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AUGMENTED REALITY IN HIGHER EDUCATION: A 10-YEAR SYSTEMATIC LITERATURE REVIEW

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ABSTRACT

Higher education is increasingly using augmented reality (AR) as a teaching and learning tool. The purpose of this systematic literature review (SLR) is to investigate the current situation of the art of research on augmented reality (AR) in higher education. The study synthesizes 20 peer-reviewed articles that were written between 2011 and 2022 with a focus on examining certain criteria, such as the total number of studies performed over time, the countries that have used augmented reality in higher education, the duration of the study, the academic fields that have used augmented reality, the variables that have been measured, and the data collection techniques used. The study comes to the conclusion that augmented reality technology has the potential to improve student outcomes in higher education, including engagement and learning processes. The review identifies the knowledge gaps that might be investigated in future studies and offers insightful information about the use of augmented reality in higher education overall.

Keywords: *Augmented Reality, Higher education, AR, Mobile learning, Education.*

1.0 INTRODUCTION:

With the development of new multimedia tools and strategies intended to improve the learning experience, educational technology has significantly advanced recently. Augmented Reality (AR) has developed as one of these, and it shows promise as a teaching and learning tool in higher education. AR creates an immersive and interactive experience for learners by merging the actual world with virtual components [1].

A variety of subjects have been covered in the expanding body of research on the use of augmented reality in education, such as preparing teachers for employing augmented reality [2], student attitudes toward augmented reality [3], and the effect of augmented reality on learning outcomes [4].

Despite these results, additional research is still required to fully understand the potential of augmented reality in higher education and how it might be successfully incorporated into the classroom. In higher education, augmented reality has been utilized to improve students' learning in a variety of subjects, including the arts and humanities [5].

This systematic literature review (SLR) aims to provide an in-depth and up-to-date overview of the most recent research on the application of augmented reality (AR) in higher education. is crucial for combining existing research, identifying trends and gaps, evaluating results, advancing knowledge, and assisting in the successful integration of augmented reality in higher education settings. The review concentrated on certain factors, including the total number of studies conducted over time, countries that have used augmented reality in higher education, the time frame of the study, the fields that have used augmented reality, the variables that have been measured, and the data collection methods used. This SLR provides insights into the advantages and restrictions of employing augmented reality in higher education by summarizing the

relevant research, as well as suggest opportunities for further investigation.

2.0 METHODOLOGY

In order to better understand the concept, usage, impacts, and evaluation of augmented reality applications in higher education, as well as the experimental methodology, sample sizes, and outcome measurement techniques, the researchers set out to conduct a number of studies. Researchers followed the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) guidelines when performing a Systematic Literature Review (SLR) to accomplish this. The PRISMA guidelines are a collection of evidence-based requirements for reporting in systematic reviews and meta-analyses, according to Moher et al. [6] and Yasin et al. [7]. These guidelines emphasize the reporting of reviews that evaluate the impact of treatments as their primary focus.

The Systematic Literature Review was conducted through a series of steps, beginning with the identification of research questions. The next step involved constructing a research strategy, which included selecting academic research databases, such as Scopus, Web of Science, IEEE, and Science Direct. The third step was to construct inclusion and exclusion criteria, including population, study type, time frame (2011-2022), and education level.

The fourth step included a screening procedure based on the research publications' titles and abstracts. while the fifth step included information retrieval based on certain criteria, such as research title, type of experimental study used, and data collection method, as well as the field of higher education.

Finally, the findings and analysis of the Systematic Literature Review were presented. *Figure 1* illustrates the steps involved in conducting this review.

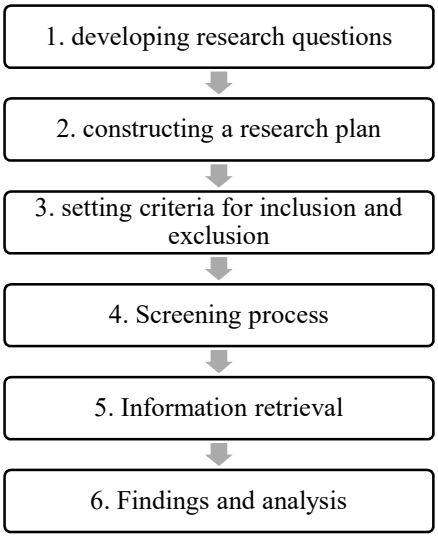

Figure 1: The steps of a systematic review of the literature

2.1 Research questions:

In this section, we will present the research question that guided this systematic literature review, providing a clear focus and direction for the investigation.

RQ 01: How has the number of research papers examining the use of augmented reality in higher education changed over the past ten years?

RQ 02: What countries have investigated augmented reality applications?

RQ 03: How have the sample sizes and study durations varied in studies investigating Augmented reality applications in different academic domains or specializations?

RQ 04: Which variables related to the use of augmented reality in higher education have been measured in the past decade?

RQ 05: Which academic domains or specializations have examined or tested Augmented reality applications?

RQ 06: What are the methods and tools employed to measure the variables and collect the data related to the application of augmented reality in higher education?

RQ 07: What are the potential areas for future research on the use of augmented reality in higher education?

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2.2 Objectives

The purpose of this systematic review of the literature was to offer a comprehensive assessment of academic articles that examine the usage of augmented reality in higher education over the past ten years. Through the exploration of key research questions, this review aims to identify the trends, variables, methods, and academic domains related to the use of augmented reality in higher education. Additionally, this review seeks to provide insights into the sample sizes, study durations, and geographic locations of studies investigating augmented reality applications in higher education. By reaching these goals, this review will offer insightful information about the current state of augmented reality research in higher education and potential research fields. The objectives of the systematic literature review were:

1. To identify and examine the ten-year trend in academic articles looking into the use of augmented reality in higher education.
2. To identify countries that investigated into the use of augmented reality in higher education.
3. To analyze the sample sizes and study durations used in studies investigating augmented reality applications in different academic domains or specializations.
4. To identify the variables that have been assessed in research on the application of augmented reality in higher education over the previous ten years.
5. To identify the academic domains or specializations that have examined or tested augmented reality applications.
6. To examine the methods and tools used to measure the variables related to the use of augmented reality in higher education.
7. To identify potential areas for future research on the use of augmented reality in higher education.
8.

2.3 Search string

Between 2011 and 2022, a search was conducted in several academic research databases, namely Scopus, Web of Science, IEEE, and Science Direct. The search query was based on keywords related to Augmented Reality and higher education.

Quick database search identified relevant terms and phrases for accurate keyword identification in this paper, ensuring up-to-date research materials.

The specific keywords used to formulate the search query were:(Augmented AND Reality) AND (Application OR software) AND (Experimental or quasi-experimental) AND (“Higher Education” OR University)

In order to ensure that no relevant papers were overlooked (avoiding false negatives), we conducted additional searches using fresh synonymous keywords. This process was continued until no new documents meeting the inclusion criteria were identified.

Figure 02 illustrates the steps that were followed in conducting a systematic literature review (SLR) for this study.

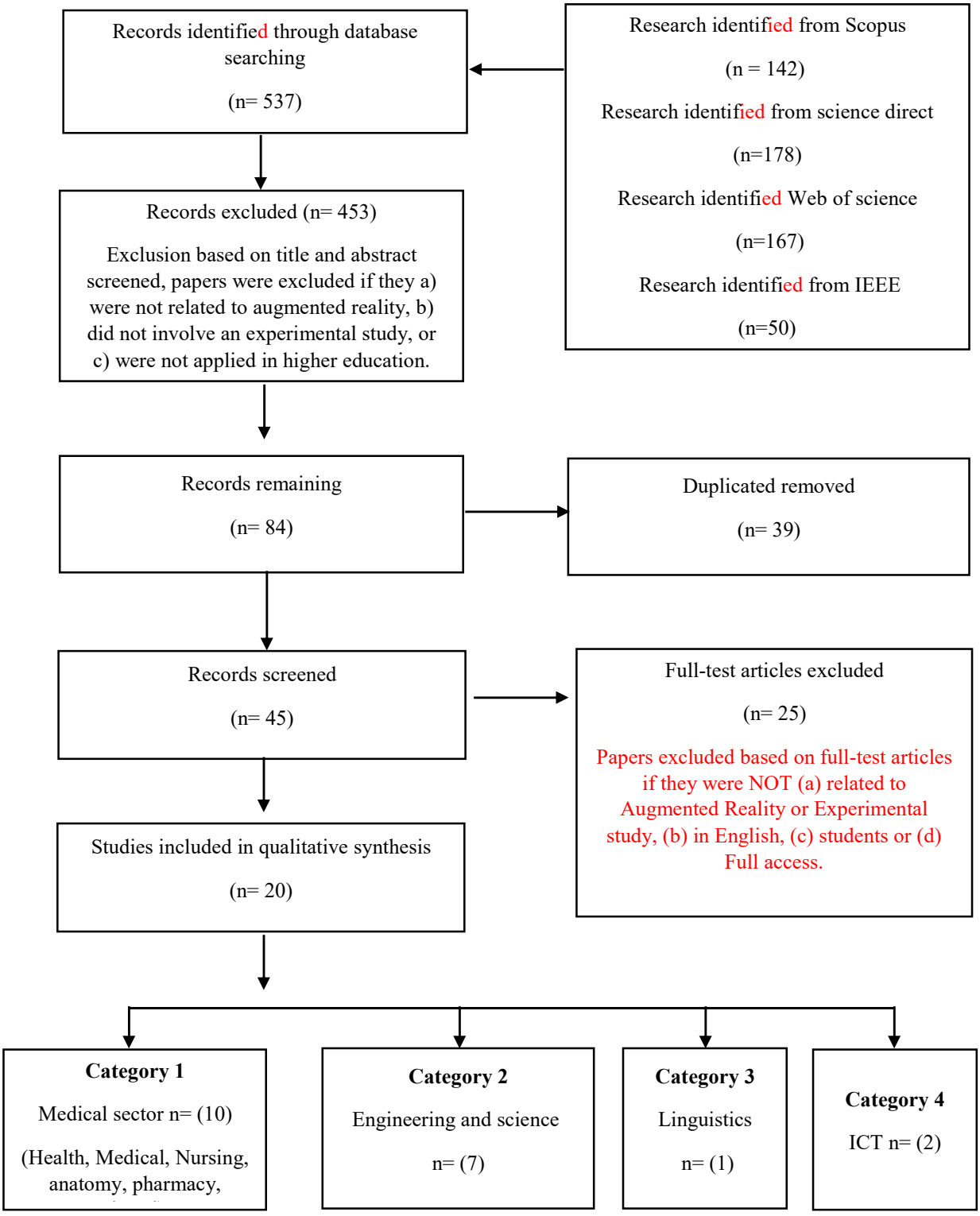


Figure 2: Procedure for Collecting and Processing Data in Accordance with PRISMA Guidelines

2.4 Eligibility criteria

Defining precise inclusion and exclusion criteria is crucial to guarantee a thorough and concentrated examination of the relevant literature on utilizing AR in higher education. The following criteria must be met by the papers to be considered for inclusion in this review:

- The study must be relevant to the application of Augmented Reality technology in higher education.
- Publication timeframe: studies published within the past decade (between 2011 to 2022)
- Content scope: studies that concentrate on the utilization of AR in education, and its effects on student learning outcomes and experiences.
- Study methodology: experimental and quasi-experimental studies investigating the utilization of AR in higher education.
- Conversely, papers were not included if they met any of the following criteria:
- Studies that focus on AR technology development or AR applications outside of higher education.
- Studies conducted for experts, teachers and instructors.
- Studies that employ other forms of technology-enhanced learning, such as Virtual Reality (VR) or 3D environments, and do not primarily concentrate on AR.
- Non-English language studies were excluded.

2.5 Classify of the papers

After the initial screening process, the selected papers were subjected to a thorough coding and analysis process using Microsoft Excel. In order to ensure the reliability of judgments, two authors independently read and analyzed all the papers, attempting to assign them to distinct categories such as sample size, data collection method, variables, year, country, domain, duration, results, problem statement, and research method.

To ensure consistency in assessing and categorizing the papers, the authors provided definitions and explanations for each category to the readers. In case of any disagreement between the two authors, a third author intervened to reach a decision [8]. All authors then discussed the papers together and worked towards a consensus.

This rigorous process ensured the accuracy and validity of the categorization and analysis of the selected papers.

2.6 Data extraction

The findings from the coding and analysis process are summarized in *Table 1*, which presents a detailed breakdown of the factors collected in order to answer the research question. These factors include country, data collection method, sample size, level, duration, variables, and domain. The results in *Table 1* serves as a valuable reference for understanding the specific contributions that each study made to the broader body of research on the use of augmented reality in higher education.

By presenting this information in a clear and organized manner, *Table 2* enables readers to quickly identify the main findings and conclusions of each study and to compare and contrast the results across different studies.

Table 1: Data extraction form

References	Country	Data collection Method	Sample	Duration	Variables	Domain
Dukalskaya & Tabueva, 2022 [9]	Russia	oral survey	42	1 semester	Motivation Performance	Linguistic Education
Christopoulos et al., 2022 [10]	Finland	pre and post test questionnaire	C: 30 E:30	4 weeks	Academic achievement Training satisfaction	Medical Education

References	Country	Data collection Method	Sample	Duration	Variables	Domain
Nordin, Nordin, & Omar, 2022 [11]	Malaysia	pre and post test course assessment	55	1 semester	Students' knowledge Effectiveness of AR app	Management
Herbert et al., 2021 [12]	US	Pre and post test questionnaire	C: 14 E:19	1 semester	Academic achievement Satisfaction Usability	Medical Education
Södervik et al., 2021 [13]	Finland	Pre and post test questionnaire	C: 6 E:10	not clear	Learning outcomes Usability	Medical Education
Kurt & Öztürk, 2021 [14]	Turkey	Pre and post test persistence test, injection evaluation checklist	C: 58 E:64	3 weeks	Knowledge Skills	Medical Education
Fernandes, Teles, & Teixeira, 2020 [15]	Brazil	Questionnaire	C: 40 E:40	not clear	Usability	Medical Education
Robinson, Mitchell & Brenseke, 2020 [16]	US	pre and post activity	C: 5 E:5	1 week	Knowledge	Medical Education
Bork et al., 2021 [17]	Germany	Survey pre and post questionnaire system usability scale	C: 8 E:8	1 day	Usability Motivation Knowledge	Medical Education
Mladenovic et al., 2019 [18]	Serbia	Application of anesthesia Post questionnaire	C: 19 E:22	4 weeks	Effectiveness Knowledge Skills	Medical Education
Kwiatek et al., 2019 [19]	Canada	practical test	61	not clear	Spatial cognitive abilities	Engineering
Reuter et al., 2019 [20]	Germany	questionnaire	C: 7 E:7	not clear	Effectiveness Performance Motivation	Software Engineering
Ali et al., 2017 [21]	Malaysia	Interview, pre and post test	C: 30 E:30	not clear	not clear	Engineering

References	Country	Data collection Method	Sample	Duration	Variables	Domain
Bal & Bicen, 2016 [22]	Turkey	Pre and post test, Questionnaire	C: 25 E:25	1 semester	Achievement	Education
Küçük et al. (2016) [23]	Turkey	academic achievement test (post test for both groups) Cognitive load scale	C: 36 E:34	1 semester	Academic achievement Cognitive load	Medical Education
Akçayir et al., 2016 [24]	Turkey	Pre and post test Pre and post questionnaire interview	C: 38 E:38	5 weeks	Skills Attitudes	Education
Sánchez et al., 2015 [25]	Spain	pre and post test questionnaire	146	3 days	Usability Academic performance Effectiveness Efficiency Satisfaction	Engineering
Gutiérrez & Fernández, 2014 [26]	Spain	Exam questionnaire	C: 22 E:25	6 weeks	Academic achievement Effectiveness Efficiency Satisfaction Motivation	Engineering
Lee et al., 2013 [27]	Korea	Practical test questionnaire	40	not clear	Performance Effectiveness	Medical Education
Martin-Gutierrez, 2011 [28]	Spain	Post text questionnaire	C: 22 E:25	6 weeks	Motivation Satisfaction Effectiveness	Engineering

C, Control group; E, Experimental group

Table 2 provides a comprehensive overview of the key findings from each individual study that was included in the analysis.

Table 2: Included studies findings

References	Findings
Dukalskaya & Tabueva, 2022 [9]	The findings suggest that incorporating Information and Communication Technology (ICT) into English language instruction is effective for non-linguistic students.
Christopoulos et al., 2022 [10]	Participants in the experimental group outperformed their counterparts by a significant margin.

References	Findings
Nordin, Nordin, & Omar, 2022 [11]	Results indicate that students performed better on all tests taken before using REV-OPOLY.
Herbert et al., 2021 [12]	Although more students said they preferred the AR app, there were no appreciable improvements in learning.
Södervik et al., 2021 [13]	Compared to conventional laboratory instruction, AR proved more effective at improving performance in the scientific lab and reducing error rates.
Kurt & Öztürk, 2021 [14]	It was found that MAR apps helped nursing students retain their newly acquired knowledge and abilities and had a beneficial impact on their levels of knowledge and proficiency in relation to injection techniques.
Fernandes, Teles, & Teixeira, 2020 [15]	In terms of usability and learning factor, the results were encouraging. We came to the conclusion that using NitLabEduca as an addition to printed information when studying the spinal cord appears to favor learning.
Robinson, Mitchell & Brenseke, 2020 [16]	According to research, MR is a useful teaching tool that enhances the learning process.
Bork et al., 2021 [17]	The outcomes demonstrated the collaborative AR system's potential for improving students' 3D grasp of topographic anatomy as well as its advantages over similar single-user AR systems.
Mladenovic et al., 2019 [18]	Overall, the students who combined their education in augmented reality with the mobile simulator were able to complete anesthetic procedures for the IANB more quickly and with greater success than the students who only used the traditional teaching methods.
Kwiatek et al., 2019 [19]	Both inexperienced engineers and skilled professional pipe fitters can significantly reduce the amount of time spent assembling pipe spools compared to using the traditional methods.
Reuter et al., 2019 [20]	We found that participants in the experimental group tended to be more motivated than those in the control group. Both teams gave equally good performances.
Ali et al., 2017 [21]	The majority of respondents found it challenging to visualize 3-dimensional objects from 2-dimensional projection images and vice versa, so they preferred learning with the aid of 3-D computer-aided animation. In addition, this study discovered that using an augmented reality learning environment helps students develop their abilities to combine 2-dimensional objects.
Bal & Bicen, 2016 [22]	The experimental group has a higher level of achievement. Results in this context demonstrated that integrating augmented reality and QR codes into computer hardware course applications has a positive impact on students' academic achievements and their perceptions of the course.

References	Findings
Küçük et al. (2016) [23]	The experimental group reported greater achievement and decreased cognitive load while using mAR applications. The creation of an efficient and effective learning environment was facilitated by the use of mAR applications in anatomy instruction.
Akçayir et al., 2016 [24]	The laboratory skills of university students were developed significantly more effectively thanks to AR technology. AR technology helped the students develop better laboratory skills and more positive attitudes toward physics labs.
Sánchez et al., 2015 [25]	The PRE and POST test results, along with questionnaire responses, reveal high qualification levels in terms of effectiveness, efficiency, and satisfaction.
Gutiérrez & Fernández, 2014 [26]	Results show that when the newest technological tools are incorporated into the teaching process, engineering students perform better academically and are more motivated.
Lee et al., 2013 [27]	AR simulation has been proven to be a very effective tool for training medical personnel, even though the system used in this study needs to be modified before it can be adopted for veterinary educational use.
Martin-Gutierrez, 2011 [28]	The findings reveal that the experimental group's students enjoyed learning with augmented reality technology and even performed better on a test of content evaluation.

2.7 RESULTS AND DISCUSSION

In this section, the results and discuss the findings of our systematic literature review on the use of augmented reality in higher education have been presented. Key research questions, covering aspects such as research trends, countries involved, sample sizes, measured variables, academic domains, methods/tools used, and potential areas for future research have been addressed.

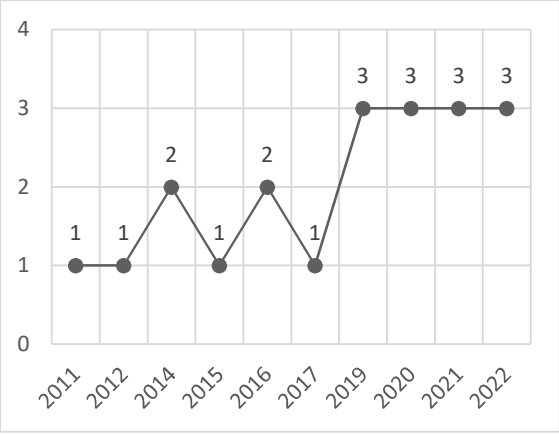


Figure 3: Year of Publication

This may point to an increase in interest in the field of multimedia learning and its potential applications across different industries, possibly due in part to the COVID-19 pandemic and the shift towards remote and online learning.

It is crucial to carry out research in this field to better understand how multimedia affects learning outcomes and to investigate fresh approaches to integrating multimedia into training and educational environments.

2.7.1 year of publication

The research articles included in the study have been growing gradually since 2011 As shown in *Figure 03*, according to the data you provided. The number of papers reached a peak in 2014, and

since 2019, the number has been increasing continuously.

2.7.2 study location

The SLR paper demonstrates a diverse range of countries represented in the research articles, as shown in *Figure 04*. Turkey had the highest number of papers, followed by Spain, Finland, Germany, Malaysia, and the US, with the remaining countries each having one article. This diversity suggests that research on the effectiveness of educational and training programs is a global phenomenon, which may be influenced by cultural, linguistic, and social differences.

The country of origin may also reflect the availability of research funding, institutional support, and expertise in the domain of the study. This information can be useful in understanding the context of the research and its practical applications. However, as most studies were conducted in

developed countries, it is essential to explore the effectiveness of educational technologies in different socio-cultural contexts where access to technology and resources may be limited.

Research from developing and least developed countries can provide valuable insights into the unique challenges and opportunities for education and training in these contexts. However, researchers in these countries may face additional barriers and challenges when conducting and publishing their research, such as limited funding and access to resources. Collaborations and partnerships between researchers in developed and developing countries can help to address these challenges and promote knowledge sharing and collaboration across borders.

Moreover, more comparative studies are needed to understand how cultural and educational contexts impact the effectiveness of educational technologies. For instance, a comparative study of the effectiveness of AR technology in Turkey and Korea, or in Spain and Albania, could provide insights into the role of culture and educational systems in shaping the adoption and impact of educational technologies.

2.7.3 sample size

As illustrated in *Figure 05*, Although there are studies where it was not clear how many groups that students divide into, like Lee et al.,[27], Sánchez et al., [25], Kwiatek et al., [19], Nordin, Nordin, & Omar, [11] and Dukalskaya & Tabueva, [9] there is a significant difference and variation in the number of students who participated in the studies. Some studies used very limited numbers, such as 5 students per group Robinson, Mitchell & Brenseke, [16], Bork et al., [17], Södervik et al., [13] and Reuter et al., [20], while Kurt & Öztürk, [14] study used larger number exceeding 50 students in each group.

All other half of the studies used moderate numbers of 25-40 students relative to the studies included in the research. All studies did not clearly indicate the study population or the method of selecting the study sample, and this does not allow us to infer a clear rule that determines the appropriateness of the study sample used in the research.

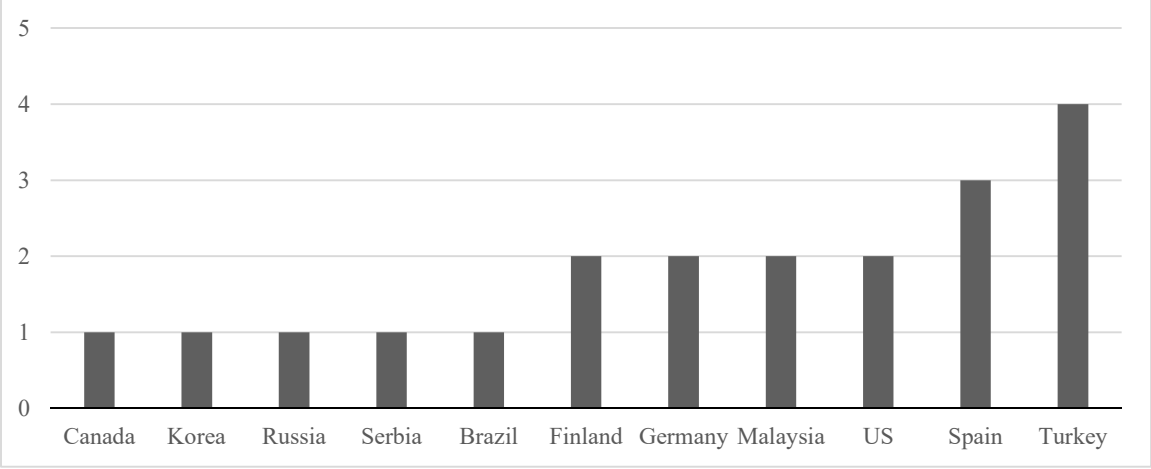


Figure 4: Study location

2.7.4 study duration

Based on the *Figure 6*, it appears that the duration of the experiments included in SLR paper varied widely. The most commonly reported duration was one semester, with 5 articles indicating that their experiment lasted for this length of time. The next most common durations were less than a week and 2 to 4 weeks, each of which appeared in 3 articles. 5 to 8 weeks was also a commonly reported duration, appearing in 3 articles. Finally, 6 articles did not clearly report the duration of their experiment.

This information can be helpful in understanding the range of durations used in previous studies and can also be useful in planning future research. It suggests that a range of durations can be effective in measuring the variables related to educational and training programs, and that the appropriate duration may depend on the specific goals and context of the experiment. For example, shorter experiments may be more feasible for measuring certain variables, while longer experiments may be necessary to capture changes over time or to assess the longer-term impact of a program.

Figure 5: Sample size

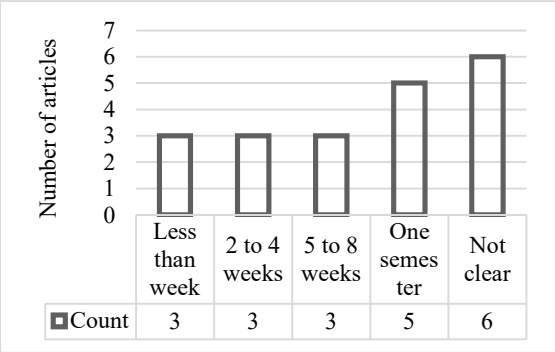
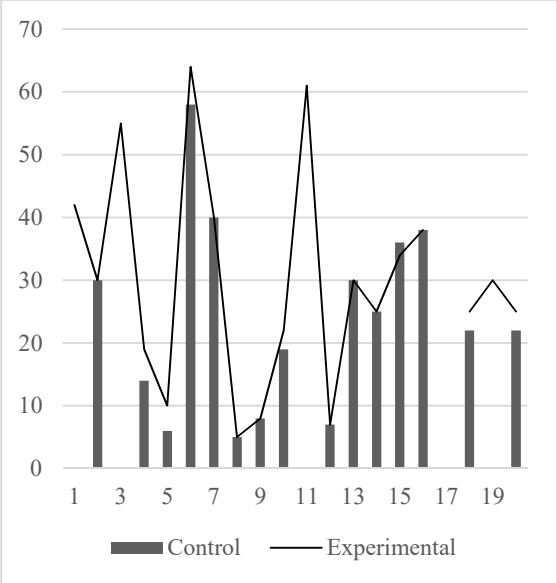


Figure 6: Study duration

2.7.5 variables measured in the study

Based on *Figure 7*, it appears that effectiveness was the most commonly measured variable across the studies included in SLR paper, with 7 articles measuring this variable. Motivation and academic achievement were tied for the second most commonly measured variables, each appearing in 5 articles. Satisfaction, knowledge, and usability were also frequently measured, with 5 articles each. Performance and skills were measured in 4 and 3 articles, respectively. Efficiency, learning outcomes, spatial cognitive abilities, cognitive load, and attitudes were less frequently measured, each appearing in only 2 or fewer articles. This information can help identify that some variables like effectiveness, motivation and achievement have received the most attention in the literature. It can also help to identify areas where more research may be needed to build a more complete understanding of the effectiveness of educational and training programs such as Efficiency, learning outcomes,



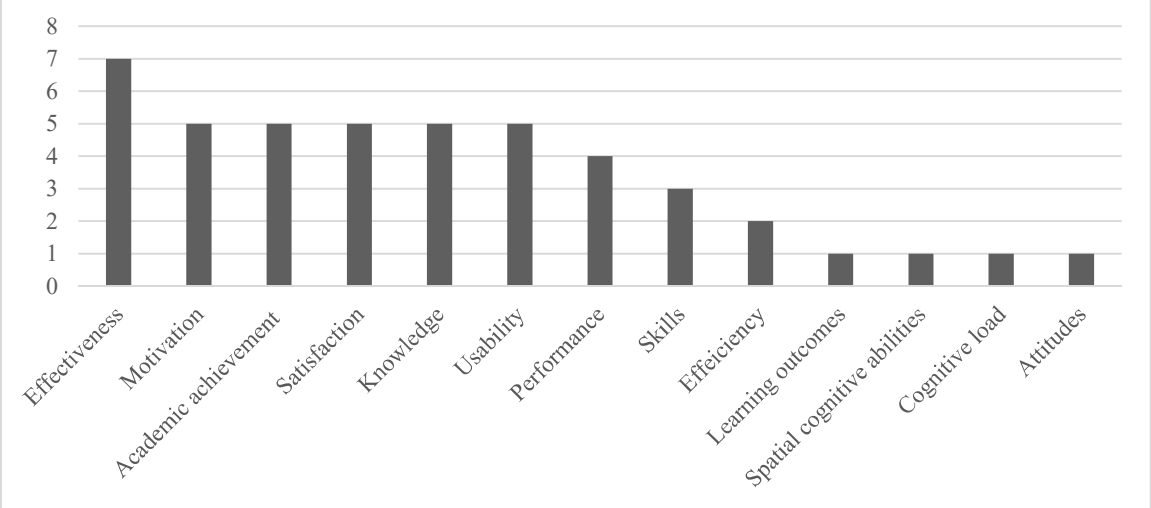


Figure 7: Variables measured in the study

spatial cognitive abilities, cognitive load, and attitude toward using AR application.

Based on the variables and their frequency of measurement in the literature, here are a few suggestions for future research in the field of educational and training programs:

1. Further explore the relationship between effectiveness and other variables: Given that effectiveness was the most commonly measured variable, it may be beneficial to further explore its relationship with other variables, such as motivation, satisfaction, and performance. This can help identify the key factors that contribute to the effectiveness of educational and training programs.

2. Investigate the impact of efficiency on program outcomes: Although efficiency was only measured in 2 articles, it can be an important factor in determining the success of educational and training programs. Future research could explore the impact of efficient program design and delivery on learner outcomes.

3. Study the relationship between cognitive load and other variables: Cognitive load was only measured in 1 article, but it can be an important factor to consider when designing educational and training programs. Future research could explore the relationship between cognitive load and other variables, such as performance, satisfaction, and learning outcomes.

4. Examine the role of attitudes in program success: Attitudes were also only measured in 1 article, but they can play a significant role in determining learner engagement and success in educational and training programs. Future research could explore how attitudes impact motivation, satisfaction, and other key program outcomes.

Overall, future research in this field can help build a more complete understanding of the factors that contribute to the effectiveness of educational and training programs, and can help inform the design and delivery of more successful programs in the future.

2.7.6 academic domain

From the literature review, and referring to *Figure 8*, it appears that the majority of the articles included were related to medical education, with 10 articles reporting this domain. Engineering was also a commonly studied domain, with 5 articles reporting this focus. Education was the domain of focus for 2 articles, while linguistic education, management, and software engineering each appeared in 1 article.

This information can be useful in understanding the areas of focus for the variables related to educational and training programs. It suggests that there is a significant body of research in medical education and that this area may be particularly well-developed in terms of studying the effectiveness of educational and training programs. Other domains, such as engineering, also appear to have a considerable amount of research in this area. Additionally, it may be important to consider the domain of focus when interpreting findings and

generalizing results, as different domains such as using AR application in teaching and learning Information technology, arts, computer engineering and many other academic domains that may have unique characteristics or challenges that affect the

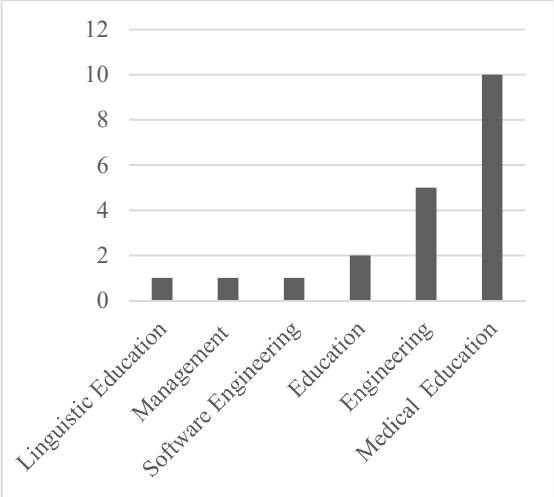


Figure 8: Academic domain

effectiveness of educational and training programs.

2.7.7 data collection method

Based on the data collection methods, it seems that most studies used pre and post tests, questionnaires, and surveys to evaluate the effectiveness, efficiency, and satisfaction of the experimental interventions. Future studies could consider using more objective measures such as practical tests or recordings of task completion times to supplement the subjective data collected through questionnaires and surveys. See *Figure 9*.

It's also worth noting that some studies included interviews or qualitative data collection methods to gather more in-depth information on the experiences and perspectives of the participants. This could be a valuable addition to future studies as it can provide a deeper understanding of the impact of the intervention on the participants.

Overall, it's important for future studies to use a combination of both subjective and objective data collection methods to ensure a comprehensive evaluation of the effectiveness of the interventions.

The experimental group consistently outperformed the control group in terms of academic performance, knowledge/skill acquisition, motivation, satisfaction, and attitude toward technology, according to the articles included in the systematic literature review. Particularly, it has been demonstrated that using mobile apps and AR technology effectively increases student engagement and learning outcomes. Students typically view technology use in the classroom favorably and find it simple to use and learn from. Additionally, the use of AR technology appears to benefit the development of language/vocabulary, lab skills, and spatial cognition. Overall, the results imply that using technology in the classroom can improve motivation and learning among students.

2.7.8 discussion of results

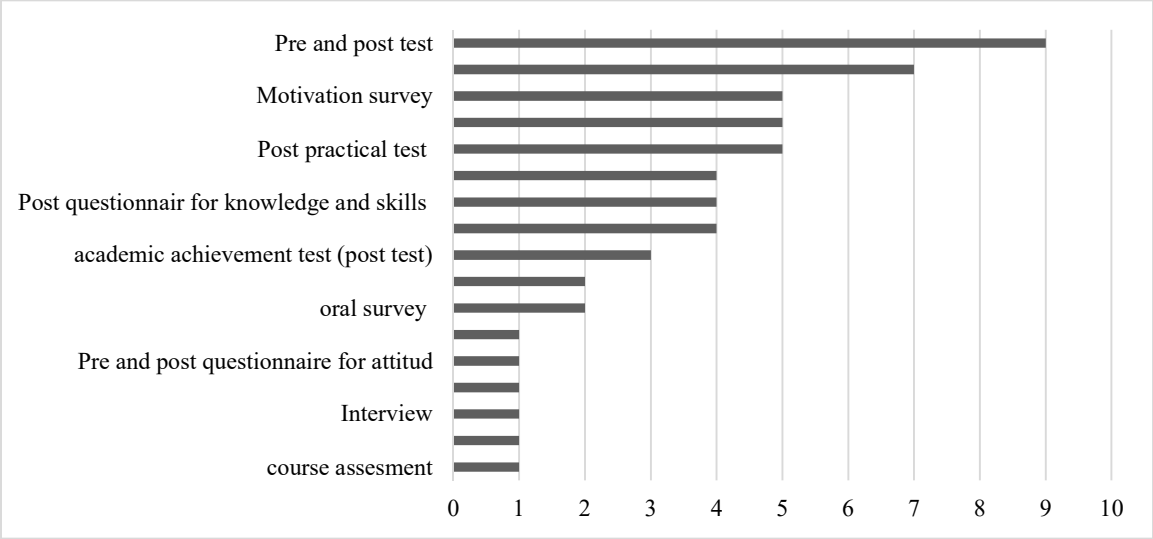


Figure 9: Data collection method

The SLR articles under discussion here use experimental and quasi-experimental research designs to compare at least two groups—one using conventional teaching and learning methods and the other using an AR application—in order to examine the efficacy of AR applications in higher education, in this section all the presented results will be discussed and the key findings of the study will be described in detail.

AR has been discovered to be especially helpful in the engineering and health sectors. While Kwiatek et al. [19] discovered that AR can significantly speed up pipe spool assembly compared to traditional methods, Bork et al. [17] and Ali et al. [21] noted that AR applications can help students better understand complex 3D structures that are challenging to represent in real or fake models. Additionally, AR applications have been reported to improve students' laboratory skills by Akçayir et al. [24], Kurt & ÖZtürk [14], and Mladenovic et al. [18]. In their 2016 study on the impact of AR on cognitive load, Küçük et al. [23] discovered that the group using AR had higher achievement and less cognitive load. In addition, several studies (Gutiérrez & Fernández,[26]; Lee et al., [27]) noted the learners' positive attitudes toward the use of AR in learning and teaching, as well as their increased engagement and motivation. Overall, the majority of studies discovered that experimental students who used augmented reality (AR) applications outperformed their peers who used conventional teaching and learning techniques. Positive effects on students' knowledge and skill levels have been reported by Christopoulos et al. [10], Nordin, Nordin, & Omar [11], Kurt & ztürk [14], and Martin-Gutierrez [28]. Only Herbert et al.'s study from 2021 [12] found no significant distinctions between experimental and control groups in terms of learning, but the results show that students preferred the AR app.

It is clear from the results that the field of using augmented reality technologies in higher education has developed significantly in the last five years, and this may be due to the rapid development of augmented reality technologies that have become used in many domains. However, there is still a lack of studies, and there is an urgent need for more studies that are concerned with studying the use of augmented reality technologies and their effectiveness.

With regard to the locations of implementation of these studies, the results indicate that most of the studies were conducted in developed countries, and this can be due to their possession of a distinguished technological infrastructure that helps them in employing augmented reality technologies without any major obstacles. On the other hand, there is a scarcity of studies in developing countries that need to develop their technological infrastructure, pay more attention to improving the technological reality there, and try to benefit from modern technologies in education and other fields.

The results also indicate that there are no clear and specific criteria related to the used samples and their characteristics, as well as the duration of conducting such studies which ranged between one day to 4 months. Therefore, it is worth noting that the results of some of these studies are not strong, cannot be relied upon and that there is a need for more studies that would create new, clear and specific criteria that help in reaching to more coherent and powerful results.

With regard to the adopted variables in these studies, the results showed that most of the included studies focused largely on one variable, which is the “effectiveness” of using augmented reality technologies. This can be explained by the fact that the issue of employing these technologies is still in the beginning and needs further exploration. Also, variables such as motivation, academic achievement, participant satisfaction, and increasing knowledge and skills came in the second level in terms of importance. Based on this, it is clear that there is a tendency towards the augmented reality in developing the educational process and its key participants. However, this study did not find a single, complete and comprehensive study that deals with the variables in a more focused manner to clarify or explain the meanings and uses of these variables, or even attempts to classify them based on specific and well-known criteria.

For the academic domains in which these studies were implemented, most of the studies focused on studying the use of augmented reality technologies in the “health” domains such as medicine and nursing, as well as engineering domain. While there was no considered focus on other domains, which indicates the importance of conducting more research and studies in other domains that can benefit from the technologies of augmented reality.

The real contribution of this study is that it did not address the issue of using augmented reality technologies from a specific angle or in a specific domain, like the rest of the previous studies, the systematic review conducted by Lee [29] focused on

augmented reality in education and training, Similarly Sırakaya and Alsancak Sırakaya [30] study focused on augmented reality in STEM (Science, Technology, Engineering and Mathematic) education, encompassing schools and higher education. In the same way Akçayır and Akçayır [31] study concerning the utilization of augmented reality (AR) in educational environments with considering various factors, including publication year, learner type (e.g., K-12, higher education, and adult), AR technologies employed, as well as the benefits and challenges associated with using AR in educational settings. Tang et al., [32] explored the application of augmented reality in medical education, focusing exclusively on this specific domain. but this study tried to draw a complete picture of the reality of scientific research related to augmented reality technologies in higher education. The expected next step is to build on the results of this study and explore more research areas, such as: conducting studies on augmented reality in developing countries, studies that focus on employing new methods and methodologies in research, studies that focus on exploring and testing relevant variables using Augmented reality, studies in new environments and contexts other than those presented in this study, and more.

3.0 FUTURE WORK

The aim of this study was to explore the use of augmented reality technologies in higher education. Based on the obtained results of the study, it was found that there are several research areas that need more research studies in the future. Among these research areas are the following:

1. Focus on developing countries: Conducting studies on augmented reality in higher education, particularly in regions with limited research representation.
2. Focus on studying other subjects: Exploring the integration of augmented reality in teaching other subjects.
3. The influence of demographic variables on augmented reality: Studying the impact of culture, gender, age and other demographic variables on using AR.

4.0 LIMITATIONS OF THE REVIEW

Although this study relied on more than one researcher to be more reliable and robust, there were some limitations appeared which might have affected the activities of this study and its results. The major limitations of this SLR are bias in the selection of articles and inaccuracy while extracting data from the articles.

To ensure that the process of selecting articles is not biased, a protocol was established based on some research questions to organize the review in general and the process of selecting articles in particular from the beginning of the study. The research questions guide the researchers during the keywords' construction, selection process and even during the data extraction. However, it is essential to recognize that the augmented reality terms are not standardized and that they can be both discipline- and language-specific. Therefore, due to our choice of keywords and search statements, there is a probability that some relevant studies were omitted. Furthermore, since our focus was on experimental research, we excluded ‘‘theoretical” papers and papers that were based merely on author opinion. If the SLR had included these papers, the current study could, in principle, have provided more data. In that case, it might have been more likely to have more general conclusions and findings. In addition, to avoid unbiased in the selection of articles, the selection process was carried out through several stages, with the participation of two researchers, and through several discussion sessions, as described in section (2.5) and suggested by many researchers.

During the data extraction process, we found that there were some articles that lacked details, such as: the clarity of objectives, utilized research methods, nature of sample and its size, ambiguity of the tested variables, and others. As a result, all data from all the 20 primary studies were extracted by the three authors in consensus meetings according to a predefined extraction criteria. However, the data extraction process faced obstacles related to the quality of the included papers and the style of their documentation. In addition, there is often a significant amount of information missing in some papers or not addressed in a proper detail. Therefore, there is a low possibility that the data extraction process may sometimes be inaccurate or lack of some details.

5.0 CONCLUSION

In conclusion, the systematic literature review has explored the use of Augmented Reality (AR) applications in higher education, and the impact of AR on student satisfaction, acceptance, and achievement. The review has synthesized the evidence from a number of studies, and has provided

a comprehensive understanding of the use of AR in higher education.

The findings of the review suggest that AR technology has the potential to positively impact student satisfaction, acceptance, and achievement in higher education. The use of AR technology can enhance the learning experience and increase student engagement, leading to improved outcomes in higher education.

However, the systematic literature review has also highlighted some limitations and challenges associated with the use of AR in higher education. The quality of the studies included in the review can vary greatly, and the selection of studies for inclusion can be subject to bias. Additionally, the findings from the review may not be generalizable to other populations or settings, as the studies included in the review may be limited to a specific population or geographical location.

Despite these limitations, the systematic literature review provides valuable insights into the use of AR in higher education, and the impact of AR on student satisfaction, acceptance, and achievement. The review highlights the potential benefits of AR technology for higher education, and provides a foundation for future research on this topic.

REFFERENCESS

[1] Bekhit A. Computer Vision and Augmented Reality in iOS. Apress Berkeley, 2021, pp. 4842-7462. https://doi.org/10.1007/978-1-4842-7462-0.

[2] Guler HI, Ozden MY. Investigating preservice teachers' perceived self-efficacy and attitudes towards augmented reality technology integration. Journal of Education and Practice (Vol 11, Issue 32), 2020, pp. 35-43.

[3] Yilmaz, N., & Alkan, G. An exploratory study of Turkish teachers' beliefs and attitudes towards augmented reality technology integration into classroom instruction. Education and Information Technologies (Vol 25, Issue 1), 2020, pp. 23-43.

[4] Ketelhut, DJ, Dede, C, Clarke, J, Nelson, B. A Multi-User Virtual Environment for Building and Enhancing Social Capital in Online Teacher Professional Development. Journal of Interactive Learning Research (Vol 21, Issue 2), 2010, pp. 181-202.

[5] Chang YC, Hsu CH, Chen CC. An Exploration of Augmented Reality in Higher Education: A Review of Literature. Journal of Educational Technology Development and Exchange (Vol 3, Issue 1), 2020, pp. 1-18.

[6] Moher, D., Liberati, A., Tetzlaff, J., Altman, D. G., & PRISMA Group. Preferred reporting items for systematic reviews and meta-analyses: The PRISMA statement. Annals of Internal Medicine (Vol 151, Issue 4), 2009, pp. 264-269, W64. https://doi.org/10.7326/0003-4819-151-4-200908180-00135.

[7] Yasin, Y. M., Kerr, M. S., Wong, C. A., & Bélanger, C. H. Factors affecting nurses' job satisfaction in rural and urban acute care settings: A PRISMA systematic review. Journal of Advanced Nursing (Vol. 76, Issue 4), 2020, pp. 963-979.

[8] Johnston, M. C., Crilly, M., Black, C., Prescott, G. J., & Mercer, S. W. (2019). Defining and measuring multimorbidity: a systematic review of systematic reviews. European journal of public health, 29(1), 182-189.

[9] Dukalskaya IV, Tabueva IN. Promoting augmented reality technology in teaching English language to non-linguistic students in higher education. European Journal of Contemporary Education (Vol 11, Issue 1), 2022, pp. 47-58. doi:10.13187/ejced.2022.1.47.

[10] Christopoulos, A., Pellas, N., Kurczaba, J., & Macredie, R. The effects of augmented reality-supported instruction in tertiary-level medical education. British Journal of Educational Technology (Vol 53, Issue 2), 2022, pp. 307-325. doi:10.1111/bjet.13167.

[11] Nordin, N., Nordin, N. R. M., & Omar, W. The efficacy of REV-OPOLY augmented reality board game in higher education. International Journal of Emerging Technologies in Learning (Vol 17, Issue 7), 2022, pp. 22-37. doi:10.3991/ijet.v17i07.26317.

[12] Herbert, V. M., Perry, R. J., LeBlanc, C. A., Haase, K. N., Corey, R. R., Giudice, N. A., & Howell, C. Developing a smartphone app with augmented reality to support virtual learning of nursing students on heart failure. Clinical Simulation in Nursing (Vol 54), 2021, pp. 77-85.

[13] Södervik I, Katajavuori N, Kapp K, Laurén P, Aejmelaeus M, Sivén M. Fostering performance in hands-on laboratory work with the use of mobile augmented reality (AR) glasses. Educ Sci (Vol 11, Issue 12). 2021; doi:10.3390/educsci11120816.

[14] Kurt, Y., & Öztürk, H. The effect of mobile augmented reality application developed for injections on the knowledge and skill levels of

nursing students: An experimental controlled study. Nurse Education Today (Vol 103), 2021, pp. doi:10.1016/j.nedt.2021.104955.

[15] Fernandes J, Teles A, Teixeira S. An augmented reality-based mobile application facilitates the learning about the spinal cord. Education Sciences (Vol 10, Issue 12), 2020, pp. 1-18. doi:10.3390/educsci10120376.

[16] Robinson, B. L., Mitchell, T. R., & Brenseke, B. M. Evaluating the use of mixed reality to teach gross and microscopic respiratory anatomy. Medical Science Educator (Vol 30, Issue 4), 2020, pp. 1745-1748. doi:10.1007/s40670-020-01064-2.

[17] Bork, F., Lehner, A., Eck, U., Navab, N., Waschke, J., & Kugelmann, D. The effectiveness of collaborative augmented reality in gross anatomy teaching: A quantitative and qualitative pilot study. Anatomical Sciences Education (Vol 14, Issue 5), 2021, pp. 590-604.

[18] Mladenovic, R., Pereira, L. A. P., Mladenovic, K., Videnovic, N., Bukumiric, Z., & Mladenovic, J. Effectiveness of augmented reality mobile simulator in teaching local anesthesia of inferior alveolar nerve block. Journal of Dental Education (Vol 83, Issue 4), 2019, pp. 423-428. doi:10.21815/JDE.019.050.

[19] Kwiatek, C., Sharif, M., Li, S., Haas, C., & Walbridge, S. Impact of augmented reality and spatial cognition on assembly in construction. Automation in Construction (Vol 108), 2019, pp. 102935.

[20] Reuter, R., Hauser, F., Muckelbauer, D., Stark, T., Antoni, E., Mottok, J., & Wolff, C. Using augmented reality in software engineering education? First insights to a comparative study of 2D and AR UML modeling. Paper presented at the Proceedings of the Annual Hawaii International Conference on System Sciences, 2019-January, pp. 7798-7807. Retrieved from www.scopus.com.

[21] Ali DF, Omar M, Ibrahim NH, Surif J, Ali M, Ismail S. Overcoming the problems faced by students in learning engineering drawing with the implementation of augmented reality learning environment. Man in India (Vol 97, Issue 17), 2017, pp. 147-159.

[22] Bal, E., & Bicen, H., Computer hardware course application through augmented reality and QR code integration: Achievement levels and views of students. Paper presented at the Procedia Computer Science (102), 2016, 267-272. doi:10.1016/j.procs.2016.09.400 Retrieved from www.scopus.com.

[23] Küçük, S., Kapakin, S., & Göktaş, Y. Learning anatomy via mobile augmented reality: Effects on achievement and cognitive load. Anatomical Sciences Education (Vol 9, Issue 5), 2016, pp. 411-421. doi:10.1002/ase.1603.

[24] Akçayir M, Akçayir G, Pektaş HM, Ocak MA. Augmented reality in science laboratories: The effects of augmented reality on university students' laboratory skills and attitudes toward science laboratories. Computers in Human Behavior (Vol 57), 2016, pp. 334-342. doi:10.1016/j.chb.2015.12.054.

[25] Sánchez, A., Redondo, E., Fonseca, D., & Navarro, I. Academic performance assessment using augmented reality in engineering degree course. Paper presented at the Proceedings - Frontiers in Education Conference, FIE, 2015-February (February). doi:10.1109/FIE.2014.7044238. Retrieved from www.scopus.com.

[26] Gutiérrez JM, Fernández MDM. Applying augmented reality in engineering education to improve academic performance & student motivation. International Journal of Engineering Education (Vol 30, Issue 3), 2014, pp. 625-635. Retrieved from www.scopus.com.

[27] Lee, S., Lee, J., Lee, A., Park, N., Song, S., Seo, A., ... & Eom, K. Augmented reality intravenous injection simulator based 3D medical imaging for veterinary medicine. The Veterinary Journal (Vol 196, Issue 2), 2013, pp. 197-202.

[28] Martin-Gutierrez, J. Proposal of methodology for learning of standard mechanical elements using augmented reality. Proceedings - Frontiers in Education Conference, 2011, pp. 10.1109/FIE.2011.6142708.

[29] Lee, K. (2012). Augmented reality in education and training. TechTrends, 56, 13-21.

[30] Sırakaya, M., & Alsancak Sırakaya, D. (2022). Augmented reality in STEM education: A systematic review. Interactive Learning Environments, 30(8), 1556-1569.

[31] Akçayır, M., & Akçayır, G. (2017). Advantages and challenges associated with augmented reality for education: A systematic review of the literature. Educational research review, 20, 1-11.

[32] Tang, K. S., Cheng, D. L., Mi, E., & Greenberg, P. B. (2020). Augmented reality in medical education: a systematic review. Canadian medical education journal, 11(1), e81.