The Use of Mobile Augmented Reality (MAR) in Mathematics Learning: A Bibliometric Analysis

Prahesti Tirta Safitri[1,2]*, Basuki Wibawa[1] and Eveline Siregar[1]

[1] State University of Jakarta, Jakarta, 13220, Indonesia
[2] Muhammadiyah University of Tangerang, Tangerang, 15118, Indonesia
*prahestitirta@gmail.com

Abstract. To This study aims to examine the use of Mobile Augmented Reality (MAR) in mathematics learning using bibliometric analysis aided by VOS Viewer software. The method employed in this research is bibliometric analysis. Four classification clusters were identified through VOS Viewer software. This study presents the research findings on Mobile Augmented Reality (MAR) to researchers and practitioners. The obtained research results consist of articles that encompass keywords such as Mobile Augmented Reality (MAR), mathematics learning, digital learning, Android applications, and mathematical simulation from 2019 to 2023. Four clusters were identified in this study, discussing the topic of using mobile augmented reality in mathematics learning. The annual number of mobile augmented reality articles has increased from 2020. From the analysis conducted by the researcher using VOS Viewer, it was found that the term Augmented Reality has been extensively studied in mathematics learning, but for Mobile Augmented Reality (MAR), research findings are still scarce, both in terms of teaching and mathematical learning media.

Keywords: Mobile Augmented Reality (MAR), mathematics learning, digital learning

1 Introduction

This study aims to review and analyze the research results related to the use of Mobile Augmented Reality in mathematics learning. Mobile Augmented Reality is attractive to learners because it can facilitate an efficient and enjoyable learning process through Augmented Reality-based learning [1]. Learning with digital learning media can optimize the duration of student learning and can correct deficiencies in the learning process [2]. There are so many strategies that can be done in the implementation of mathematics learning. Still, the strategy is specifically tailored to the needs of students in achieving their learning goals. The IDEAL learning strategy is a unique metacognitive approach emphasizing efficacy and efficiency in reasoning and addressing issues. The first step in solving problems effectively is identifying potential challenges, and the identification of the problem will then follow. Learners take action on their solutions [3]. Before arriving at strong problem-solving skills, each indi-

M. Salimi et al. (eds.), *Proceedings of the 7th International Conference on Learning Innovation and Quality Education (ICLIQE 2023)*, Advances in Social Science, Education and Humanities Research 873,
https://doi.org/10.2991/978-2-38476-301-6_84

vidual must have a basic understanding of the problems faced. Thatolving a problem becomes easier and smoother because it has a strong foundation in the material. Learning mathematics using augmented reality can be applied to certain learning models. The learning model must have innovative characteristics, such as being easy to use, logical and systematic, interactive and interesting. In addition, the model can be tested easily by other peer instructors [4].

The use of Mobile Augmented Reality in mathematics learning not only impacts the ability to understand concepts but also on higher-order thinking skills, inquiry skills, and the ability to think to complete learning. In its implementation, researchers can directly collaborate Augmented Reality learning activities in mathematics lessons because more studies and investigations are still needed [5]. Mobile Augmented Reality is one of the latest technologies in the field of Informatics. The world of education has successfully implemented it by utilizing the characteristics of mobile learning and augmented reality. Mobile Augmented Reality's (MAR) primary goal is to maximize learning objectives' attainment. To ensure that students have a positive learning experience, MAR should have novel features including being intuitive, rational, and methodical [6]. To date, research on augmented reality in education has mainly investigated learning with augmented reality work. It is important for researchers and practitioners to understand that while augmented reality can be utilized to create engaging and successful learning settings, it can also be used to create inefficient and subpar learning environments [7].

For many pupils, grasping abstract mathematics concepts like vector geometry remains challenging. It is suggested that augmented reality be used to overcome this obstacle. In order to achieve this, a thorough literature analysis is provided along with the impact on the didactic interaction and learning process. This approach is not often utilized in classrooms because of the dearth of user-friendly software. As a result, the study offers a modular application for augmented reality that makes geometric objects visible when placed on the actual world [8]. Its application, which is strong and has a straightforward design, tries to make vector geometry and parametric equations easier to understand. Students are actively involved since they can interactively alter the numbers' types and characteristics and test at their own speed. Spatial imagination is enhanced by augmented reality, which might be challenging to do with more conventional 2D materials [8].

The accomplishment of predefined learning objectives can be facilitated by the selection and application of appropriate learning methods supported by appropriate learning media [9]. Based on this, the importance of mobile augmented reality as a medium that can optimize mathematics learning is needed to support the success of mathematics learning. Thus, the purpose of this study is to use VOSViewer software and a bibliometric approach to examine mathematics learning through mobile augmented reality. Bibliometric visualization techniques are used in mapping groups of relationships between journals, co-authoring, researchers, and the emergence of selected keywords to know the development of mobile augmented reality in mathematics learning and to show current research trends and future research directions. From the results of this study, novelty was obtained, namely the use of augmented reality in

the form of applications that can be used anywhere so that the learning process becomes easier and more fun than not using mobile augmented reality.

2 Method

The method used in this study is bibliometric analysis. Bibliometric analysis is a scientific method useful for researchers who will retrospectively analyze a broad and complete field in a study [10]. The bibliometric methodology has gained great popularity lately due to the usefulness of the use of bibliometric software and databases that make it much easier for researchers to conduct assessments of large amounts of scientific data [10]. The gathering, examination, and interpretation of bibliographic data, or data obtained from bibliographic databases, are typically included in the field of bibliometrics. Next, the productivity, impact, and effect of scientific and research work in a branch of science are assessed using this bibliographic data. Bibliometric analysis methods can help researchers study bibliographic content and analyze citations from each article taken from Harzing's Publish or Perish database [11]. Therefore, researchers determined the research theme be analyzed in bibliometric mapping, namely using mobile augmented reality in mathematics learning.

A bibliometric analysis was conducted using the Publish or Perish database sourced from Google Scholar as many as 200 articles. Research article searches were conducted using Publish or Perish with mobile augmented reality keyword searches, math learning, and digital learning. All articles are collected from the Google Scholar database. To keep the article current, researchers determined the range of search years for the last five years, starting from 2019-2023. Then, using VOS-Viewer software, the RIS-formatted metadata from Publish or Perish is processed to provide visualizations in bibliometric maps. Methods for mapping groupings of relationships between journals and co-authoring authors using bibliometric visualization, and keyword emergence to find out related developments about mobile augmented reality in mathematics learning. Research themes are keywords that are collected from publication titles and abstracts, or they can be keywords that the author uses in his piece. Three different kinds of visualizations will be shown by the VOS-Viewer software: network, overlay, and density visualizations.

3 Results And Discussion

In searching research data on mobile augmented reality, researchers used three keywords: mobile augmented reality, mathematics learning, and digital learning using publish or perish software. In publish or perish by determining the maximum number of results of 200 articles and the search year for the last five years (2019-2023). The source that the researcher determines is the Google Scholar database. After obtaining 200 related articles, the researchers saved the RIS format as the main material for data processing using VOSViewer. After the researcher filters and processes the search result data on the publish or perish application, the researcher continues the analysis using VOSViewer software. In the analysis of the use of mobile augmented reality in

mathematics learning with the full counting method, 3185 words were obtained with the minimum limit of occurrence of each word set 10 times, then 55 words were selected into 33 words and grouped into four clusters.

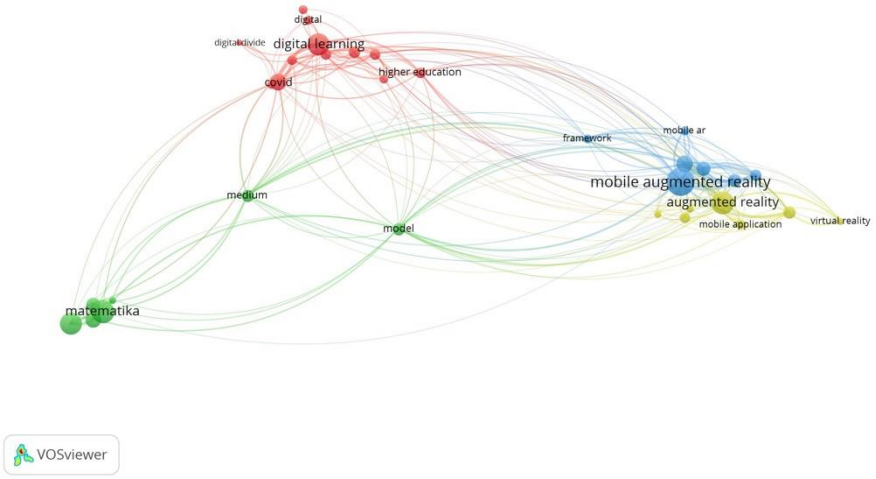

Fig. 1. Network Visualization of 33 Items with Four Cluster

The analysis using the full counting method showed a more distributed grouping. Cluster 1 is marked in red, and the words included in this cluster are about digital learning, digital devices, and so on. Cluster 2 is marked in blue, and the words included in this cluster are mobile augmented reality, mobile ar, and so on. Cluster 3 is marked in yellow, and the words included in this cluster are augmented reality, virtual reality, and so on. The 4th cluster is marked in green, and the words included in this cluster are mathematics, mathematics learning, and so on.

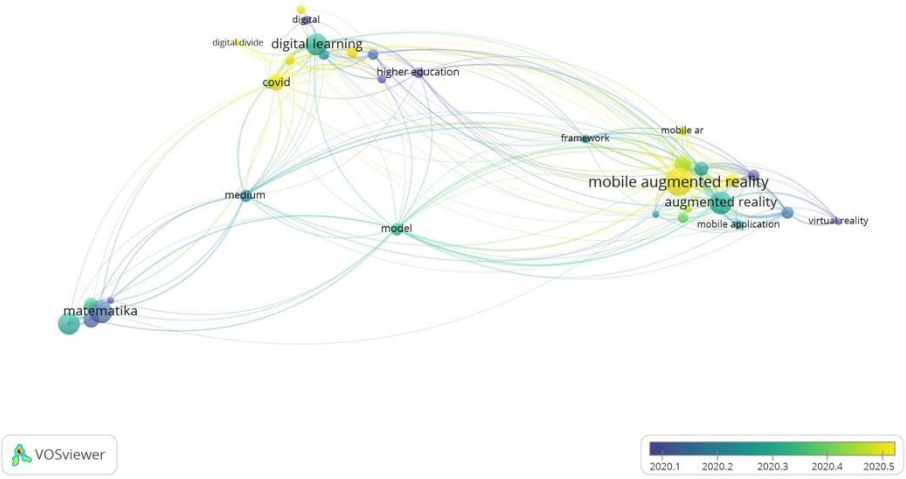

Fig. 2. Overlay Visualization of 55 Items with Four Cluster

Figure 2 of VOSViewer showcases the latest research related to mobile augmented reality in math learning by year. All research related to mobile augmented reality in mathematics learning was widely researched in 2020, but before 2020 research on mobile augmented reality in mathematics learning was still not widely conducted. This result of the research can be seen from the bar listed in Figure 2.

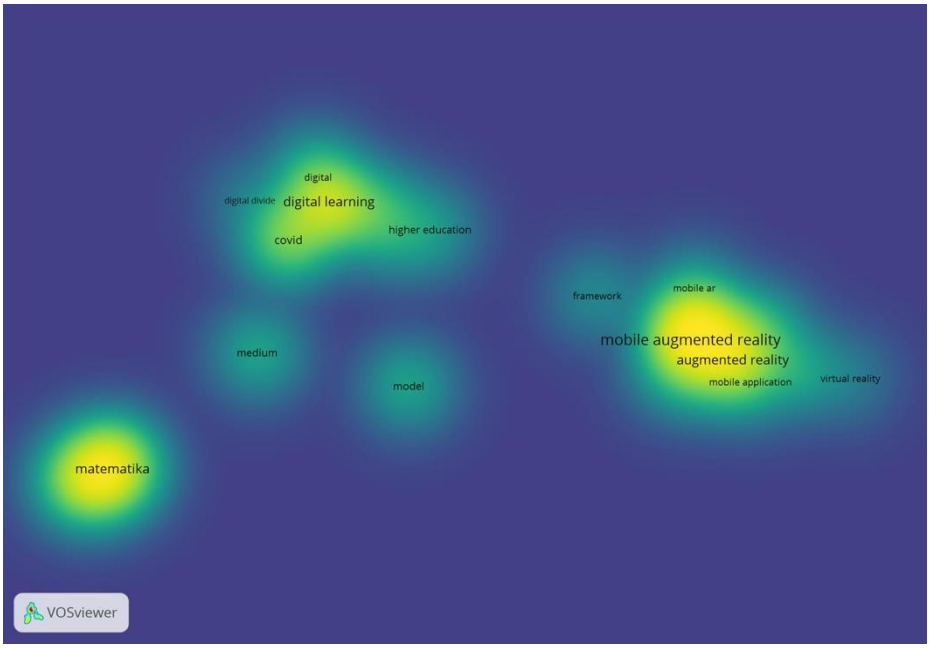

Fig. 3. Density Visualization of 55 items with Four Cluster

Figure 3 of the VOSViewer results show that items included in the cluster will be displayed on the density visualization screen. Each color has its meaning according to the item's density. The light color that appears indicates that a lot of research has been done. In contrast, the dark color indicates that much research has not been done in the specified analysis period; the results appeared in 2020. From the image analysis on the VOSViewer display, the word augmented reality car often appears, meaning that there has been a lot of research on mobile augmented reality. But it becomes a novelty when associated with mathematics learning both from the teaching segment and the learning media. In mathematics learning, mobile augmented reality is the right strategy to optimize the existing learning process.

The results of research conducted by Schutera et al. show that learners' understanding of 3D space increases in a fun and didactic way. Teachers also invented applications adapted to deal with vector geometry. The app's ease of use with QR codes is a key feature. In augmented reality, media can also add other 3D geometric figures or allow users to see 2D shapes created by the intersection of planes and spheres. In-app exercises can also be applied, keeping in mind how to have an easy interface and functions to avoid overwhelming learners [8]. Another study suggests that Augmented Reality-based math learning can help visualize content better as marker-based Augmented Reality is more popular than markerless Augmented Reality apps that are mostly developed using Unity 3D with Vuforia SDK. The review also found that using Augmented Reality in mathematics teaching and learning provides learners with a fun and interactive learning process, enhances understanding, and improves learners' visualization [12].

The development of mobile augmented reality systems for learning is also carried out in Preservice Students Teachers (PSTs) can be used to improve PSTs' understanding of mathematical developments, including activities of working, making images, owning images, paying attention to properties, formalizing, observing, compiling and discovering. The findings indicated that at some levels, level 7 or structuring had the maximum value. These findings provide an explanation for the degree of mathematical knowledge; as media use increases, so does the degree of structure, which causes an increase in that level. It can be argued that PSTs do not have special preparation to understand better the concept of using augmented reality-based media from such systems [13]. Through mathematical modeling cycles, augmented reality-enabled mobile applications assist students in connecting mathematical principles to real-world scenarios while solving problems. For this program to be developed and implemented, more research is required. The goal of development is to adapt to the abilities required for math learning while adding features made possible by the quick advancement of technology. Furthermore, the extension of its application warrants further research on other mathematical problems as well as the subject of application in various contexts with distinct features [14].

Even though these aspects of learning outcomes may be challenging to assess, more augmented reality studies are needed to examine how augmented reality affects learners' authentic performance, higher-order thinking skills, discipline-specific skills (inquiry skills), or computational thinking as learning outcomes. Thus far, augmented reality research has not fully considered the potential of augmented reality to generate these learning outcomes [15]. The experimental group's students' improved motivational achievement and improved visual thinking can be attributed to an active learning environment filled with augmented reality technology-provided images and videos. This, in turn, improves the students' cognitive structure, fosters their development of visual thinking, and increases their motivation to learn. Furthermore, comparing skills side by side with their details using augmented reality technology improves learning compared to traditional methods and fosters the growth of visual thinking abilities. Similar studies that validate the effect of augmented reality technology on students' perceptions and orientations in many subjects and cover additional educational stages are recommended by both researchers [16].

Students find augmented reality entertaining and want to repeat encounters. Although uncomplicated 3D models are required to represent augmented reality, alternative representations of these real phenomena pose motivation for educators. Even though research has shown that augmented reality may be used in any industry, we advise picking one where the requirement for 3D models that depict the appearance of various products exists. Even though augmented reality is built on 3D models, it is still unclear how using computer-based models in real-world scenarios might raise student achievement [17].

4 Conclusion

This study concludes that the use of mobile augmented reality in mathematics learning is still very important to be researched because not many have researched the relationship between these two keywords such as the following explanation (1) mobile augmented reality is a consideration in mathematics learning to strengthen the mathematical concepts being studied; (2) the development of digital technology such as mobile augmented reality can be the latest knowledge discovery in the field of mathematics education; and (3) the use of mobile augmented reality can be a leap forward in the field of mathematics education and has important practical significance in optimizing student learning outcomes. The recommendation in this study is the use of mobile augmented reality to explain mathematical material with the aim of making it easier to provide understanding to students so that learning achievement can increase.

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