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Compilation of Augmented Reality Studies Conducted with Teacher Candidates

Abstract

The aim of this paper is to determine the level of teachers' readiness to use AR technology in teaching based on a systematic analysis of studies on the use of augmented reality (AR) in education. The study included research focusing on pre-service teachers, with no year limitation, and based on the following databases: Google Scholar, National Thesis, Eric, Scopus, Ebscohost, Web of Science, PsycInfo, JSTOR, ProQuest, Education Research Complete and Education Source. A systematic review was conducted based on the PRISMA model, with eleven keywords such as 'AR technology and pre-service teacher education' searched in Turkish and English. The process highlighted 47 studies, with 42 studies meeting the inclusion criteria set. The included studies were analysed in terms of years, keywords, branch, purpose, method, sample size, results and recommendations, resulting in a compilation and presentation of studies on AR involving pre-service teachers.

Keywords: AR technology, augmented reality, augmented reality in education, teacher candidates, systematic review model

Introduction

The rapid development of technology has led to a change in the way technology is used in education, with technology standing out as a new tool that facilitates learning, and technological tools used for educational purposes increasingly integrated into classroom learning and teaching processes (Ekiçi, 2021). One such area of technology use in education is augmented reality. Augmented reality (AR) is an information technology in which real and virtual objects are combined in the same space and time, in a three-dimensional environment in a way that appeals to the five senses through devices such as tablets and phones (Klopfer & Sheldon, 2010; Ünal & Şimşir, 2023; Wu et al., 2013; van Krevelen & Poelman, 2010).

AR's feature of bringing real and virtual environments together has attracted the attention of educational researchers, with widespread use in educational environments (Seyhan & Küçük, 2021). It is the responsibility of teachers and other stakeholders to keep up with the development of technology in education and apply such technologies in classroom environments (Çelik, 2019). In order to fulfil this responsibility, knowledge about the problems, ideas and concerns of teachers about the use of technology in teaching could be a guide for training 21st century prospective teachers (Ürün Arıcı, 2022).

There are many studies in the literature on the use of AR applications in education (Altıntaş, 2018; Belda-Medina & Calvo-Ferrer, 2022; Fidan & Tuncel, 2018; Görgülü Arı & Sivri, 2020; Grinshkun et al., 2021), which show that the use of AR applications in education provides significant contributions to teaching processes regardless of the sample group (Carmigniani et al., 2011; Çakır & Çelik, 2019).

One of these contributions is the fact that AR facilitates the understanding of complex subjects by making abstract concepts concrete (Yalçın Çelik, 2019), while another

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one is that it increases students' interest in the lesson with three-dimensional elements (Ürün Arıcı, 2022). In addition, AR provides a different dimension to textbooks by showing spatial relationships between concepts, which contributes to the development of students' cognitive and psychomotor skills (Kapucu & Yıldırım, 2019).

Although these features increase the importance of AR technology in education, to benefit from these contributions effectively teachers need to know how to integrate AR technology into lessons (Devran et al., 2021).

The literature includes studies examining the use of AR in education and the pre-service teacher sample group (Aydın & Şahin, 2021; Figueroa et al., 2021; Hursen & Beyoğlu, 2020; Risdianto et al., 2021; Sáez-López et al., 2020; Wahyu et al., 2020). However, it has been stated that the limited number of sample groups in such studies makes it difficult to reveal the effect of AR on pre-service teachers holistically (Mena et al., 2023).

According to Akarçay Ulutaş and Boz (2019), gathering the results of studies on similar topics under a single title can contribute to the progress of social sciences by revealing different perspectives on the subject. In this regard, a review study was conducted to determine the level of integration of AR into pre-service teachers' education and to guide other studies to be conducted on this subject.

In this study, research on the use of AR in education were examined and studies focusing on pre-service teachers were discussed. For this purpose, the following questions were asked:

1. In which teaching branch were the studies in the field of AR, the sample group of which consists of pre-service teachers, predominantly conducted, and what is their distribution?
2. What is the distribution of the studies in the field of AR, the sample group of which consists of pre-service teachers, over the years?
3. What is the distribution of the studies in the field of AR, the sample group of which consists of pre-service teachers, according to keywords, sample size, method, result and purpose?
4. What suggestions did the sample group make in the studies conducted in the field of AR consisting of pre-service teachers?

Method

This study utilised the systematic review method, which is a research approach in which more than one research on the same subject is synthesised in a comprehensive and detailed way by experts according to selection criteria (Karaçam, 2013; Küçükaydın, 2020; Yılmaz, 2021). A systematic review is a detailed and extensive review of the literature on the selected topic (Gülpınar & Güçlü, 2013). The internationally recognised checklist developed by PRISMA was used to write a good review, as it is widely accepted as the most appropriate procedure in systematic reviews (Mena et al., 2023). The study was based on 6 items out of 12 in the checklist, namely: determination of inclusion criteria, identification of information sources, screening, specifying the study selection, explaining the data collection process and synthesising the results.

Determination of Inclusion Criteria

A single inclusion criterion was used in the study, determined to include studies that examine AR applications in education and in which the sample group consists of pre-service teachers. The purpose for choosing this criterion is to more clearly examine the effect of AR technology on the education of pre-service teachers in the field of education. Pre-service teachers were included in these studies as a group that experienced the use of these technologies in education and evaluated the potential benefits in education as a result of these experiences, which enabled a more in-depth analysis of pre-service teachers' AR experiences and their impact on teacher education. Clearly defining the inclusion criterion increased the methodological validity of the study, while at the same time strengthening its replicability and reliability. Considering the determined criterion, 11 keywords were created in English, but also searched in Turkish. The determined keywords were teacher candidates with augmented reality, AR and prospective teachers, augmented reality education and pre-service teachers, AR use in teacher training, augmented reality & teacher training, AR technology & pre-service teacher education, pre-service teachers' AR experiences, augmented reality applications in teacher education, Innovation in AR and teacher education, augmented technology training of pre-service teachers, methods of training teachers with AR. The keywords were chosen in both Turkish and English in order to broadly cover the scope of the subject. This allowed for scanning all relevant studies in the international literature and providing access to the data source without a language barrier.

Identification of Information Sources

To determine the keywords in information sources, 10 databases were used as the source and a subsequent search was made. The databases searched were Google Scholar, National Thesis, Eric, Scopus, Ebscohost, Web of Science, PsycInfo, JSTOR, ProQuest, Education Research Complete and Education Source, with the identified databases searched at regular intervals. Advanced search was used without language and time limitations, with the last scan performed in November 2023.

Scanning

As a result of the search, 47 studies were identified in the Google Scholar, National Thesis, Eric, Scopus, Ebscohost and Web of Science databases, which were selected because they provide reliable and comprehensive academic resources. Google Scholar provides access to a wide range of literature, while Ulusal Tez

includes master's and doctoral studies in Türkiye. Eric focuses on educational sciences, Scopus covers multidisciplinary studies, Ebscohost offers journal access in the field of social sciences, while Web of Science provides access to peer-reviewed academic publications. These databases provide a comprehensive search on the use of AR technology in education and collect data from different disciplines. However, no studies were encountered in databases such as PsycInfo, JSTOR, ProQuest, Education Research Complete and Education Source. The review process showed that studies on AR practices with pre-service teachers in these sources were limited, with the intensity of the literature varying depending on the subject. This rigorous method increases the reliability and validity of the study.

Indication of Study Selection

Following a short preliminary examination of 47 studies, 5 studies were eliminated based on the sample group not consisting of pre-service teachers. One of the studies was eliminated because the sample group consisted of 321 students from the Faculty of Mechanical Engineering, Faculty of Civil Engineering, Faculty of Electrical Engineering and Information Technology, Faculty of Architecture, Faculty of Technology and Metallurgy, Faculty of Furniture, Interior Design and Technology and 12 university teachers, while another was eliminated because the sample group consisted of 21 science teachers, 16 female and 5 male, working in public schools. Other studies were eliminated due to conducting a methodological evaluation of studies from different sample groups, a systematic review, and a meta-analytic and thematic comparative analysis. A further 42 studies included in the research were analysed in detail. The studies included in the research are shown in Appendix 1.

Explaining the Data Collection Process

The inclusion criteria were determined as the first step in the study. The second step was determining Turkish and English keywords, while the third step was determining the information sources to be searched. The databases were then searched regularly at specific intervals until November 2023. The data obtained through the searches was pre-examined and the studies with a sample group not consisting of pre-service teachers were excluded from the data. After a detailed examination of the remaining data by year, keyword, branch, purpose, method, sample size, results and recommendations, the obtained findings were synthesised.

Synthesising the Results

The studies that met the inclusion criteria were examined in detail in terms of year, keyword, purpose, method, number of samples, branches of pre-service teachers in the sample, results and recommendations, with the findings obtained from the analyses synthesised and presented in different figures, tables and texts.

Validity and Reliability Measures

Various measures were taken in this study to ensure validity and reliability. Firstly, the studies selected from reliable sources were meticulously analysed and the sample size and participant characteristics were evaluated. More than one researcher was involved in the data collection process, with a cross-validation method applied and the steps in the review process regularly reviewed and discussed. In addition, the database selection and screening process was meticulously determined and only 10 reliable and comprehensive databases were used, which broadened the scope of the study to include different perspectives. The literature search was conducted with common and valid keywords, and the most recent data was accessed without language limitation. The search results were cross validated by more than one researcher, and only studies that met the valid criteria were selected. These steps increased the reproducibility and reliability of the study.

Results

Table 1 presents the frequency distribution of the studies in the data set according to years. As seen in Table 1, the first of the studies on AR in education, the sample group of which consists of pre-service teachers, was published in 2014. Three studies were published in 2016, three in 2017, four in 2018, eight in 2019, seven in 2020, eight in 2021, three in 2022, and five in 2023. It was observed that the most studies on the subject were conducted in 2019 and 2021, with 8 publications each, and the least studies were conducted in 2015 and 2014, respectively.

Table 2 shows the codes and frequency distribution of the sample number, branch, method and result categories of the studies in the data set, showing that there were 21 studies with a sample size between 1 and 50, 14 studies with a sample size between 51 and 100, and 7 studies with a sample size of

Table 1

Frequency Table by Year

Year	Frequency
2014	1
2015	0
2016	3
2017	3
2018	4
2019	8
2020	7
2021	8
2022	3
2023	5

Source: authors' own work.

Table 2

Codes and Frequencies for Sample Number, Branch, Method and Result Categories

Category	Code	Frequency
Number of samples	1–50	20
	51–100	14
	101 and above	7
Branch	Primary school mathematics teaching	3
	Science teacher	4
	Classroom teaching	7
	Social teaching	5
	Physics Teaching	1
	Chemistry Teaching	1
	Biology Teaching	1
	Computer and Instructional Technologies Education	6
	English teacher	1
	Pre-school teaching	2
	Guidance and Psychological Counselling	1
	Other	11
Method	Quantitative	8
	Qualitative	11
	Mixed	19
	Application development	2
	Case study	1
Result	Positive	30
	Negative	14
	Neutral	5

Source: authors' own work.

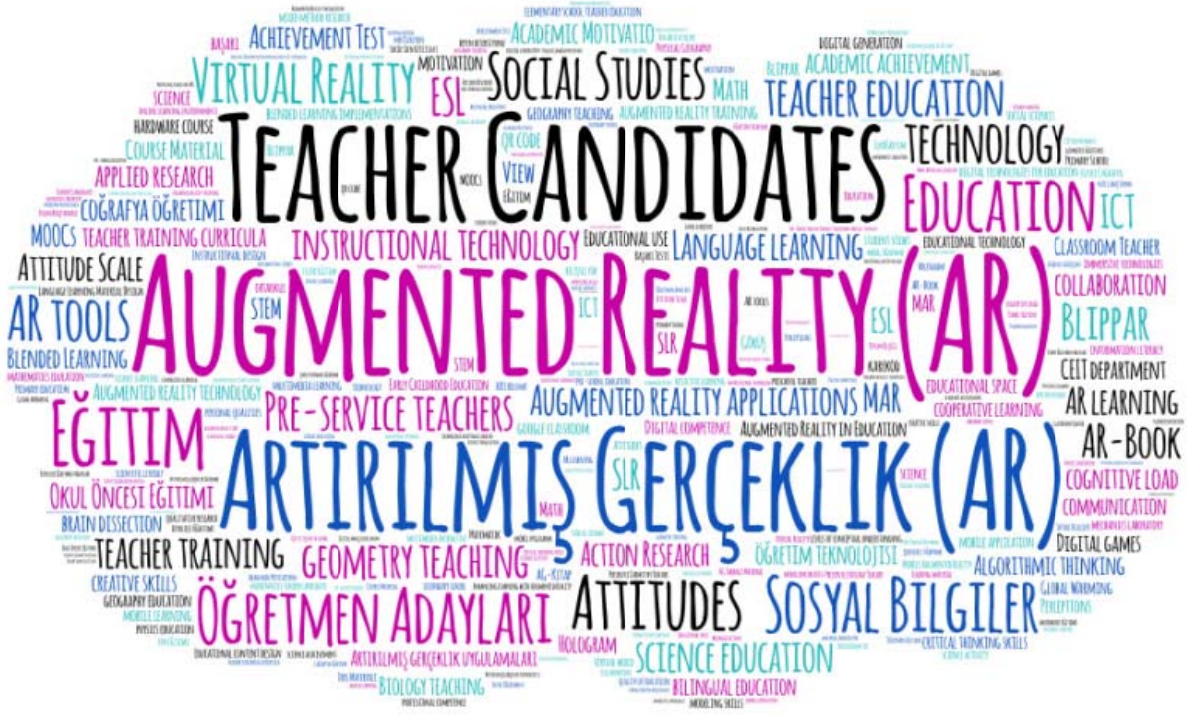
101 and above. It was observed that the sample size was mostly between 1 and 50, with the smallest number of samples in the studies is 101 and above. The data obtained was also evaluated according to the branches of the pre-service teachers in the sample group as seen in Table 2. It was seen that there were 3 studies on elementary mathematics teaching, 4 studies on science teaching, 7 studies on classroom teaching, 5 studies on social teaching, 1 study on physics teaching, 1 study on chemistry teaching, 1 study on biology teaching, 6 studies on computer and instructional technology education, 1 study on English teaching, 2 studies on preschool teaching, 2 studies on guidance and psychological counselling and 11 studies on education faculty students in general. Most of the studies were conducted with students from different branches of the faculty of education, followed by classroom teaching, and computer and instructional technology education. The least studies were conducted with physics, chemistry, biology, English language teaching, guidance and psychological counselling. Analysing the obtained data according to these methods showed that 19 of the studies were mixed, 11 were qualitative, 8 were quantitative, 2 were application development and 1 was a case study. While the most studies were conducted using mixed methods, the least concerned case studies and application development, respectively. Analysis of the studies in terms of their results showed that 30 studies had positive results, 14 studies had negative results, and 5 studies had neutral results.

Figure 1 shows the word cloud of Turkish and English keywords of the studies in the dataset. The reason for giving the keywords as a word cloud is to show how the density changes.

Coding was made by examining the aims of the studies conducted for prospective teachers, with the created codes shown in Table 3.

Table 3 shows codes and frequencies related to the aims of the studies in the data set. Aims of the studies: usefulness of AR, determination of intention to use, determination of satisfaction, multimedia, determination of awareness levels about AR, determination of their opinions, examination of their acceptance

Figure 1
Keywords



Source: authors own work using the WordArt programme.

Table 3
Codes and Frequencies for the Purpose Category

Code	Frequency
Mobile application development with AR	6
Determining the effects of AR	4
Determining the impact on academic success	6
Determining the effect on academic motivation	1
Determining the impact on perceptions	2
Determining the impact on scientific literacy	1
Determining the impact on trends in using information technologies	1
Determining the effect on cognitive load	1
Determining the impact on their digital competence	1
Determining the effects on developing critical thinking skills	1
Effect on epistemological belief	1
Effectiveness of AR	1
Determining the impact on their interests	1
Determining the effect on misconceptions	1
Determining the impact on their anxiety	1

Code	Frequency
The usefulness of AR	1
Determining the intention to use	1
Determination of satisfaction	1
Multimedia	1
Determining awareness levels about AR	1
Determining opinions	20
Examining the acceptance of technology	1
The need to use AR in training	2
Systematic review on using AR in teacher education	1
Effect on self-efficacy	4
Determining the effect of virtual reality on education	1
Determining its limitations	1
Examining system quality	1
Determining the effect on attitude	7
Examining the effect on reflective thinking	1
Determining the benefits	1
Determining the effect on creative skills	1

Source: authors' own work.

of technology, need for using AR in their education, systematic review on using AR in teacher education, effect on their self-efficacy, determination of the effect of virtual reality on education, determination of its limitations, examination of system quality, determination of its effect on attitude, examination of its effect on reflective thinking, determination of its benefits, determination of its effect on creative skills. As can be seen in Table 3, the researchers mostly asked pre-service teachers for their opinions about AR, followed by an investigation of the effects of AR on pre-service teachers' attitudes and academic achievement and studies on AR mobile application development.

The suggestion titles of the obtained studies were also analysed, and later grouped under two headings and itemised as follows.

Suggestions for Researchers

- Similar studies can be repeated with teacher candidates from different departments, on different socioscientific subjects, in different age groups, at different education levels, in different courses or laboratory applied courses.
- Longer-term experimental studies on AR applications can be carried out using control and experimental groups.
- The process of integration of AR technology into education faculties can be examined in terms of different variables (student, teacher, administrator, university, educational environment, etc.).
- Cognitive and affective features of AR applications (e.g. higher order thinking skills, attitude, success, well-being, anxiety, cognitive and affective load), spatial ability, learning opportunities, level of knowledge, problem-solving skills, permanence of learned information, creative thinking. The effects of different variables such as learning strategies and learning strategies can be examined.
- Research can be conducted on the use of AR applications by teachers.
- AR applications can be integrated with different learning approaches suitable for course content (e.g. problem-based learning, project-based learning, inquiry-based learning, game-based learning, collaborative learning, individual teaching methods), and comparative experimental studies can be conducted to determine which approach is more effective on learning.
- AR applications can be used to concretise abstract concepts and elements that are less likely to be observed in daily life.
- Different types of AR applications (e.g. location-based, etc.) can be developed to determine their contributions to education.
- The possibilities of using AR applications in out-of-class learning environments can be determined, and their potential contributions can be identified.
- More advanced data collection tools can be developed and utilised.
- Detailed scales regarding AR applications can be developed by expert academics in the field.
- The perception of AR applications from different disciplines and stakeholders can be determined.
- In Türkiye, the concepts of Virtual Reality and Augmented Reality are often confused. Detailed studies can be conducted to prevent this confusion.
- It has been identified that some students do not interact sufficiently with AR tools or do not enjoy using them. Qualitative research can be conducted to determine the reasons for these results and to increase the effectiveness of these students in the teaching process.
- New studies can be conducted on how AR tools can be organised or integrated into teaching in large groups.
- Intercultural applications can be conducted to discuss the impact of the provided education.

Recommendations for Practitioners

- AR based teaching applications can be developed for various subjects and concepts to support the educational process.
- Making AR applications compatible with daily life scenarios can make the applications more attractive.
- Researchers planning to improve teaching effectiveness with AR may prefer to initially use freely available software.
- Interdisciplinary collaboration among software development experts, educational technologists and teachers can lead to the creation of AR applications with richer Turkish language support, suitable for gains and student development, with minimised technical issues.
- Attempts can be made to develop self-learning skills using AR technology.
- Different forms of AR learning materials (videos, 3D models, 3D animations) can be prepared and compiled into a content library to be freely accessible on platforms such as the Education Informatics Network (EBA) for students, teachers and teacher candidates, especially for subjects containing abstract concepts such as physics, chemistry and biology, or for situations where fieldwork and technical excursions are not possible.
- Virtual screens and AR glasses can be used, or sound and detailed information can be added to AR applications to create a more realistic effect for the developed 3D models.
- Everything that needs to be known about the use of new educational technologies, including how to prepare AR materials and which educational activities they can be used in, as well as the benefits and risks of new technologies, can be conveyed to teachers and teacher candidates through seminars, workshops, TÜBÝTAK projects, or in-service training. For example,

they can receive training in online environments through the Distance Education Center (UZEM) or face-to-face training sessions on Information Technologies and Digital Literacy.
- To enhance individuals' digital literacy and information culture, a digital literacy course can be given face-to-face as a compulsory course at all universities, especially in education faculties.
- Elective courses covering both technological and pedagogical aspects of new technologies, such as virtual reality, augmented reality and artificial intelligence, can be added to the curriculum or integrated into courses at universities, especially in education faculties.
- AR learning material can be integrated with infographics and concept maps to serve as pointers.
- AR applications that are compatible with all software platforms (Android, iOS, etc.) can be designed.
- Infrastructure can be established in schools to address the need for technologies like AR, as not all school districts have the economic means to utilise such technologies.
- Facilitative measures (such as allowing the use of mobile technological devices in classrooms) and decisions supporting school costs can be made by the Ministry of National Education (MEB) and school administrators to increase the applicability of technologies like AR.
- Incentive financial support can be provided to encourage teachers to use technologies like AR more frequently during teaching.

Analysis of the study suggestions pointed out that similar studies could be conducted with pre-service teachers from different departments, on different socioscientific issues, in different age groups, at different educational levels, in different courses or in laboratory applied courses. In addition, the researchers stated that the integration process of AR technology into faculties of education could be examined in terms of different variables, and that the effects of AR applications on different variables such as cognitive and affective characteristics could be examined. They also suggested that AR applications could be integrated with different learning approaches suitable for the course content, and support could be provided to the education and training process by developing AR-based course applications related to different subjects and concepts. In addition, in order to minimise technical problems, software development experts, instructional technologists and teachers suggested that AR applications could be created by conducting interdisciplinary studies together. They also suggested that teachers and prospective teachers could be trained on how to prepare AR materials and in which educational activities they could be used, and that digital literacy could be taught as a course. Finally, it was seen that the necessary infrastructure could be created and AR applications compatible with all software could be designed.

Conclusions

Analysis of the data collected in this study by years shows that a significant increase in the number of studies on augmented reality (AR) applications in education was observed in recent years, with the peak of this increase in 2019. This situation shows that AR technologies have started to be adopted more in the field of education and are frequently used in studies conducted with pre-service teachers. AR, which is increasing day by day in the field of education, just as it is in every field, has the potential to renew our perspective on education by addressing multiple sensory organs to improve knowledge and skills (Ozarslan, 2016). For this reason, teachers, who make the greatest contribution to the education process, should be able to use this technology effectively (Değirmenci & İnel, 2020). The familiarity with this technology of future teachers will enable AR applications to be used more effectively in lessons (Özçakı r & Aydın, 2019).

It was determined that most of the studies were carried out with small sample groups, and that the studies with a sample number of 101 or more were quite limited, which creates limitations in generalising the findings obtained to a wider universe and reduces the generalisation power. It has also been observed that studies on AR are concentrated in certain branches, with a limited number of studies conducted in some branches, and no studies found in some branches. This situation shows that technological developments are not equally integrated into different branches, with some fields neglected.

In terms of research methods, it was determined that most of the studies were conducted with mixed methods, although application development and case study methods were less preferred. In addition, the number of qualitative studies is higher than quantitative studies, with the preference for qualitative methods providing more in-depth data on AR issues; however, the limited number of application development studies may limit the use of these technologies in education.

While the majority of the analysed studies yielded positive results, some of them yielded negative results and others yielded neutral results, which shows that AR materials do not always produce positive results. Positive results can be called advantages of AR applications, while negative results can be called disadvantages. Some of the advantages of AR applications are that they provide students with a 3D learning environment (Zainuddin et al., 2010), that learning can be done in any desired environment (Satpute et al., 2015), that they arouse a sense of curiosity (Delello, 2014), that students are active and interactive (Baysan & Uluyol, 2016), and that abstract concepts are concretised and students' understanding of the subject is facilitated (Abdüsselam & Karal, 2012). The disadvantages of AR applications are that such applications can create technology addiction (Akkuş & Kapıdere, 2015), that not every student has access to mobile

devices and the internet, and that the development of such applications is difficult and requires expertise (Yalçın Çelik, 2019), and that there is no AR application suitable for every subject and outcome (Bodur et al., 2016). When using AR applications in education, this diversity should be taken into consideration, and the possible effects of the applications should be carefully evaluated.

The keywords of the reviewed studies show that the effects of AR applications on pre-service teachers have become an important research topic in the field of education, and that the interest in the use of these technologies in different educational fields is increasing. Analysis of the objectives of the studies found that the most common one was to determine the opinions of pre-service teachers about AR applications, followed by examining the effects of AR on pre-service teachers' attitudes, academic achievement and self-efficacy. In addition, studies on developing mobile applications with AR and determining the general effects of AR in education also held a noticeable position. These findings reveal that there is an intensive effort to understand the different effects of AR applications on pre-service teachers and the integration of these technologies with mobile platforms continues to be investigated. In the recommendations section of the research, various suggestions are presented in order to increase the effectiveness of AR applications in education and to enable teachers to use this technology more efficiently.

Recommendations

In order to increase the efficiency of education, it is believed that it would be a good idea to include AR applications in the development of teacher candidates. It was concluded that it is necessary to further develop the research on this subject, because it is thought that it will contribute to a better understanding of the effect of AR, dissemination, etc. However, while conducting dissemination studies, it is foreseen that the necessary infrastructure should be created for students to reach sufficient technological equipment, and that applications suitable for each subject and acquisition suitable for the use of AR technologies should be developed together with experts, with the interfaces of the applications simplified. In addition, it is thought that providing necessary training for teachers and pre-service teachers to be competent in AR technologies will further contribute. It will be important to conduct these studies with larger sample groups in terms of validity and generalisability of the data obtained. In order to better determine the advantages and disadvantages of AR, the research topics and applications suggested in the research available in the literature should be taken into consideration.

The appendix is available in the online version of the journal.

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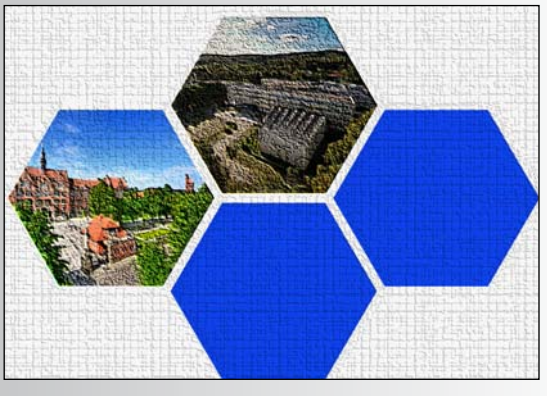
We recommend



The 6th BPM Symposium, April 24–26 2025, Sopot (Poland)

The 6th BPM Symposium will take place from April 24 to 26, 2025, at the Eureka Hotel (Emilii Plater Street 7/9/11) in Sopot, Poland. The symposium is organized by Gdansk University of Technology and the University of Gdansk as part of the Fahrenheit Universities.
The BPM Symposium in Sopot continues the series of scientific meetings previously held at the AGH University of Science and Technology in Krakow, the University of Warsaw, and the University of Economics in Katowice. It provides a unique opportunity for researchers interested in Business Process Management (BPM) to connect. We hope the event will once again foster the exchange of scientific ideas, the presentation of the latest research findings, and the establishment of new collaborations. Additionally, it will be an excellent occasion to invite participants to the International BPM Conference, which will take place in Seville in 2025.
The symposium will feature presentations on current BPM research results during sessions held on April 24 and 25. On Saturday, April 26, workshops for PhD students are planned.
Papers that receive positive reviews will be published in the e-mentor journal or REME (https://journal.mostwiedzy.pl/index.php/reme/index).
We cordially invite You to participate.
Dr. Eng. Marzena Grzesiak, Prof. Gdansk University of Technology, Faculty of Management and Economics
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