

Research Trends in the Use of Augmented Reality in Engineering Education: A Bibliometric Analysis

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Abstract:

This study aims to report on the overall research trend of research progress in the Augmented Reality (AR) field in engineering education. The research method used is bibliometric analysis (BA) using VoSviewer. The data is taken from the Scopus database. The findings show an increasing trend in citations and publications showing interest in using AR over the last decade. AR research in engineering education started in 2006 until now. Screening of selected articles from 2012 to 2022. The screening process based on inclusion and exclusion included the chosen language in English and based on the publication of final articles, resulting in a total of 858 articles. The results reveal that augmented reality, engineering education, and mobile learning are the most used keywords in the article. In contrast, the focus of the new article tends to be on augmented reality. In addition, the results show that the latest articles mostly focus on virtual and mobile learning. The most frequently used words in the abstract are engineering education, student, e-learning, education, and teaching. Recent articles have largely focused on students' and teachers' knowledge of technology-based learning. Billingham, Dede, and Martin are the most cited authors in this field, as they are the principal authors of AR. The journals cited are Computers & Education, Coeur Workshop Proceedings, Computers in Human Behavior, and the Journal of Science Education and Technology. The journal is the most prominent on the use of technology in education.

Keywords: *Augmented Reality, Bibliometric Analysis, Research Trends.*

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Introduction

The rapid development of information and communication technology has changed the lifestyle of individuals and communities to become an important indicator of a country's progress and level of development. The great advances in technology and information affected the field of education like any other (Karagozlu et al., 2019). The use of technology in education helps students access information more easily, encourages the development of cognitive skills, and allows students to construct information (Leutner, 2014). Technology in education can influence students to learn and encourage appropriate learning methods. Augmented Reality (AR) seems to have tremendous potential to influence more adequate learning procedures (Al-Azawi et al., 2019). In education, AR has been used in laboratories and recently tested in real classrooms. Previous research efforts on the use of AR in education have shown that in its implementation in the classroom, students tend to work more effectively collaboratively incorporating device-generated visualizations (Davidsson et al., 2012). AR can complement real-world perception and interaction, allowing users to see real environments augmented by device-generated 3D objects (Cubillo et al., 2012). AR can potentially improve instructional materials or instructional design that help reduce the cognitive load of unfamiliar and intimate. Researchers and academics have incorporated technology-enriched learning tools to provide students with a unique learning experience. Over the years, much research has been done to develop virtual remote laboratories and other laboratory experiences for students to enhance their learning, motivation, engagement, and satisfaction (Barata et al., 2015; Kilani et al., 2018; Potkonjak et al., 2016). The high cost of procuring and maintaining laboratory equipment and rapid advances in computer processing capabilities are driving the use of AR technology to create unique laboratory experiences. In addition, reducing the cost of information technology and internet services is an added advantage to using AR (Singh et al., 2019).

Improving students' visualization skills in engineering education is crucial for developing practical skills in various engineering fields (Papakostas et al., 2021). In engineering education, laboratory experience is significant as it develops and verifies theoretical concepts. Laboratory experience effectively develops engineering graduates' technical skills by designing and conducting practical experiments (Singh et al., 2019). So far, in the learning process in technical education, the instructor only explains the basic material using the lecture method, etc. In practice, technical education instructors do not pay attention or do not help all students because the number of students is too many. As a result, most students do activities the wrong way, leading to work accidents (Monroy Reyes et al., 2016). Currently, many solutions can make it easier for teachers to carry out the learning process, one of which is the application of ICT in engineering education, namely the application of AR in engineering education. There are many research works found in the literature that lead to the utilization of Augmented Reality to improve the visualization of subject matter for better understanding (Di Serio et al., 2013; Gutiérrez & Fernández, 2014). Therefore, to take advantage of the initial idea, a real-time interactive learning system has been developed for engineering education students, which can help them visualize various theoretical concepts; which otherwise would be difficult for them to understand in a traditional teaching and learning environment (Kaur et al., 2021; Prit Kaur et al., 2022). This study only focuses on reporting the overall research trend of research progress in the field of Augmented Reality (AR) in engineering education over the last ten years (2012–2022). The research method used is bibliometric analysis (BA) using the VoSviewer tool. The research questions set out in this study include:

1. The most frequently used keyword distribution in articles about AR in engineering education?
2. The most widely used word distribution in the article's abstract about the use of AR in engineering education?
3. Who are the most cited authors (citation and co-citation) in articles on the use of AR in engineering education?
4. Which journals (citation and co-citation) are the most cited articles publishing articles on the use of AR in engineering education?

Research Method

Data Collection

In this study, bibliometric mapping was carried out. The process of selecting this article begins with a search for articles published on Scopus data in June 2022 using the keywords "augmented reality" AND "engineering education." The search results from Scopus found 937 articles filtered then filtered based on the year of publication between 2012 and 2022 (the last ten years), based on the selected language "English," based on the publication of the final article resulting in a total of 858 articles. Each article was examined by three investigators, taking into account the inclusion and exclusion criteria. The first inclusion criteria were articles related to technical education. The second is whether the AR application is featured in the article. Some articles are not specifically concerned with engineering education. As a result, 16 articles were selected for analysis in this study from various journals. The resulting data is then downloaded

and analyzed using Microsoft Excel and VOSviewer applications. The process of selecting articles for this research is summarized in Figure 1.

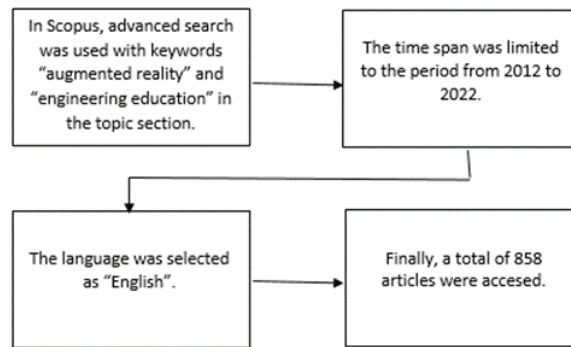


Figure 1. The process of selecting articles for this research

Data Analysis

The data analysis technique in this study uses the VOSviewer application and Microsoft Excel to visualize the analyzed data. VOSviewer helps visualize research trends from the most used keywords, words used in abstracts, author and co-author analysis, citation analysis, and article co-citation analysis. Microsoft Excel to store the results of the literature review according to the parts that have been needed by the author, such as journal number, author, year of publication, title, the field of study, research objectives, variables, AR type, methods, data collection tools, and research results made in the form of a table. The data analysis procedure was carried out by three researchers (two lecturers and one student). Each selected article is then studied and discussed together during the analysis process. Thus, descriptive statistics were used to analyze the findings.

Result and Discussion

Result

Bibliometric Mapping Analysis Findings

Most used keywords in the articles related to the use of AR in engineering education

In order to create a map based on text data for the most frequently used keywords, co-occurrence analysis was used, and author keywords were selected. The minimum number of occurrences of a keyword was set as 10, and the number of keywords selected was automatically given as 31. The map created is illustrated in Fig. 2 (a). It shows three clusters, and the most used keyword is 'augmented reality' ($f = 523$). In addition, it was revealed that 'virtual reality' ($f = 195$), 'engineering education' ($f = 134$), 'education' ($f = 106$), and 'mobile learning' ($f = 68$) were the most used keywords. . These results indicate that most of the articles focus on mobile learning and virtual-based learning. Therefore, it can be seen that AR research in engineering education began to increase in number in 2015, although the first study was published in Scopus in 2000. The distribution of the number of articles by year is presented in Figure 2 (b)

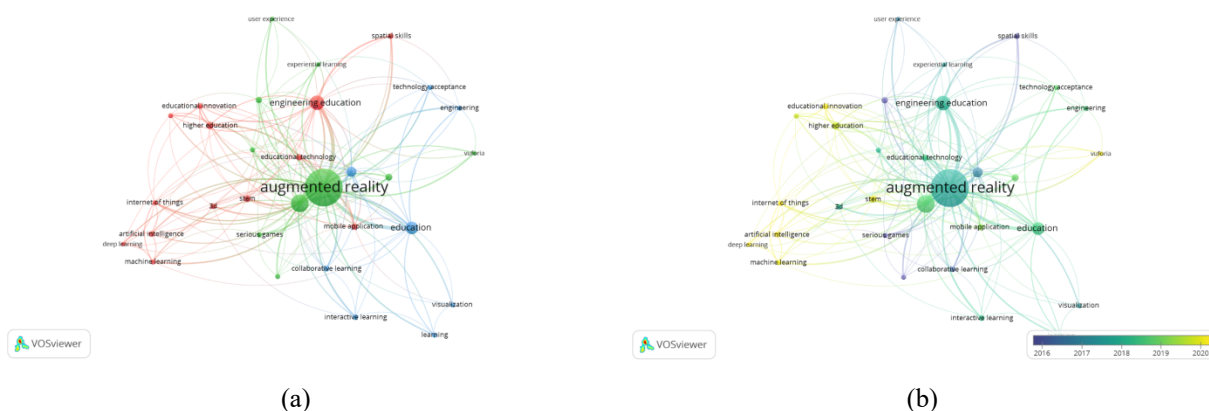


Figure 2. The most used keywords in articles relating to the use of AR in engineering education (a), Distribution of the number of articles using the keywords by year (b)

Most used words in abstract sections

To create a map based on text data for the most frequently used words in the abstract, a Scopus bibliographic database file was uploaded into the program. Then, the abstract calculation method is selected as the field. The minimum number of occurrences of a term was set as 22, and the number of terms to be selected was automatically stated to be 49. A map created from this is given in Fig. 3 (a). It shows five groups and the word 'augmented reality' is the most frequently used word in the abstract ($f = 3539$). The most frequently used keywords were: engineering education ($f = 3440$), student ($f = 1714$), e-learning ($f = 1202$), virtual reality ($f = 1122$), education ($f = 916$), and teaching ($f = 817$). These results indicate that most articles focus on technical education, student knowledge, electronic learning media, and virtual-based learning media. When the distribution of these words is shown from year to year, it is evident that more recent articles tend to focus on increasing students' knowledge and achievement using learning models. The distribution of the most used words in the abstract by year is presented in Fig. 3 (b).

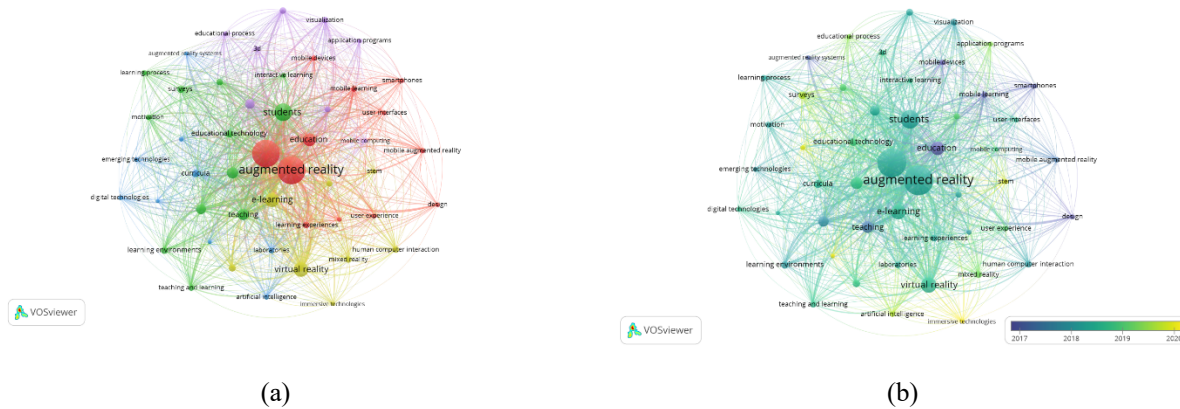


Figure 3. Most used words are found in article abstracts. (a), . Distribution of most used words in article abstracts by year (b)

Most cited authors

To create a map of the most cited authors, a citation and author analysis were selected. The minimum number of documents by a particular author was four, and the minimum number of citations of an author was 100. The number of authors to be selected was automatically given as 10. The map created is shown in Figure 6. This indicates that Gardner. M (388 citations) and Delgado-Kloos C (310 citations) are the most cited authors in this field. In addition, a co-citation analysis and cited authors were selected. The minimum number of citations from an author was set as 50, and the number of authors selected was automatically assigned as 35. The map created is shown in Figure 7. This shows that Billinghamurst, M (217 citations), Dede, C (138 citations), and Martin- Gutierrez, J (115 citations) are the most cited co-citation in this field.

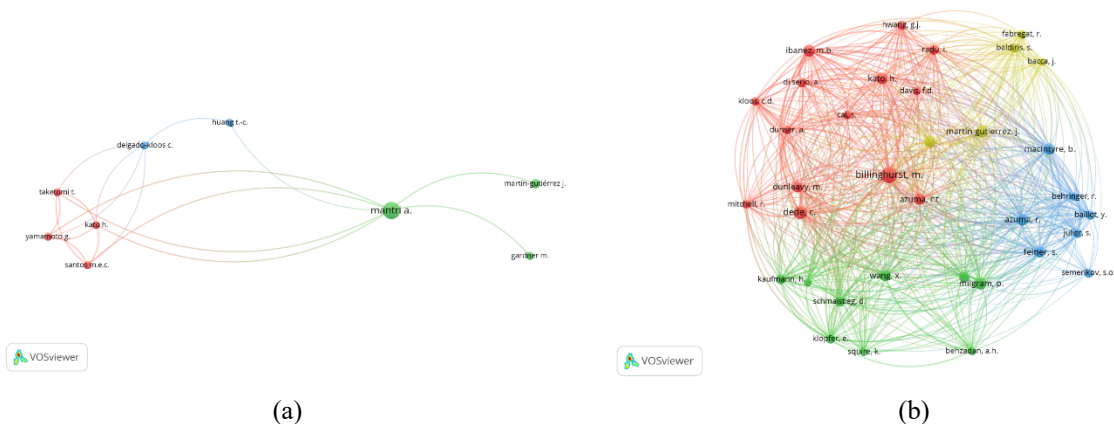


Figure 4. Most cited authors (Citation analysis) (a), Most cited authors (Co-citation analysis) (b)

Most cited journals (citation and Co-Citation)

Create maps for the most cited journals, and analyze citations and selected sources. The minimum number of source documents was five, and the minimum number of source citations was 200. The number of sources to be automatically selected is given as 6. The map created from this is presented in Fig. 8. This shows that the most cited journals are Computers & Education (2021 citations, seven documents), Computers In Human Behavior (635 citations, six documents), and Coeur Workshop Proceedings (500 citations, 43 documents). In addition, a co-citation analysis and cited sources were selected. The minimum number of source citations was set to 35, and the number of sources was automatically set to 30. Figure 9 shows the resulting map. This shows that the most cited journals are Computers & Education (429 co-citations), Coeur Workshop Proceedings (239 co-citations), and Comput. Educ (134 co-citations), Computers in Human Behavior (113 co-citations), and the Journal of Science Education and Technology (98 co-citations).

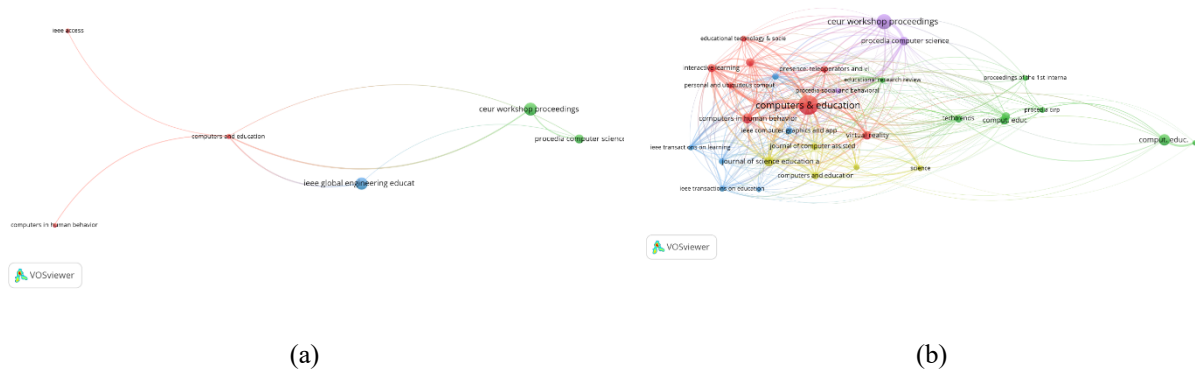


Figure 5. The most cited journals (citation analysis) (a), Most cited journals (co-citation analysis) (b)

Discussion

This study reveals research trends over the last ten years and results from a bibliometric analysis of articles related to the use of AR in engineering education. It involves bibliometric mapping analysis and content analysis. The results of the bibliometric analysis show that the most widely used keywords in articles related to the use of AR in engineering education are: augmented reality, virtual reality, engineering education, education, and mobile learning. The results showed that most articles focused on mobile and virtual-based learning. When the distribution of the number of articles using keywords is considered from year to year, it appears that recent articles have mainly focused on virtual learning. This finding can be explained by the increasing availability of virtual technology worldwide. AR technology has been widely used for education, as mentioned by Martin et al. in their research on Augmented Reality as a new trend (Martin et al., 2011). Also, the most used words in the abstract are technical education, student knowledge, electronic learning media, and virtual-based learning media. This shows that the article mainly focuses on student knowledge, electronic learning, and virtual learning media. When the distribution of these words is examined annually, it is evident that recent articles have focused primarily on improving students' knowledge and achievement using learning models. The development of AR technology further increases learners' learning effectiveness (Ibáñez et al., 2014). Today, AR applications have become portable and available on mobile devices.

AR is desired for entertainment, games, travel, maintenance, and marketing to get more interesting experiences (Chen et al., 2011). In addition, virtual technology can increase students' interest and motivation in the learning process, supported by virtual media features that can provide visualizations that look real compared to others (Wulandari et al., 2019). According to citation and co-citation analysis, Billinghamurst, M, Dede, C, and Martin-Gutierrez, J are the most cited authors in this field. This is not surprising as they are probably the main authors of AR in the literature. Computers & Education, Coeur Workshop Proceedings, and Comput are the most cited journals. Educ, Computers in Human Behavior, and Journal of Science Education and Technology. It is the most prominent journal on the use of technology in education.

Conclusion

This study reveals research trends and results of AR bibliometric analysis in engineering education over the last ten years. The results of the bibliometric analysis show that the most widely used keywords in articles related to the use of AR in engineering education namely augmented reality, virtual reality, engineering education, education, and mobile learning. When the distribution of the number of articles shows that the latest articles focus more on virtual learning, this finding can be explained by one of the most developed technologies in recent years is AR, which consists of

presenting additional information to users in 3D which can be visualized using their mobile device. Augmented reality is a live and interactive environment formed by adding virtual objects to the real image obtained by the camera. According to another definition, AR is a range of technologies that allow users to see the real world developed, enriched, or augmented by adding information such as text, images, sound, and many others. Also, the most used words in the abstract are engineering education, student, e-learning, education, and teaching. When the distribution of these words is examined annually, it is evident that recent articles have focused primarily on using ICT-based instructional media in vocational education for students and teachers. This finding is evidenced by Augmented Reality (AR), which offers many benefits to support the teaching and learning process. According to citation and cocitation analysis, Billingham, Dede, and Martin are the most cited authors in this field as they are the main authors of AR. Computers & Education, Coeur Workshop Proceedings, and Comput are the most cited journals. Educ, Computers in Human Behavior, and Journal of Science Education and Technology.

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