Biggs, is used as a basis for the development of the game. The primary target group are undergraduate students, namely students studying mechanical engineering, logistics and industrial engineering.

The game will consist of three scenes. In the first scene, students will be asked to find the correct machine element in an assortment of different parts through the use of a technical drawing. This scene will help students recognize parts by means of technical drawings. It will also act as a tutorial that will teach students how the controls inside the game work. In a second scene, the functions of different machine elements, like ball bearings, will be asked so that the students understand the purpose of these parts. In the last scene the assignment will be to assemble a ball-sorting machine. All the knowledge that has been gained in the previous scenes will be necessary to finish the last assignment. In the following tests, only the last scene was used since the first two scenes are still early in development.

For the development of the game, the game engine Unity version 2021.3.9f1 in combination with Virtual Reality Toolkit (VRTK) is used. The prototype of the game that was used in the following tests can be seen in Fig. 1. The main goal of the game is to assemble the given sorting-machine with the help of a technical drawing and a parts list. Two VR controllers, which are visualized as hands inside the VR environment, are used to grab, move and combine objects so that the assembly can be completed. The main parts of the assembly are situated on a table where most of the assembly work is done. On the left side of the player, different standard parts that are required for the assembly can be taken out of labeled storage boxes. A white board with the technical drawing of the assembly and the parts list is positioned on the right side of the player (see Fig. 2). The controls of the game are displayed behind the table. An assembled ball-sorting machine is also placed on the table as a comparison, although this assembly will be removed in the final version.

Different functions have been implemented to support the player inside the game. First of all, grabbed objects will be highlighted on the parts list, as seen in Fig. 2. These parts still have to be associated with the technical drawing by the player. Secondly, markers and an eraser can be used on the white board to draw and erase comments on the technical drawing and the parts list. Lastly, parts that are near the intended position, given that the assembly order is correct, will be highlighted to signalize the assembled position on the release of the object. The purpose of these supports is to guide the students to the correct solution without interrupting the learning process. While the main functionality of the third scene is already implemented (the assembly of the ball-sorting machine), it still lacks game elements. One such element that is planned is a time trial where students will be able to time their attempts at assembly. These times will be saved on a score board to further motivate the usage of the software.

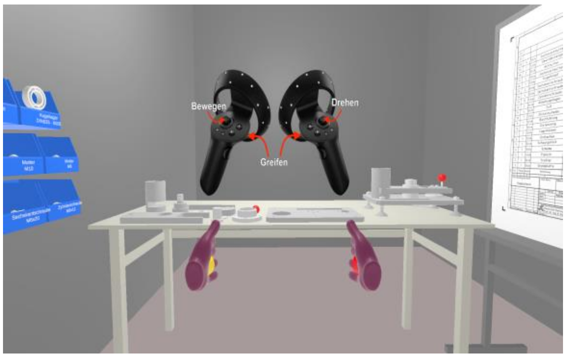


Figure 1. Overview of the VR environment

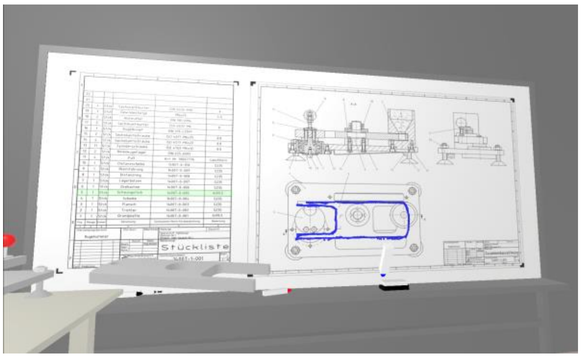


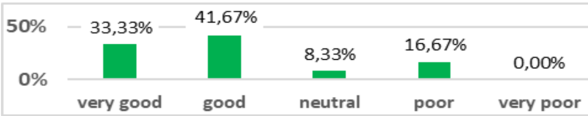
Figure 2. Whiteboard with a technical drawing and a parts list

3. PRETEST AND EVALUATION

A pretest was conducted with a small group of students (13) for excellent academic teaching purposes. The results should help the developers to focus on important target goals of the target group. These survey results (see Table 1) are now being described in the following paragraphs. Around 80 % of the students study mechanical engineering or other programs such as logistics, industrial engineering and computer science. All students who participated in the survey completed the module of technical drawings and should have the necessary knowledge for this topic (see Q1). When it comes to rating their own spatial understanding, the results are scattered, because they have different prior knowledge and experiences (see Q2). This should be considered to adapt the difficulty of the progress and assignments inside the program. Due to the different skills, the answers to the question as to whether there are any problems in imagining the 2D technical drawing in three dimensions differ.

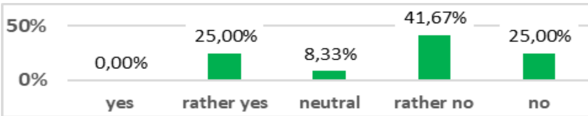
Table 1. Survey results (m: arithmetic mean, σ : standard deviation, very good: 1 – very poor: 5)

Q1: How do you rate your spatial visualization awareness?



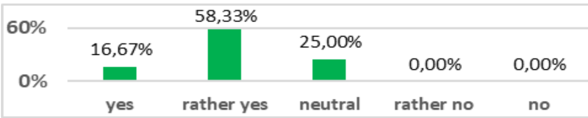
m = 2.08
σ = 1.08

Q2: Did you have any problems imagining the technical drawing in three dimensions?



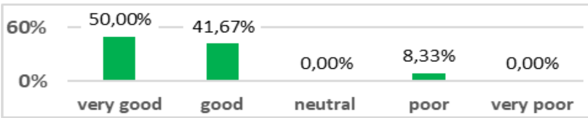
m = 3.67
σ = 1.15

Q3: Have you improved your three-dimensional imagination in general as a result of using the program?
How well did the three-dimensional visualization of the two-dimensional technical drawing work out?



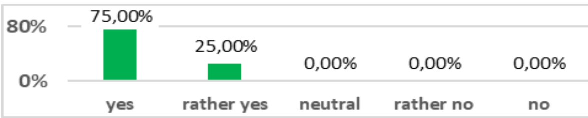
m = 2.08
σ = 0.67

Q4: How well did the three-dimensional visualization of the two-dimensional technical drawing work out?



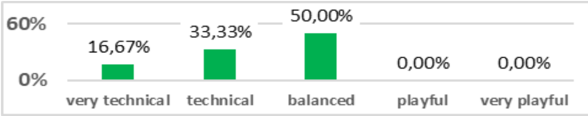
m = 1.67
σ = 0.89

Q5: Is the game fun to play?



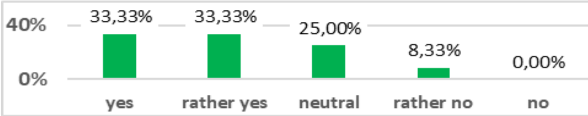
m = 1.25
σ = 0.45

Q6: How do you rate the implementation to achieve the learning objectives (Improved ability to read and interpret technical drawings) vs. playful implementation within the software? The game design is...



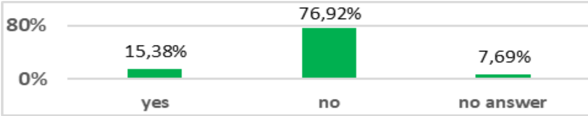
m = 2.33
σ = 0.78

Q7: Does the program help you apply the skills you learned in the lectures to other problems?



m = 2.08
σ = 1

Q8: Do you own a VR headset?



Furthermore, the spatial understanding is an important skill that engineering students need for future studies and professions. All students have more or less improved their spatial visualization ability by using the software (see Q3) and they rate the three-dimensional visualization quality as good or very good. Only a few students (around 10 %) rated the visualization inside the game as poor (see Q4). Maybe the latter will be convinced in the next stages of the development of the program when the focus lies on the design.

Moreover, the majority of students agreed that the game is fun to play (see Q5). It also helps achieving several learning objectives. However, the current development status is stated as technical, where one improvement could be the implementation of a strategic gameplay to make the software more playful (see Q6).

On the other hand the software helps also to apply interdisciplinary skills (see Q7). The opinions of the students are split in this case, so it could be useful to make those interdisciplinary objectives more transparent that the students realize and understand those aims. Secondly, some more interdisciplinary learning objectives from other sources could be added. To be able to use the software, access to the VR technology is a key factor. Currently, most of the students do not own a VR headset (around 80 %, see Q8). This is where institutions should step in and make this technology available by providing the free use in their learning spaces. The TU Dortmund University for example offers a VR lab for students.

These are the most occurrent answers in the open box, where the students gave the following feedback:

- Students wish more game-like elements such as a timer or a scoreboard for gameplay purpose,
- Students wish a more realistic visualization regarding part details like threads by adding textures.

4. CONCLUSION

The results of the surveys show that there is an interest in a VR solution for improving the spatial understanding of students. All students had fun using the VR software and the visual representation of the objects compared to the technical drawings seems to be well received, which indicates a clear advantage of such a solution. Nevertheless, there is still a lot of potential for enhancements. First of all, the first two scenes that act as a tutorial and prepare the player for the assembly assignment need to be completed. Secondly, a system to assist the player if they have issues should be implemented. Some students couldn’t progress due to the difficulty of the assignment which meant that supervisors had to give out tips on how to progress. This shouldn’t be necessary in the final version of the software since the independent skill training is one of the key points of this project. Furthermore, the pretest has shown that not every function that was available inside the VR environment has been used by the students. For example, most students didn’t realize that objects that have been picked up by them were shown on the parts list. This can be improved with the use of audio cues that direct the player’s attention to the white board once they pick up an object. Lastly, more game elements like high scores should be implemented to attract the students’ attention and motivate the use of the software. After the implementation of these enhancements another evaluation with a larger group of students will be performed. In this test, students without the knowledge of technical drawings should also participate so that the software can be reviewed more accurately. Moreover, there is the problem of the availability of VR headsets. Not only should the Department of Machine Elements provide setups to use this software, but it should also be made available to use in other faculties of the TU Dortmund University, for example at a VR lab. After the feedback gained from the tests as well as other function have been implemented, the software will be made accessible for use in early 2024.

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