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RESEARCH ARTICLE

BIBLIOMETRIC ANALYSIS OF IMPLEMENTATION TRENDS OF AUGMENTED REALITY TECHNOLOGY IN SCIENCE LEARNING

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Abstract

Technological developments have brought many benefits to life, especially in the field of education, by facilitating access to information, increasing learning interactions, and expanding learning opportunities. In education, technology can be included in learning media. However, there are many challenges faced in applying technology in learning. One technology that can be applied in learning is Augmented Reality (AR). AR technology is able to present the virtual world as if it were real. The application of AR in learning has many challenges such as funding and students' lack of digital literacy. So this research was carried out in the form of a bibliometric analysis of the use of AR in learning. This analysis was carried out using the publish or perish application and VOSviewer to search and analyze articles. Research articles starting from 2014-2024 state the use of AR in the last 10 years. The results of the bibliometric analysis state that the use of AR in learning is divided into 5 clusters, this research has started to emerge since 2022, and research that has not yet been widely carried out is the use of digital teaching materials with AR. Research related to digital teaching materials with AR could become a new trend in 2024.

Introduction:-

Technological developments have brought significant changes in various aspects of life, including in the world of education. Modern technology, such as the internet, educational software, and digital learning platforms, has changed the way students access and process information (Santoso, 2022; Alenezi, 2023). The book "Teaching in a Digital Age" by Tony Bates shows that technology not only facilitates access to information, but also encourages more collaborative and interactive learning methods (Bates, 2022). Through the use of technology, students can collaborate with classmates and teachers in real time, expanding the reach of learning beyond physical boundaries (Iskandar, 2023). In addition, educational software allows customization of learning materials according to individual student needs, therebyincreasing the effectiveness and efficiency of the learning process (Castro, 2019; Resya, 2023). Thus, the integration of technology in education not only enriches the learning experience, but also prepares students to face future challenges in an increasingly digital world.

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The importance of applying technology in education is increasingly clear with the presence of innovative learning media, digital learning resources and interactive tools. Technology allows personalization in the learning process, where material can be adapted to the needs and abilities of each student (Soegiarto, 2023). The application of technology in education can increase student engagement, facilitate access to quality resources, and develop 21st century skills (Kareem, 2022; Anas, 2024). With technology, students can access rich and varied learning resources anytime and anywhere. This not only broadens the scope of learning but also increases student motivation and interest. Additionally, interactive tools encourage more collaborative and dynamic learning, preparing students for future challenges.

Education with technological developments has brought about a major transformation in the way we learn and teach. In this digital era, technology is not only a tool, but also the core of an innovative educational process (Purba, 2023). The importance of digital education is increasingly visible as technology allows access to a wider and more diverse range of educational resources, supporting more personalized and interactive learning. Despite its great potential, many education systems still face the problem of lack of application of technology in learning (Akbar, 2019). These obstacles are often caused by limited infrastructure, lack of training for teaching staff, high costs of technology integration and resistance to change (Syifa, 2024; Siwitomo; 2023). These obstacles are often caused by inadequate internet infrastructure, unsupportive school facilities, and lack of training for teachers to use technology effectively (Dewantara, 2024). Research shows that unequal access to technology widens the education gap between urban and rural areas (Anwar, 2022). With the many limitations and challenges in the application of technology it can influence student learning outcomes.

As a solution to these problems, the integration of augmented reality (AR) in education offers great opportunities. AR can create a more interesting and interactive learning environment, allowing students to interact with digital content in a real-world context (Kuswinardi, 2023). AR can help students understand complex concepts more easily (Geroimenko, 2020). Through the use of AR, students can make abstract visualizations real, improving their understanding significantly. In addition, AR can increase student involvement in the learning process. Thus, AR not only enriches the learning experience but also prepares students for future challenges in an increasingly digital world.

The importance of AR in learning cannot be ignored as this technology not only increases student engagement but also supports deeper and more meaningful learning. AR enables the visualization and manipulation of 3D objects, which helps in understanding material that is difficult to explain by conventional means (Hurrahman, 2022; Virijai, 2023). AR is able to present illustrations in virtual form as if they were real which can attract students' attention in learning. Objects that cannot be displayed in front of the class can be shown in virtual form without changing the concept of the object. Learning using AR can make learning more efficient.

To understand how AR can be applied effectively in learning and identify trends and challenges in this research, a systematic approach such as bibliometric analysis is needed. This analysis helps collect and analyze data from various scientific publications to provide a comprehensive picture of the development of AR research in education. By conducting bibliometric research, we can evaluate the extent to which AR has been applied, identify research relevance on AR, and understand the direction and focus of future research. This article aims to present a bibliometric analysis of the use of AR in learning, providing useful insights for educational development in the digital era.

Method:-

This research discusses bibliometric analysis regarding the use of augmented reality (AR) in learning. This research involves quantitative analysis of relevant literature to identify research trends, related research topics and future research trends (Muhammad, 2023). The bibliometric literature review research method is an approach used to analyze and measure the influence of various scientific publications in a field of study (Budianto, 2023). This method allows researchers to identify trends, patterns, and developments in academic literature through quantitative analysis. By using bibliometrics, researchers can assess the performance of authors, institutions and journals based on the number of citations and publications. This method also helps in identifying collaborations between researchers and institutions and highlights the most frequently discussed topics. Additionally, bibliometrics can be used to reveal research gaps that have not been widely explored. Thus, this method is very useful in understanding scientific developments and determining future research directions.

The steps in bibliometric research include several important stages that must be followed systematically. First, researchers must determine the objectives and scope of the research to ensure a clear focus (Muhammad, 2023). This bibliometric research examines the use of augmented reality in learning. Second, researchers collect bibliometric data from various sources, such as scientific databases and academic journals. Bibliometric data uses the publish or perish application which collects articles from Google Scholar and Scopus. After that, the data is organized and filtered to eliminate duplication and ensure relevance. The next step is data analysis using bibliometric tools to identify patterns and trends. The bibliometric tool used is VOSviewers which can map bibliometric results. The results of the analysis are then interpreted to answer research questions and identify practical implications. Finally, the researcher prepares a research report which includes findings and recommendations based on the bibliometric analysis that has been carried out.

Collection and selection of articles in bibliometric research can be done using the Publish or Perish application. This application allows researchers to search and download bibliometric data from various sources, such as Google Scholar and Scopus. This process begins with a literature search using trusted academic databases such as Scopus, Web of Science, or Google Scholar, with specific keywords such as "education", "augmented reality". "learning media" and "physics". Publish or Perish provides information about the study topic, which helps in assessing the bibliometric analysis of AR usage. With this application, the data collection process becomes more efficient and structured to focus on data analysis and interpretation.

Data analysis techniques in bibliometric research are often carried out using the VOSviewer application. This tool allows researchers to identify research clusters and themes that dominate in the academic literature. Additionally, VOSviewer can display temporal developments in a field of study, helping researchers to see how research topics develop over time. With clear and informative visualizations, VOSviewer makes it easy for researchers to analyze bibliometric data in depth and comprehensively. Visualization techniques such as distribution maps or collaboration networks are also used to facilitate data interpretation. This study provides insight into developments and research directions in the field of AR in learning and identifies areas that require further attention.

Results and Discussion:-

The results of this bibliometric analysis show that there has been a significant increase in the number of publications regarding the use of augmented reality in learning over the last 10 years. These studies are spread across various countries, showing global interest in the implementation of AR in education from 2014-2024. Search for research related to bibliometric analysis of the use of AR in learning using the keywords, namely "education", "augmented reality". "learning media" and "physics". Research that examined according to keywords obtained 1000 articles. Article searches were carried out using the publish and perish application. Searches using this application can include sources from Google Scolar and Scopus.

Networking visualization

The results of using the VOSviewer application show the development of scientific publications regarding the use of AR in learning from 2014-2024 and a map of the development of AR research publications based on relevant keywords. The research results are displayed in many colors which indicate the clusters of the research. Vosviewer also displays network connections from research on the use of AR in learning. The first research result, namely the development of AR scientific publications, is shown from 2014-2024 in Figure 1.

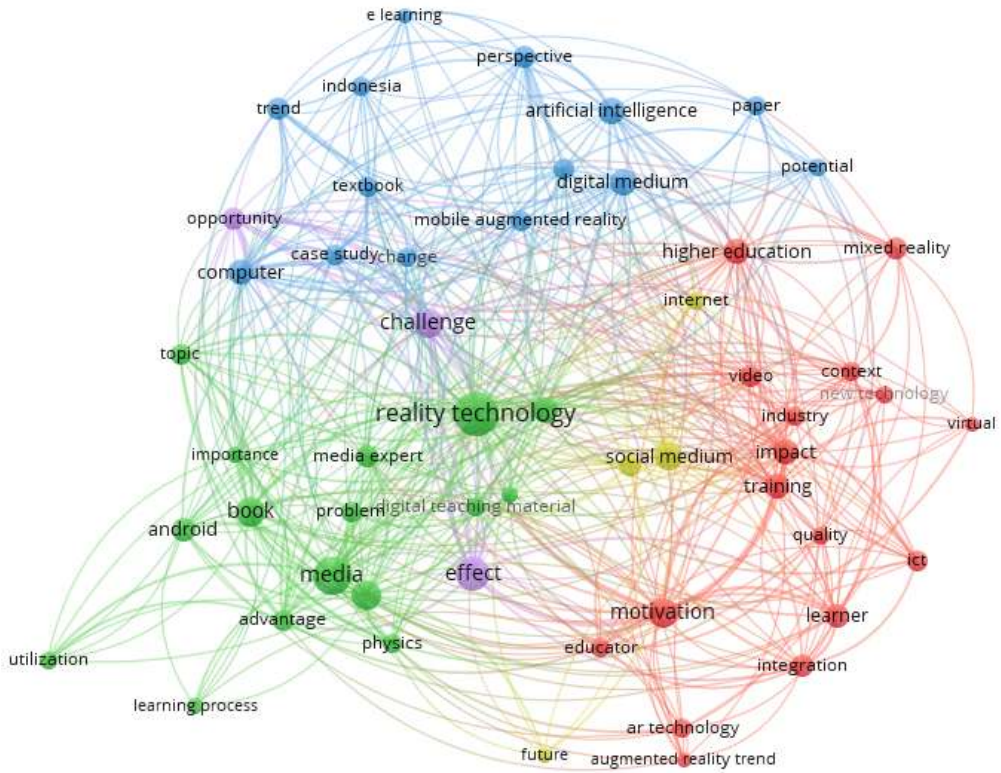

Figure 1:- Networking visualization.

Based on Figure 1 obtained from the VOSviewer application, it displays the networking visualization results. This explains the relationship between related articles. The more threads that connect them reveal the many connections that researchers have made before. Based on the ibi network visualization, it can state 5 network clusters. The first cluster states scientific studies about AR Technology, Augmented Reality trend, context, educator, higher education, ICT, impact, industry, integration, learner, mixed reality, motivation, new technology, quality, training, video, and virtual. In cluster 1, scientific studies were found discussing the use of ICT in learning with video, virtual in the form of the Augmented reality trend. The integration of technology in learning in the form of AR can improve the quality of learning in terms of student learning outcomes and skills (Novit, 2023). Therefore, the application of Ar in learning in this digital era really helps the learning process in terms of efficient learning implementation and learning outcomes.

In cluster 2, scientific studies were found discussing advantage, android, book, digital teaching material, importance, innovation, learning process, media, media expert, module, physics, problem, real word, reality technology, topic, and utilization. In cluster 2, studies were found regarding the application of Augmented Reality in learning, which can take the form of innovation in the use of learning media. The use of AR in learning can be done using books integrated with AR, applying AR via Android, and applying AR in learning media (Indrayani, 2024; Zakaria, 2023). The application of Ar in learning is often found in Physics learning, this can display the virtual world as if it were real so that students can understand the concepts well. Furthermore, the results of networking visualization in cluster 3 discuss additional scientific studies, artificial intelligence (AI), case studies, computers, digital media, e-learning, mobile augmented reality, papers, perspectives, potential, textbooks, trends, and Indonesia. Cluster 3 discusses scientific studies regarding the medium for using AR, which can be through computers, textbooks that are integrated with AR, the application of e-learning with AR, the application of AR together with AI and trends in the use of AR in Indonesia. The use of AR with e-learning and AI is stated to be able to increase students' technological literacy and improve student learning outcomes (Arroyan, 2022; Maulana, 2019).

Cluster 4 discusses scientific studies about digital technology, future, internet and social media. Cluster 4 discusses the future of using digital technology using the internet which can be expressed in the form of AR technology. AR

technology is useful in education and in industrial development (Sugiana, 2019). The application of Ar is not limited to education but can be used in a wide range in industry, commerce and many more. Cluster 5 discusses scientific studies about challenges, effects and opportunities. Cluster 5 discusses the opportunities and challenges of using AR in learning. The use of AR in learning expresses the latest integration of increasingly sophisticated technology and has many challenges in its application. Challenges in implementing AR include low student digital literacy, low technological infrastructure and many more. However, with these limitations and challenges, the opportunity to use AR in learning can improve student learning outcomes.

Overall, this bibliometric analysis provides a comprehensive picture of how AR research in learning has developed, who has contributed significantly to the field, and where this research is heading. With a better understanding of this research landscape, it is hoped that effective strategies can be found to better integrate AR in education and overcome existing barriers. Bibliometric analysis was carried out using an application called vosviewers. This application can review the relationship between one node and another based on keywords, articles, authors, institutions and countries. The size of the node depicted shows the number of articles, if the node is larger then the number of articles will also increase. The node link of each node expresses the connection and co-occurrence in the research article. Each color lists how many clusters were formed in research in recent years.

Overlay visualization

The VOSviewer application can state the latest scientific studies related to the use of AR in learning starting from 2014 to 2024. The latest discussion of scientific studies regarding the use of AR in learning is important to see the state of the art from further research. The results of the analysis of the latest scientific studies can be carried out through the VOSviewer application which is shown in Figure 2 as follows.

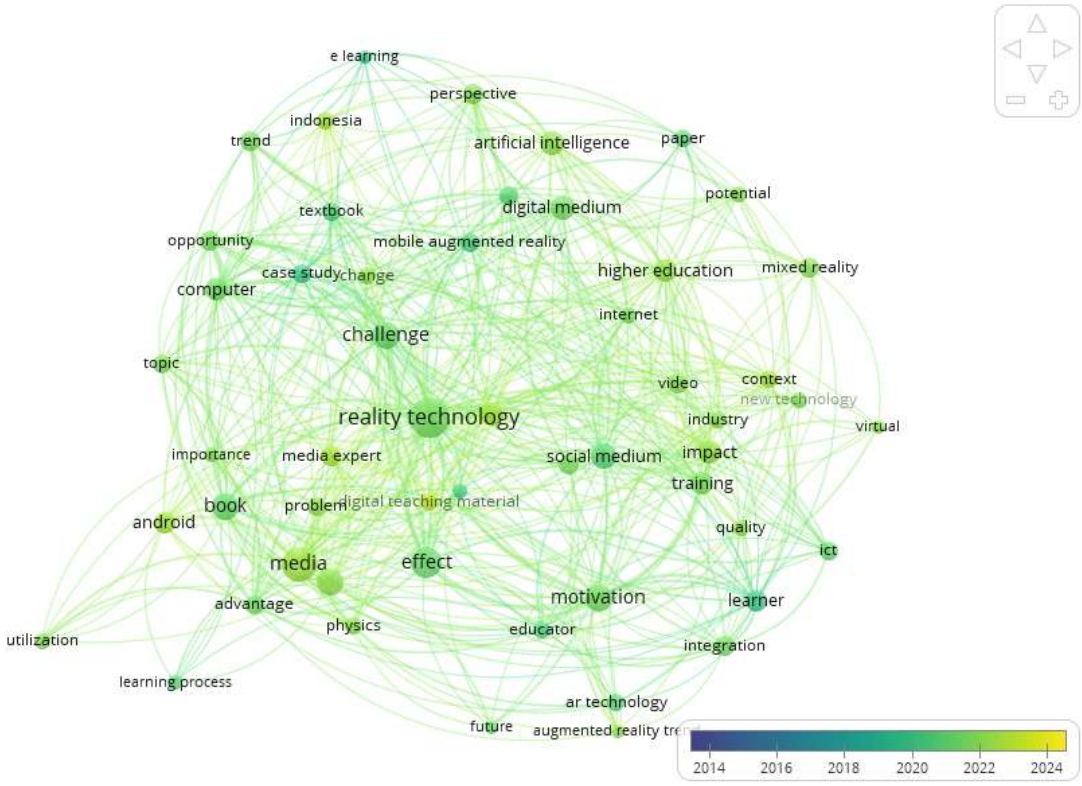

Figure 2:- Overlay visualization.

The results of the overlay visualization from the vosviewer application display an overlay of articles obtained from 2014-2024. The blue, green and yellow colors in the image indicate the range of years discussing the topic about AR. Based on this explanation, it can be stated that the results of scientific studies for the last 10 years regarding the use of AR are in the green to yellow range. Scientific studies on the use of AR in learning are something new because they are starting to be widely discussed from 2022 to 2024. The number of nodes indicates that there have been many studies discussing this topic. The smaller the node indicates that there is still little research examining a

particular topic. Scientific studies are yellow and have a small node, namely about digital teaching materials. The use of AR in digital teaching materials is still little used. This can be a research idea so that it can become a new and useful research result for research related to the use of AR in learning.

Density Visualization

The results of further research regarding density visualization explain the density level of AR use in learning. The increasingly dense research on a particular topic means that there are many researchers discussing the same topic. The density level obtained from VOSviewer can be expressed in Figure 3 as follows.

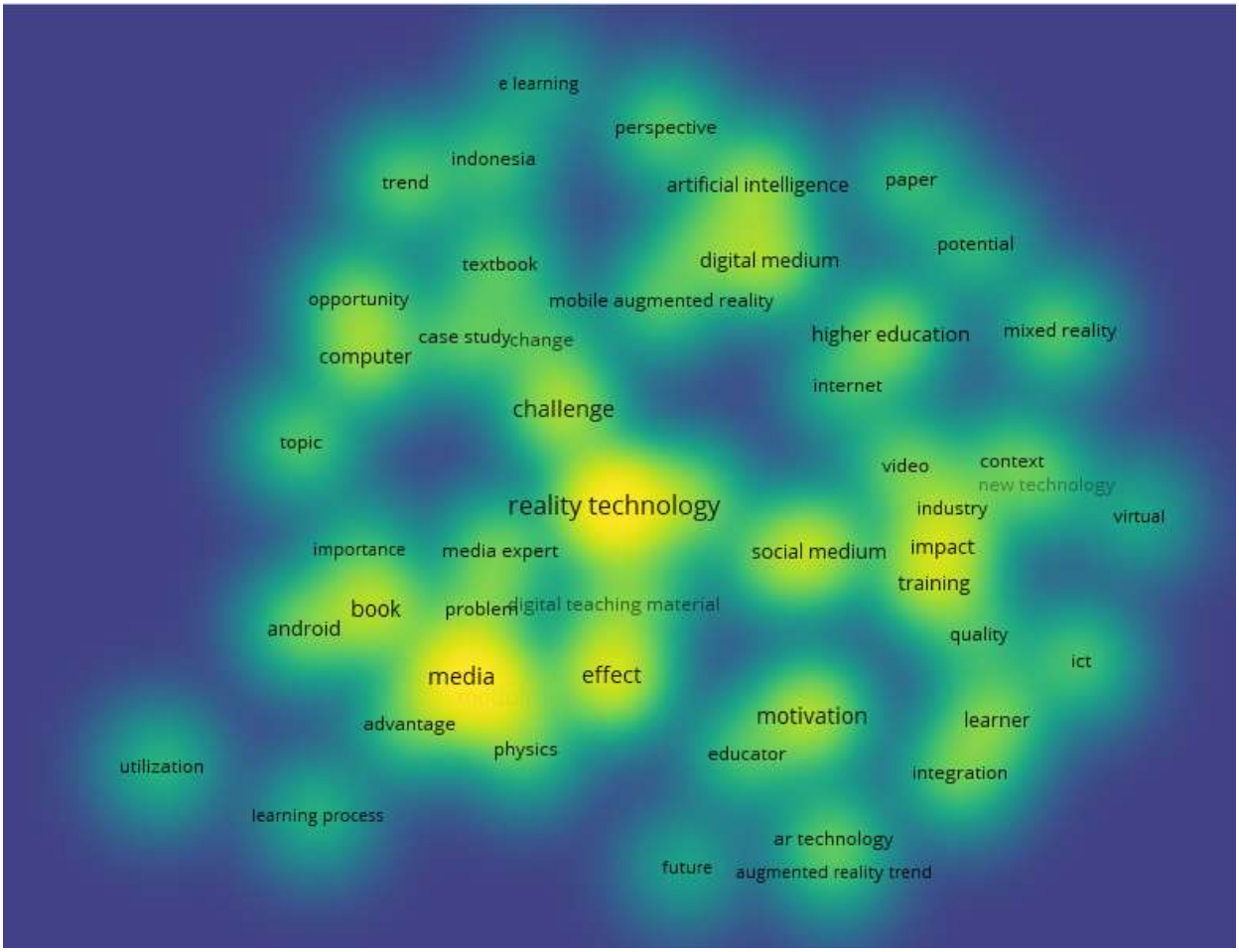

Figure 3:- Density visualization.

Based on Figure 3, it can be stated the density level of using AR in learning. The thicker yellow color of the image indicates the number of research articles that have discussed the same study. The greener to blue indicates that there are still few researchers discussing the study of that topic. Based on Figure 3 of the Reality Technology study, many researchers have studied the same topic. Studies that are still relatively new are colored bluish green, namely new technology, Augmented reality trends, and digital teaching materials. The use of AR in digital teaching materials can be an integration of new technology and become the next AR trend. In terms of research topics, most studies focus on the effectiveness of AR in improving understanding of abstract concepts in the fields of science and engineering (Hermawan, 2024). In addition, many studies have also explored the potential of AR to increase student engagement and motivation in the learning process (Ardani, 2023; Fauziyah, 2024). Despite this, there are still several challenges that need to be overcome, such as the high costs of developing AR content and the need for special training for teachers to integrate this technology into the classroom.

Although bibliometric literature review methods offer many benefits in analyzing the use of augmented reality (AR) in learning, there are several limitations that need to be noted. First, bibliometric analyzes rely heavily on data

available in academic databases, meaning research that is unpublished or outside major databases may be missed. Second, this method emphasizes quantity over quality, so highly cited articles do not always reflect the most relevant or high-quality research. Additionally, bibliometrics tends to be unable to capture the deeper nuances and context of each individual study, as its primary focus is on citation patterns and relationships between articles. Another limitation is the possibility of bias in keyword selection and topic grouping, which could influence the analysis results. Finally, technological and research developments in the field of AR are very dynamic, so bibliometric results may quickly become outdated and not reflect the latest innovations. Therefore, it is important to complement bibliometric analysis with other methods, such as systematic reviews and qualitative studies, to obtain a more comprehensive and accurate picture.

Conclusion:-

Bibliometric analysis of the use of AR in learning can conclude several things from the results and discussion above. Research on AR studies can be divided into 5 clusters which have a close relationship in improving education in the 21st century. The use of AR in learning has begun to emerge from 2022 until now. The small amount of research on digital teaching materials related to AR is obtained from visualization overlays from VOSviewer. In this way, Vosviewer is able to state the latest developments and trends in research related to studies on the use of AR in learning. With a little discussion of research on digital teaching materials with AR, it could become a future research trend.

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