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Virtual Reality in Biology Learning: Systematic Literature Review (SLR) Recent Trends (2003-2023) and Its Post-Pandemic Implications

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Abstract. This study aims to thoroughly describe virtual reality in the biology learning sector in general, the use of VR has been in the spotlight in the last two decades. This study conducted an in-depth bibliometric analysis using the Systematic Literature Review (SLR) method to identify research trends, most frequently researched topics and major contributions in this field based on 24 collected articles indexed by scopus between 2003-2023. We conducted bibliometric analysis using RStudio and VOSviewer. There was the highest increase for virtual reality research in 2021, which is the experience of the corona pandemic in various sectors. The largest average citation was in 2014. Based on the results of the analysis using RStudio and VOSviewer, the keywords virtual reality and biology have been widely carried out and are interrelated with computer programs, but for general biology learning it is still rare so that it can be used as a recommendation for further research gaps. By considering the findings from the bibliometric analysis, this study can provide practical recommendations, summaries and opportunities to find further research gaps. This literature review also underlines how VR research in biology has filled existing knowledge gaps and provided new insights into learning complex biological concepts. Recent studies, especially post-pandemic, have increasingly emphasized the pedagogical effectiveness of VR in improving student engagement, concept understanding, and learning outcomes.

Keywords: bibliometric analysis; general biology; virtual reality

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INTRODUCTION

People must prepare themselves to face developments in the era of disruption and globalization because everyone will face many global challenges with the entry of the 21st century (Atmojo & Sajidan, 2020; Thompson & Miller, 2017; Musa et al., 2012). In order to meet the high market demand for products based on science and technology in the 21st century, an education system that is able to overcome this problem is needed (Utomo et al., 2020). Digital technology is essential in the modern century to change the way students learn. Therefore, digital literacy is a very important skill for prospective teachers (Akayoglu et al., 2020; Nurzhanova et al., 2024; Öngören, 2021). According to Press et al., (2019), the world is entering the fourth industrial revolution (4.0), also known as the digital revolution. This period will change our

lives, our work and the way we learn. Technology has become an essential part of modern education, changing the way students learn (Tang & Chaw, 2016). A 2019 OECD report states that educational institutions need to take immediate action to connect education with the trends shaping the world today. Schools should consider the use of digital literacy in their curriculum (Reedy & Parker, 2017). One of the technologies utilized in learning biology is *virtual* reality (VR).

VR can be defined as a technology that makes users believe that they are in another place, based on strongly influencing the primary sensory input with computer-generated data (Hemz, 1998). This technology is developing rapidly in aspects of social life, one of which is in the world of education. VR based learning is important in this 4.0 era because VR can present immersive and interactive experiences that attract attention and increase learning motivation. VR describes the virtual world as real, using images or videos created in three-dimensional quality using a computer that makes users feel physically involved in the environment (Prahani et al., 2022; Rubio-Tamayo et al., 2017; Thuan et al., 2019). The utilization of VR can be applied to biology learning so that students can be interested and explore biology material in general which is abstract.

In biology learning, examples of utilization are useful in teaching molecular and cellular biology where concepts are difficult to grasp because they are abstract, three-dimensional, and lack real-life references that learners can use to ground their understanding. Concepts related to recombinant DNA technology and heterologous expression, for example, functional components of plasmids and protein production/ secretion, can be difficult to use in a 2-dimensional framework. Student exploration of these and other molecular aspects such as viral and cellular structures in 3D can offer new entry points for students, providing spatial context that cannot be achieved from a computer screen (Johnston et al., 2018). Students can also take advantage of VR by exploring human organ systems, such as the digestive system, nervous system, and circulatory system, in 3D that are commonly used with videos or torsos only. By utilizing this VR technology, there is innovation and attracts students to be interactive and can visualize abstract things with various points of view because of 3D and 4D.

The study in this research is a literature review by involving a scopus account as a search for indexed articles using predetermined keywords, namely virtual reality, general biology. Some articles are selected as desired, by conducting this study, the next research gap can be done.

METHOD

The Systematic Literature Review (SLR) method was used in this study. SLR is a type of secondary study that uses a well-defined methodology that aims to identify, analyze, and interpret previous research findings to answer research questions (Kitchenham et al., 2007). 273 documents were obtained during the search and then sorted for studies from computer science, engineering, psychology, energy, business, management and accounting were excluded so that they returned according to the objectives in the field of biological education and related to biological studies, the results were obtained as many as 77 and those that were eligible after analysis were 24 eligible articles. This study used Kitchenham and Charters' SLR guidelines in Software Engineering, which state that SLR consists of three main stages: planning, conducting, and reporting. The researchers used the SLR systematization proposed by (Schon et al, 2017) to systematize the SLR phases. The SLR

phases used in this study are depicted in Figure 1.

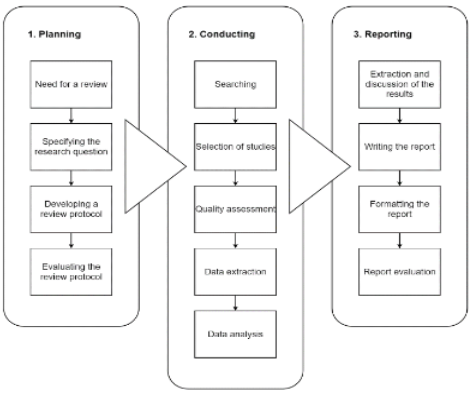

Figure 1 SLR stages by Kitchenham and Charters

Based on Figure 1, the SLR stages are as follows.

Planning stage

Need for review

VR is an alternative to the latest technology that can be used to realize or visualize abstract learning materials. Technology in the world of education is an innovation that must be optimized in the differentiated learning process, especially in learning biology. The use of VR in the educational environment has increased (Yildirim, 2018). In this study, data used in the scopus.com account which can be accessed via the url scopus.com

Specifying the Research

Research questions are made according to the needs. Research questions in this study. (1) General information about virtual reality in general biology learning? (2) Average citations per year? (3) Annual article production for 2 decades indexed by Scopus (4) Where is the location that uses VR the most? (5) literature folder with keywords to see the research gap that can be accessed?

Developing a Review Protocol

The development of a review protocol aims to determine the methods to be used in conducting SLR. This protocol is needed in order to reduce researchers bias. In this study we used the research protocol proposed by Kitchenham and Charters (2007). This protocol consists of research questions, strategies for finding primary studies, article selection criteria, article selection procedures, article quality assessment procedures, and data extraction strategies.

Conducting stage

In the conducting process, it begins with a strategic search for data. The initial step in order to access the web is to log in to the scopus.com web which automatically subscribed institutions can easily enter with each individual account to https://www.scopus.com/. The next stage is selection of studies. In this process, the researchers sorted to select articles related to the theme to be reviewed so that the article is relevant to the theme being carried. The following are the stages in searching for articles in Figure 2. After the next selection process to quality assessment and data extraction and analysis.

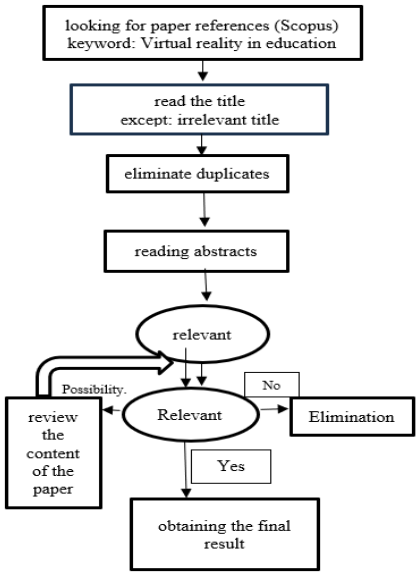

Figure 2 SLR stages in searching for articles

RESULTS AND DISCUSSION

Based on the Research question, the results that are discussed namely:

Virtual Reality in General Biology Learning

Virtual Reality (VR) can be categorized as media in learning. One of the factors that can influence the learning process is the use of learning media (Berlian et al., 2023). The need for learning innovations that stimulate students to be interested in participating in learning activities (Febrianti et al., 2022). Especially the learning process that integrates technology which is currently very developed (Pane et al., 2022). Key information is presented in Table 1.

Table 1 Key information of virtual reality theme

Description	Result
Main Information About Data	
Timespan	2006:2023
Sources (Journal, Book, etc)	24
Document	24
Annual Growth Rate %	0
Document Averange Age	7.29
Description	Result
Main Information About Data	
Average Citation Per Doc	18.08
Reference	0
Documen Ontent	
Keyword Plus (ID)	446
Author's Keywords	90
Authors	
Authors	121
Authors of single-authored docs	3
Authors Collaborations	
Single-Authored Docs	3
Co-Authors per docs	5.21
International co-authorships %	20.83
Document Types	
Article	11
Conference paper	10
Note	1
Review	2

From Table 1, the article is a *paper* that is widely produced as many as 11 articles. The search started from 2003-2023 for 2 decades but the articles that appeared started back in early 2006 so that RStudio presented the timespan 2006-2023. The keywords used are more emphasized on *virtual reality in general biology.* When articles appear related to VR, not only read and examine VR problems but also the relationship with biological content, after narrowing down the selection of new articles, save and start analyzing with the Rstudio and Vosviewer applications.

Average citations per year

On biblioshiny the average citation per year can be displayed in Figure 3.

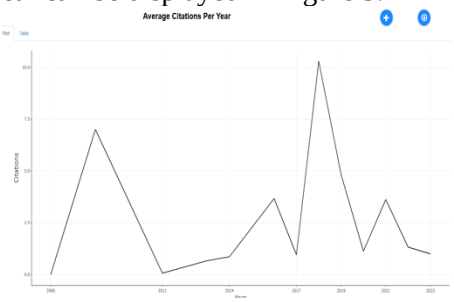

Figure 3 Average citations per year

In Figure 3, it can be seen that the curve in 2006 began to censor research related to *virtual reality.* The highest increase was in 2018-2019 along with empirical evidence of more and more research showing the effectiveness of VR in various applications, such as skills training, phobia therapy, pain management in the world of health and implemented also in the world of education. Increased interest from the scientific community to explore the potential of VR in various fields of research.

Annual article production over two decades

Scopus indexed articles related to the VR theme are presented in Table 2 as follows.

Table 2. Annual production of scopus-indexed articles

Year	Articles
2006	1
2007	0
2008	1
2009	0
2010	0
2011	1
2012	0
2013	3
2014	2
2015	0
2016	2
2017	3
2018	1
2019	1
2020	3
2021	4
2022	1
2023	1

In Table 2, articles about VR began to be released in 2006 which resulted in 1 article. Started to be researched a lot in 2013 and then in 2021 was the most production of 4 articles. In 2019 the Indonesian nation and several countries in the world experienced the 2019 covid crisis. Circular Letter number 15 of 2020, issued by the Ministry of Education and Culture to prevent the spread of the COVID-19 outbreak, regulates home learning. It prohibits face-to-face learning at all levels of education, from playgroup to college level. According to the circular, online learning is used, which consists of a learning management system and virtual face-to-face (MoEC, 2020). With this covid outbreak, it has also contributed to technology-based research, especially in Indonesia. Citation will continue to exist as long as research on VR continues to be developed in the world in various sectors, especially in the world of education to improve better learning.

Most locations where VR is used

The results of most of the locations where VR was used are shown in Figure 4.

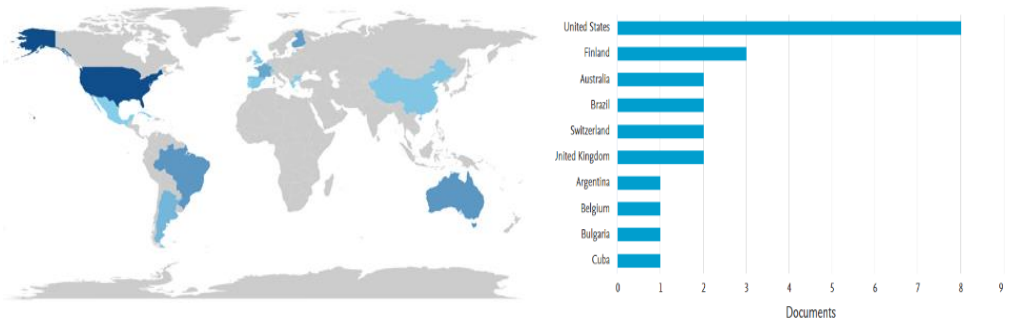

Figure 4 Map of the study distribution and interpreted into a bar chart

In Figure 4, it is visualized that a lot of VR-related research is carried out in the United States. This can be caused because the country is a developed country that has many leading universities that do a lot of VR research. If traced with *Google Scholar* VR research is widely done. Scopus indexed articles are not easy and easy so only a few can be traced by biblioshiny. The United States has a long history of technological innovation, and VR is no exception.

Virtual reality (VR) technology allows VR users to interact with environments designed and simulated by computers. This environment can be perceived as an actual environment but is actually just an imagination. This technology is intended to convey perceptions that use emotions, as we do in real life (Yunanto et al, 2018).

Literature map based on VosViewer with keyword VR

In order to make it easier to read the visualization of research on VR, it is assisted by the vosviewer application in Figure 5 as follows.

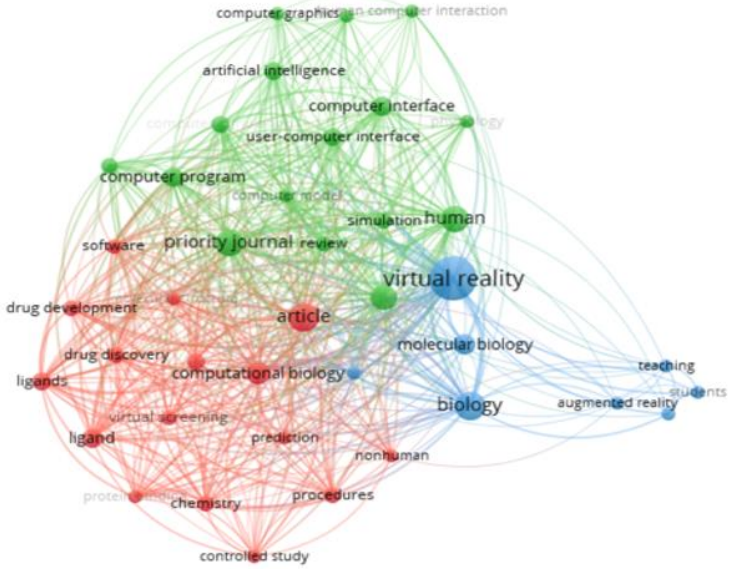

Figure 5 Literature map via VOSviewer

In the literature folder, it is presented that virtual reality is the research with the most keywords so that it can be concluded that there are lots of studies using virtual reality keywords. In biology midwives who are closely related to the research that has been done, namely in the field of molecular biology. Virtual reality is a simulation in digital form to train students so that they can still carry out their roles as if in a real situation to students. In addition, because of its digital nature, this method can train repeatedly and also knows no time limit (Lumenta, 2021). Molecular biology is one of the branches of applied biology whose content is abstract so it requires tools to visualize it. Research gaps in this literature map can be found for keywords that appear on keywords that are getting smaller or rarely seen.

CONCLUSION

Virtual reality is a powerful tool with the potential to revolutionize the way we learn, research and communicate about biology. As virtual reality technology evolves, we can expect to learn about more innovative applications in this field. Virtual reality began to increase for research in 2021 with citations increasing in 2019. This is in accordance with the state of the world experiencing the Covid-19 crisis so that learning is carried out online so that more research is carried out related to technology. The recommendation that the author can convey is that VR research has been carried out a lot, especially after the pandemic, but for integration in the field of biology education it still needs to be studied as a form of research gap that will be carried out later.

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