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Efficiency of Learning Using Augmented Reality Technology

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Abstract: *The intensive development of information technologies has led to the introduction of many innovations in the educational process. Innovations often rely on the use of new technologies in the educational process and aim to increase the efficiency and effectiveness of learning. This paper presents the use of augmented reality in training students to process graphic images. The method of using augmented reality in the training has been presented in the paper, and afterward, the results of the research, which compared student efficiency using written text instructions and student efficiency using augmented reality technology in the training process. The results of the research did not show a significant difference in efficiency. But, it should be taken into account that the students, who were part of the research, encountered this type of training for the first time, so the opportunities that augmented reality provides in the training process needs to be further investigated.*

1. INTRODUCTION

The development of fifth-generation mobile networks and information technologies that rely on these networks (artificial intelligence, cloud computing, and IoT), has affected all areas of society. Education, as one of the pillars of any society, is no exception. Mobile learning, LMS platforms, simulations, virtual labs, etc. have changed the education process. The goal of using modern information technologies in education is to impact both the quality and the scope of knowledge adopted by students (Büyükbaykal, 2015). The widespread use of new technologies and social media among the younger population has incited the educational services sector to accept them as an integral part of the learning process (Haleem et al., 2022). A special challenge is posed by the application of immersive technologies (augmented and virtual reality) in education. These technologies have already brought about certain conclusions. The most important conclusion has to do with their importance in skill acquisition in students, as well as in the increase of confidence in the application of those skills (Santos et al., 2014; Radosavljevice et al., 2018; Urlings et al., 2022).

In this paper, the authors will provide a demonstration of the experience of using augmented reality technology in education, as well as the results of a study that was conducted to find out whether students are more time-efficient in mastering learning materials through the usage of augmented reality in training. The paper is organized into several parts. After the introduction, there is an overview of relevant literature in the area of learning and augmented reality technology. Then, there is the overview of the scientific study that cross-examined the efficiency of task fulfillment using augmented reality technology as opposed to learning and work strategy that used text-based instructions. Finally, there are the results of the research with a discussion and a conclusion.

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2. LEARNING AND MODERN TECHNOLOGIES

Learning is comprised of constructive processes in which an individual activates, independently or in a group, elaborates, builds, and organizes knowledge (Seidel & Shavelson, 2007). The definition of electronic learning (e-learning) provided by the United States Distance Learning Association is "the process of mastering knowledge and skills through information and instructions received via different technologies and distance learning methods" (Levels et al., 2019). The application of various technological solutions in the learning process is a means to positively affect the factors and outcomes of learning. The learning process is considered successful if it is efficient and effective. Learning is efficient if students adopt knowledge or master skills through optimal engagement. Efficient learning encompasses learning where the number of activities a student must fulfill in order to learn is minimal. Learning is effective if the knowledge that the student adopts can be applied and tied to previous knowledge to create more complex skill sets (Hoy, 2010). The efficiency and effectiveness of learning must be adjusted to one another. An efficient learning strategy must be effective, and vice versa. A learning strategy that is efficient must realize and satisfy the criteria of effective learning through the steps it takes to realize it. A study (McMahon, 2006) defines 7 criteria of effective learning as follows:

- The scope of learning materials presented to the student must be in accordance with the ability and time the student has;
- The amount of information presented to the student must be appropriate;
- Students must be given clear instructions on the activities expected of them;
- Activities conducted by students that belong to higher-order thinking and learning must be rewarded;
- The teacher should demand students' active participation during the lecture;
- The student must be given options to choose from during the lecture;
- The student must be given feedback on their performance

The choice of learning strategy defines the steps to realize the learning process. Strategies such as learning through reading or underlining are efficient from the perspective of resources and activities taken during learning but are not considered effective. Strategies such as practice testing, which is comprised of taking tests and using flashcards, as well as distributed practice, where students use previously acquired knowledge in several timed sessions, are considered highly effective but are quite demanding in terms of efficiency, and therefore not sufficient (Biwer et al., 2020). The use of contemporary technologies in different learning strategies can contribute to the optimization of learning efficiency and effectiveness (Radosavljevic et al., 2019).

Research has shown that there is a positive effect of the application of modern technologies in teaching. Students readily accept new technologies as a part of the learning process, and they consider them an integral part (Penprase, 2018; Dunn & Kennedy, 2019; Radosavljevic et al., 2019). The use of technology in learning has a positive effect on student motivation. The increased motivation results in an increase in the participation of students, which, in turn, increases the effectiveness of learning (Kennedy & Dunn, 2018; Pechenkina & Aeschliman, 2017). Technological solutions used in the realization of the curriculum most commonly rely on the use of multimedia content, social networks, mobile phones, cloud platforms, MOOC, digital and smart classrooms, and immersive technologies.

The use of technology in education is also a positive ecological factor, as it decreases the amount of paper and other waste (Camilleri & Camilleri, 2016). The importance of introducing

technology into the educational process became especially apparent during the COVID-19 pandemic, when different e-learning platforms enabled the realization of education regardless of the situation, as students could not physically attend lectures (Hoofman & Secord, 2021; Fauzi, 2022).

Augmented reality (AR) technology is defined as the technology which merges real-world information with digitally generated information presented as a part of the real environment (Encyclopedia of Multimedia, 2006). The application of augmented reality technology has a positive impact on the motivation and performance of students during learning, as well as on the interest students have in the learning materials. Due to the way the content is presented, it is believed that augmented reality technology is important in transferring knowledge and skills that are applicable in the real world (Bacca et. al., 2014; Radosavljevic et al., 2018; Lima et al., 2022). There are more and more studies on the application of augmented reality technology in education each year. A study by Chen and Wang (Chen & Wang, 2008) examines the possibilities of tangible augmented reality (TAR), where learning is realized through the merging of digital learning materials and objects in the physical space. One of the conclusions of the study is that students tend to adopt knowledge faster than during traditional lessons. A study (Juan et al., 2016) demonstrates an increase in the efficiency of the learning process through the use of augmented technology in dentistry. Studies (Tzima et al., 2019; Uygur et al., 2018) analyze the role of teachers in augmented reality learning. A study (Radosavljevic et al., 2018) analyzes augmented reality technology in the context of professional vocational education. These studies conclude that augmented reality is still not being used to a greater extent in the education process and that this technology and its potential are still unknown to teachers. All the above-mentioned studies confirm that there is an increase in motivation and learning effectiveness when augmented reality technology is used.

3. RESEARCH AND RESULTS

The study, which tested the efficiency of learning through augmented reality technology was carried out at the ATUSS academy, ICT College in Belgrade, Serbia, in March 2022. Fifty-seven first-year students of undergraduate academic studies at the Communication Technologies study program took part in the study. All students in the study were between 19 and 23 years old and digitally literate (they know how to use mobile phones, e-mail communication, web searches, the Moodle platform for e-learning). The study was carried out during laboratory practical lectures for the course Graphic Software Tools. In these practical lectures, the students learn how to digitally process photographs using raster image processing software.

The students who participated in the study were tasked to follow a laboratory exercise in one of three possible ways. The first group, comprised of 15 students, conducted the exercise following paper-based instructions. The second group, also comprised of 15 students, used paper QR codes to load instructions in an augmented reality application. The third group used digital QR codes displayed on their monitors to load instructions. The goal of the study was to compare the time efficiency using a strategy encompassed textual instructions, as opposed to time efficiency using visual instructions through augmented reality technology.

The study was conducted in several phases. In the preparatory phase, it was necessary to create an augmented reality app that the students would use to carry out the exercise. For this purpose, the software platform Unity (https://unity.com/) was used. This is a cross-platform integrated

development environment used in the process of production of video games, simulations, 2D and 3D modeling, and interactive applications. Aside from this software, Vuforia (https://developer.vuforia.com/), a software development kit for augmented reality applications, was also used. With these platforms, an augmented reality application was developed and used during the realization of laboratory exercises. The hypothesis defined in this phase was that augmented reality technology in the learning process is more efficient than traditional text-based learning. An additional hypothesis was that the most efficient method of using augmented reality was one that encompassed digital as opposed to paper-based QR codes (as shown in Figure 1). Aside from the application development, this phase also included the preparation of instructions for the exercises in a textual form, as well as a questionnaire on the experience using augmented reality technology, which the students were asked to fill out during the study.

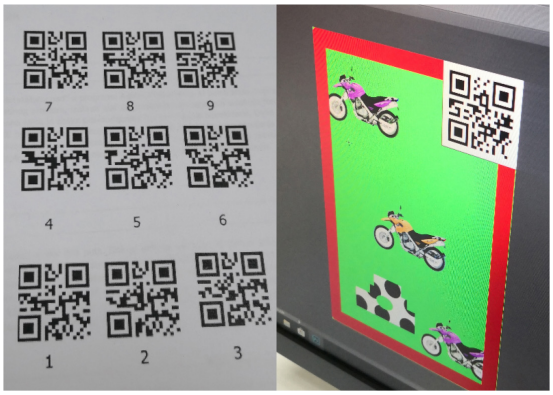

Figure 1. Printed and Digital QR Codes

Figure 2. Scanning QR codes and following instructions on mobile phones using the augmented reality application

The realization phase of the study commenced with the division of students into groups. Students were distributed into four time slots based on the number of their student cards. As that number had been assigned to students when they enrolled in the school using a random order, this method can be considered viable for the division into statistically even groups. Each group had a maximum of 15 students, as the room assigned for laboratory exercises contains 15 working stations. Each student carried out the exercise individually, following the instructions given to them in one of the three ways. The first group received the instructions in a textual form printed on paper. The second group received instructions in the form of printed QR codes. Using their phones, on which they had previously installed the augmented reality application for this exercise, these students scanned the codes. Upon scanning, they received an image with graphic instructions for the exercise. The third group received the instructions in digital form, where the QR code for the augmented reality application was integrated into the program for the exercise. Figure 2 presents the way students used the augmented reality application using digital and paper QR codes. Figure 3 presents The display of content on a mobile phone upon scanning the QR code.

In their assigned time slots, the students were given the necessary materials along with the instructions. The time required for the students to carry out the exercise was tracked. The exercise comprised the processing and montage of a photograph defined through precise steps. After finishing the exercise, the students filled out a questionnaire that gathered basic data about the students, while those students who used the augmented reality application also filled out a questionnaire regarding their experience using the application.

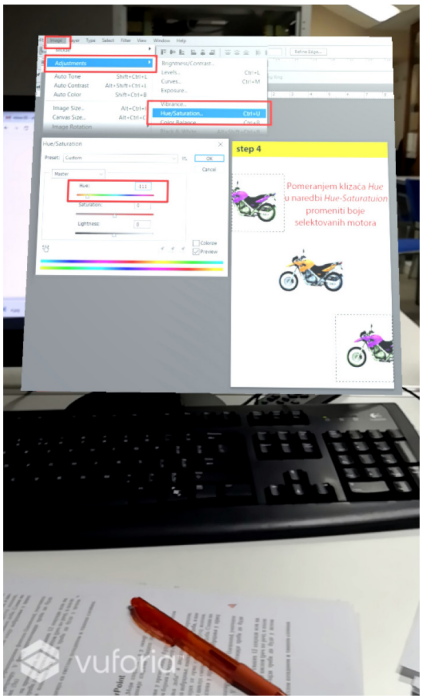

Figure 3. The display of content on a mobile phone upon scanning the QR code

The following phase of the study encompassed the processing of the gathered data. The results are presented in Figure 4 and showed that students who were given text-based instructions fulfilled the task in an average of 16.27 minutes (with a standard deviation of 5.96). The students who used the augmented reality application with printed QR codes took, on average, 18.80 minutes (with a standard deviation of 5.03). The students who used the augmented reality application with digital QR codes required, on average, 19.51 minutes (with a standard deviation of 4.40).

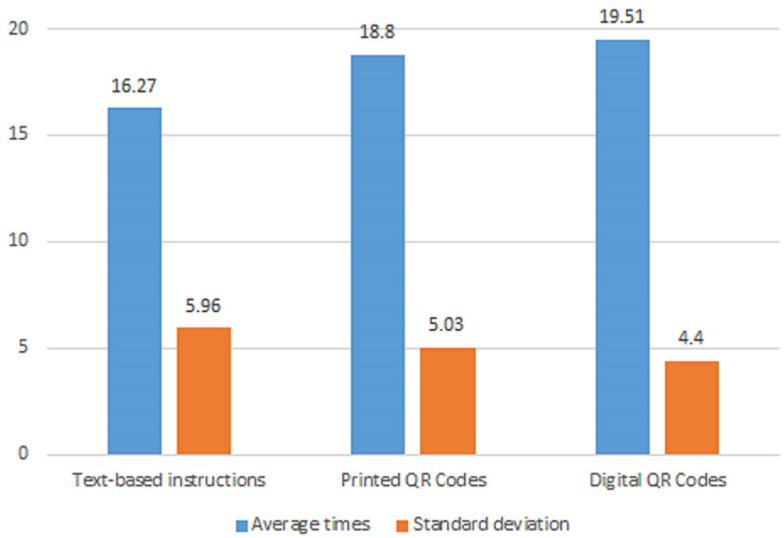

Figure 4. Average times required to carry out the exercise (in minutes) by instruction format

Source: Own research

The results presented above do not confirm the hypotheses of the study. The efficiency of learning, i.e. of the realization of the laboratory exercise, was lower when using augmented reality technology than when using text-based instructions. The students that carried out the exercises using text-based instructions required the least amount of time. The least efficient were those students

that used QR codes. One of the possible explanations for such results lies in the questionnaires that asked about the students' experience using the augmented reality application. For more than 92% of the students that used the application, this was the first time encountering this method of work and learning. The authors believe that having to get acquainted with the new method of learning, i.e. carrying out the exercise had an impact on the results that pointed out a low level of efficiency in learning using an augmented reality application. Despite these results, the general experience using this augmented reality was rated as positive. Figure 5 provides an overview of the results of the study, which point to the advantages of using augmented reality in learning. The application of augmented reality provided the students with clear instructions for carrying out the exercise; they found the concept of augmented reality understandable, and its application in the learning process entertaining, which positively affected their motivation to learn.

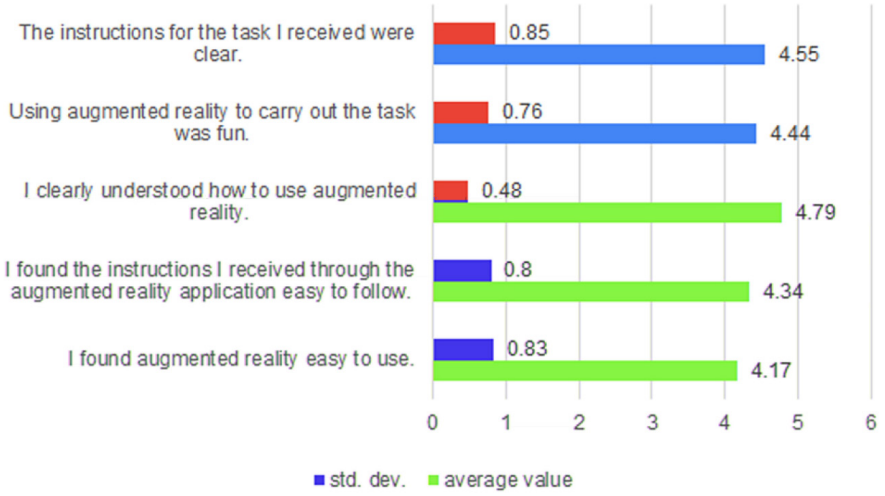

Figure 5. The advantages of the application of augmented reality in learning based on the questionnaire

Source: Own research

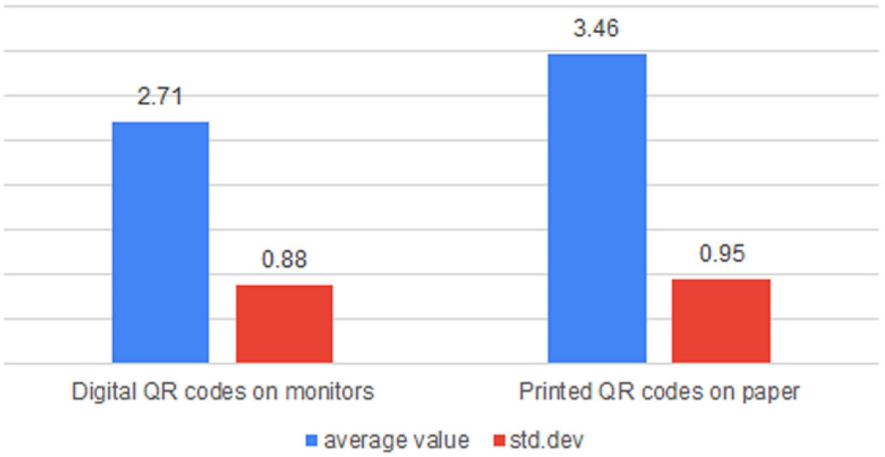

Figure 6. Image shaking with printed and digital QR code scanning

Source: Own research

The question regarding the technical aspect of the realization of augmented reality, in terms of image quality and QR codes on the screen, pointed to an issue with scanning depending on the quality of the screen. As the quality of some monitors was not at an appropriate level, there was mild image shaking and distortion, and those students who scanned their QR codes on these

monitors experienced issues. The augmented reality application had trouble recognizing the QR codes, and the content would not show up on students' mobile devices, or it would occasionally disappear. The students that had printed QR codes experienced fewer scanning issues, and their answers to the question regarding image display in the application correlated to the perceived ease of use (Figures 6 and 7). In addition, the focusing of the mobile device camera on the digital QR codes was a slower process than in the case of scanned QR codes.

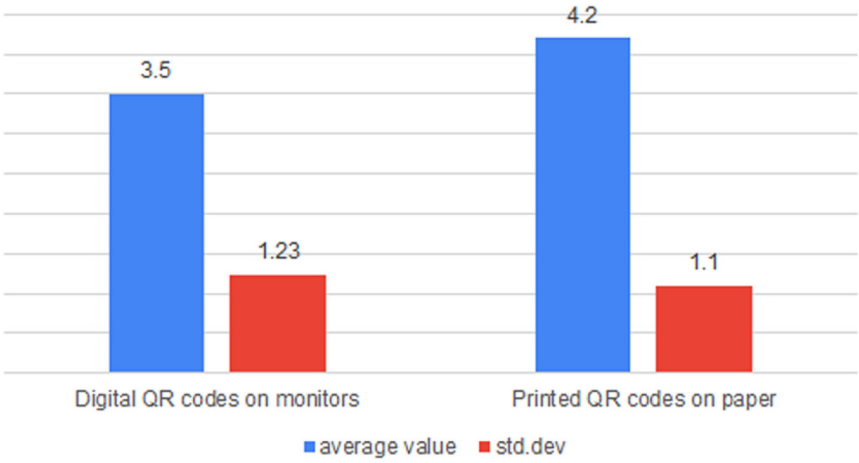

Figure 7. Ease of use of augmented reality with printed and digital QR codes
Source: Own research

4. CONCLUSION

Augmented reality technology is one of the most recent information technologies. The paper provides insight into a study that had the goal of comparing the efficiency of the learning process using augmented reality technology as opposed to a traditional learning strategy that uses printed text. The starting hypothesis that augmented reality would be more effective in the learning process was not confirmed in this study. Nevertheless, this conclusion should be taken with reservation and further examined. As most participants experienced the augmented reality learning strategy for the first time in this study, some time was necessary for them to get acquainted with this strategy during the exercise. This impacted the time necessary to carry out the task and, by extension, the students' efficiency. It has also been established that there were issues with the scanning of digital QR codes and that those QR codes were causing issues with content display in the augmented reality application. If the content was not being displayed on a high-quality monitor, there were issues with scanning the digital QR code, and the image displayed in the application was shaky. The scanning of digital QR codes was also slower as compared to printed codes, as mobile devices were experiencing issues focusing the camera on the monitor.

The positive results of the study are tied to the conclusions regarding the application of augmented reality in the learning process. It is advised that printed QR codes be used when implementing augmented reality into the learning process, as they were shown to be more reliable than digital ones. The application of augmented reality allowed for a clear transfer of knowledge and instructions for the laboratory exercises, and augmented reality was characterized as easy to use, as well as entertaining, which had a positive impact on the students' motivation to work and learn. Regardless of the hypothesis not being confirmed, this study provided results that may be useful for further research and implementation of augmented reality technology, not only in educational information systems but in other information systems as well.

References

Bacca, J., Baldiris, S., Fabregat, R., Graf, S., & Kinshuk. (2014). Augmented Reality Trends in Education: A Systematic Review of Research and Applications. Educational Technology & Society, 17 (4), 133–149.

Biwer, F., Egbrink, M., Aalten, P., & de Bruin, A. (2020). Fostering effective learning strategies in higher education—A mixed-methods study. *Journal of Applied Research in Memory and Cognition*, 9(2), pp. 186-203.

Büyükbaykal, C. (2015). Communication Technologies and Education in the Information Age. *Procedia - Social and Behavioral Sciences*, 174, pp. 636-640.

Camilleri, M., & Camilleri, A. (2016). Digital Learning Resources and Ubiquitous Technologies in Education. *Technology, Knowledge and Learning*, 22(1), pp. 65-82.

Chen, R., & Wang, X. (2008). An empirical study on tangible augmented reality learning space for design skill transfer. Tsinghua Science and Technology, 13(S1), pp. 13-18.

Dunn, T., & Kennedy, M. (2019). Technology Enhanced Learning in higher education; motivations, engagement and academic achievement. *Computers & Education*, 137, pp. 104-113.

Encyclopedia of Multimedia. (2006). Augmented Reality. pp. 29-31, ISBN:978-0-387-24395-5

Fauzi, M. (2022). E-learning in higher education institutions during COVID-19 pandemic: current and future trends through bibliometric analysis. *Heliyon*, 8(5), p.e09433.

Haleem, A., Javaid, M., Qadri, M., and Suman, R. (2022). Understanding the role of digital technologies in education: A review. *Sustainable Operations and Computers*, 3, pp. 275-285.

Hoofman, J., & Secord, E., (2021). The Effect of COVID-19 on Education. *Pediatric Clinics of North America*, 68(5), pp. 1071-1079.

Hoy, A. (2010). *Educational psychology*. Upper Saddle River, N.J.: Merrill., ISBN: 978-0-13-477432-9

Juan, M., Alexandrescu, L., Folguera, F., & García-García, I., (2016). A Mobile Augmented Reality system for the learning of dental morphology. Digital Education Review

Kennedy, M., & Dunn, T. J. (2018). Improving the use of technology enhanced learning environments in higher education in the UK: A qualitative visualization of students' views. Contemporary Educational Technology, 9(1), 76-89.

Levels, M. (DLLP), D., Opportunities, J., Chapter, J., Benefits, C., & Members, C. et al. (2019). USDLA – United States Distance Learning Association. Retrieved 5th August 2019, from https://usdla.org/

Lima, C., Walton, S. & Owen, T. (2022). A critical outlook at augmented reality and its adoption in education. *Computers and Education Open*, Vol. 3, https://doi.org/10.1016/j.caeo.2022.100103.

McMahon, T. (2006). Teaching for more effective learning: Seven maxims for practice. *Radiography*, 12(1), pp. 34-44.

Pechenkina, E., & Aeschliman, C. (2017). What Do Students Want? Making Sense of Student Preferences in Technology-enhanced Learning. *Contemporary Educational Technology*, 8(1).

Penprase, B. E. (2018). The fourth industrial revolution and higher education. Higher education in the era of the fourth industrial revolution, 10, 978-981.

Radosavljevic, S., Radosavljevic, V., & Grgurovic, B. (2018). The potential of implementing augmented reality into vocational higher education through mobile learning. Interactive Learning Environments, 28(4), pp. 404-418.

Radosavljevic, V., Radosavljevic, S., & Jelic, G. (2019). Ambient intelligence-based smart classroom model. *Interactive Learning Environments*, 30(2), pp. 307-321.

Santos, M., Chen, A., Taketomi, T., Yamamoto, G., Miyazaki, J., & Kato, H. (2014). Augmented Reality Learning Experiences: Survey of Prototype Design and Evaluation. *IEEE Transactions on Learning Technologies*, 7(1), pp. 38-56.

Seidel, T., & Shavelson, R. (2007). Teaching Effectiveness Research in the Past Decade: The Role of Theory and Research Design in Disentangling Meta-Analysis Results. *Review of Educational Research*, 77(4), pp. 454-499.

Tzima, S., Styliaras, G., & Bassounas, A., (2019). Augmented Reality Applications in Education: Teachers Point of View. Education Sciences, 9(2), p. 99.

Urlings, J., Sezer, S., ter Laan, M., Bartels, R., Maal, T., Boogaarts, J., & Henssen, D., (2022). The role and effectiveness of augmented reality in patient education: A systematic review of the literature. *Patient Education and Counseling*, 105(7), pp. 1917-1927.

Uygur, M., Yanpar, T., & Akay, C. (2018). Analyzing the Views of Pre-Service Teachers on the Use of Augmented Reality Applications in Education. European Journal of Educational Research, 7(4), pp. 849-860.