Learner Acceptance and Student Experience of Virtual Reality Usage in Biology learning: A Meta-analysis

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Abstract
Virtual Reality (VR) technology has become a popular interactive learning medium in the past decade. In science learning, VR has been used to help the learning process in high school. This report presents strong and responsive survey results on the satisfaction level and experience of using VR technology in biology learning in high school. With PRISMA guidelines, we analyze the research results on VR use in international databases, namely SAGE, Emerald, Wiley, Springer, Taylor &Francis, ScienceDirect, BMC Medical Education and Elsevier. A total of 13 studies were selected for final analysis. The main inclusion criteria are studies that report satisfaction levels and user experience at the high school level. This study shows that VR provides positive feedback, where VR becomes a valuable tool in the process of biological learning and shows substantial opportunities and has hands-on experiences that are not possible in the real world. This literature review is important to highlight more research needs in a virtual VR-based design learning environment.

Introduction

The rapid development of ICT learning media has indirectly changed the teaching culture for most teachers in the past two decades. Various materials have been packaged into interactive media and more online media. The development of learning media positively impacts teachers and students(Sahin & Yilmaz, 2020).For instance, MOOC has supported student learning dynamically and actively (Fidalgo-Blanco et al., 2014).Utilization of other technologies on moodle platform that is profitable in learning achievement(Marikar, 2016). Furthermore, Flipped Classroom is a pedagogic tool that can improve higher-order thinking skills, spur students to be more active, and collaborate.(Lin, 2019)(S Pasaribu, 2021). This shows that VR technology is one of the digital tools that can be developed in the future. VR provides a different and constantly evolving way of learning in providing a high school-level learning experience that no other technology can offer(Kamińska et al., 2019).

VR is becoming a widely used medium for learning today, although this media did not receive attention in the 2000s because it was still limited and required high costs. (Checa & Bustillo, 2019). Currently, innovative learning technology continues to develop as a result of technological advances and a paradigmatic shift in science learning technology. Changes in information transfer in the environment and incorporating technology in science education are becoming increasingly important. Today, virtual technology is evolving towards Augmented Reality (AR) and VR. AR can be described as an interactive platform that presents a combination of virtual and real-world objects (İbili & Şahin, 2015). According to Çalışkan (2017), AR and VR are the clearest examples of today's innovative technologies.In education, VR simulations can allow students to practice skills to help optimize the teaching process (Lee & Wong, 2014).

Recently, increased interest has been shown in Virtual Reality in the world of education (Pilot A, 2018). VR gives students a tight 3D simulation section quickly. Some studies have compared VR with other pursuing methods such as discussions, lectures, 2D images, and mixing instructions. According to Maresky et al. (2019), students with the help of cardiac VR simulation can significantly improve final test results. In addition, the analysis conducted (Hussein et al., 2015)on VR utilization in education showed results where VR is very effective in subjects that require an interactive environment. However, VR is no more effective in measuring knowledge and performance(Farra et al., 2015). The meta-analysis study compares traditional or digital 2D methods with VR, potentially improving anatomy teaching(Zhao et al., 2020)(Romadhona et al., 2021). This meta-analysis showed uncertain results due to a lack of standards and high heterogeneity among studies. Tinjauan literatur sistematismenunjukkanmetode pendidikan 3D lebih baik sebagai alat belajar daripada metode 2D dalam perolehan pengetahuan anatomi (Yammine & Violato, 2015).

The use of meta analytics for research on the utilization and influence in various learnings has been widely reported. However, as far as our observations, the meta-analytical approach related to VR utilization in biology learning in high school has not been reported. Some systematic review results also report the effectiveness of VR in medicine and education, but the effectiveness delivered is inconsistent (Rourke S., 2020). Generally, the virtual technology review literature is grouped into three areas: virtual technology, types of methods to study the effects of 3D media, and the types of topics studied (Hew & Cheung, 2010). In this study, we presented an analysis of aspects of VR use at the high school level. This article presents a meta-analysis of the use of VR on satisfaction (participants' perceptions of VR learning interventions) in biology learning. This review covers studies over the last ten years and is expected to provide new insight into the current literature on VR technology and a comparative analysis in virtual technology utilization and learning effectiveness.

Method

PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-analyses) guidelines were used in this study (Moher et al., 2009).This PRISMA guideline uses five steps: 1) defining the eligibility criteria; 2) define the source of information; 3) literature selection; 4) data collection process; 5) selection of data items.The eligibility criteria used in this study are:

IC1: Original research and studies written in English;

IC2: Research conducted from early 2010 to 2020;

IC3: Research using a sample of the population of high school students

IC4: This study aims to determine the effectiveness of using VR in biology learning, especially in terms of satisfaction and experience.

Resources

Electronic searches are conducted on the following databases: SAGE, Emerald, Wiley, Springer, Taylor &Francis, ScienceDirect, BMC Medical Education, and Elsevier. We conducted a study search from early 2010 to 2020. The search is done manually, checking the selected article's references to get other relevant publications.

Literature selection

The selection of literature is conducted in four stages as follows:

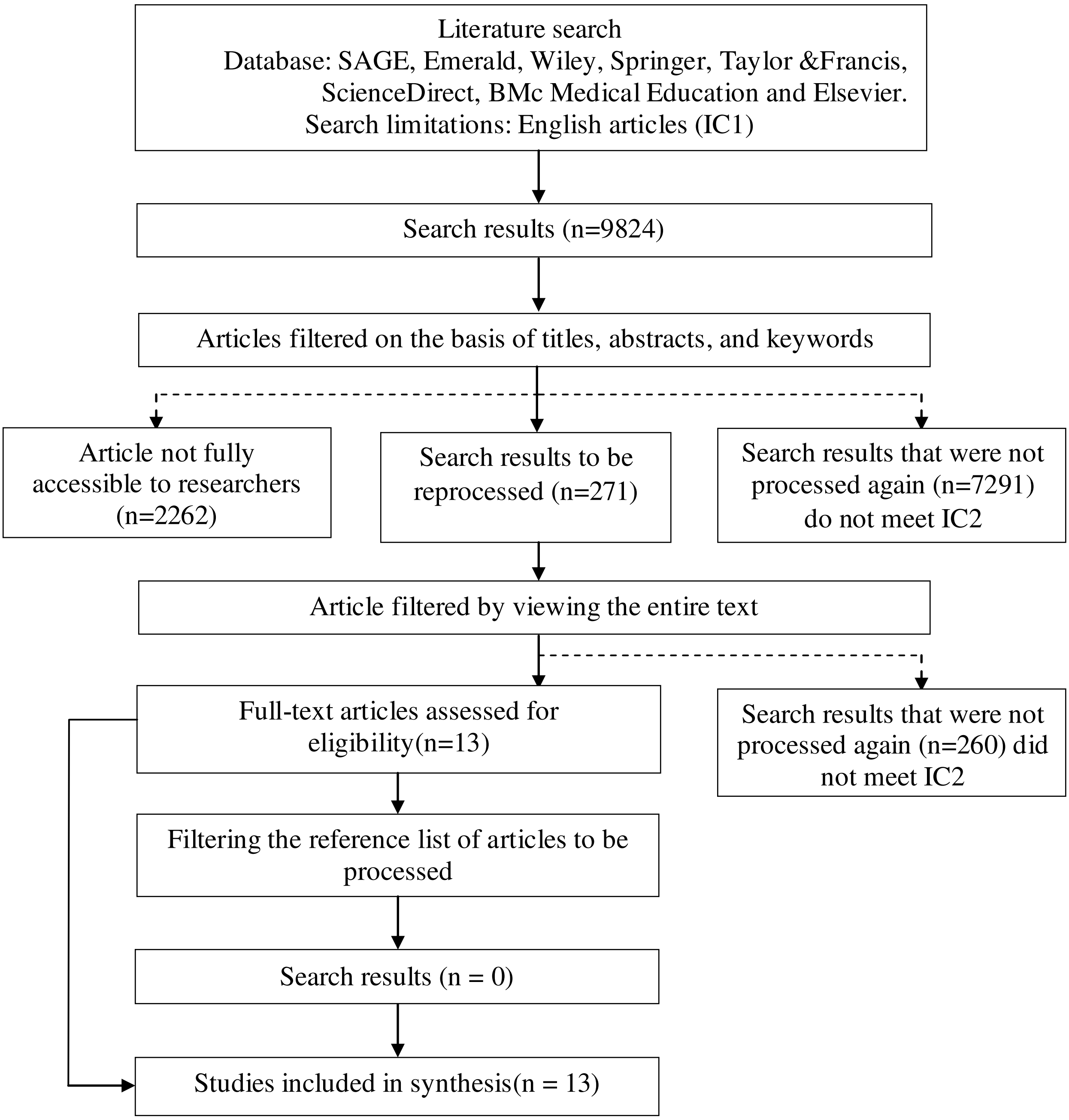
1) Keyword search following this research interest reviews the use of VR in biology at the high school level; with keywords related to "Virtual Reality","Virtual Reality study","Virtual Reality in education", "Virtual reality biology", "Virtual Reality science education", "Virtual reality learning", and "Virtual Reality school learning".
2) Identification of the article's title, abstract, and keywords is carried out based on the eligibility criteria.
3) Determination of articles must be included in the review and according to the eligibility criteria by reading the whole or part of the article that was not omitted in the previous stage.
4) The list of article references is scanned to obtain other relevant publications.. As such, any discrepancies are discussed by both authors until a unanimous agreement is reached.

Datacollection process

Data collection is done manually by using a data extraction sheet consisting of article type, author, publication date, country, participant type, research methodology, and results. Each author judges potentially relevant articles. The assessment consists of reading the full text and extracted data.

Selection of data

Information is taken from each article on the demographics of the selected article following information:Distribution of VR-related studies in biological learning, Countries conducting VR-related studies in biological learning, Types of participants, Research methodology, Results of the study.



Result

Studyselection

A total of 9824 studies that met IC1 criteria were found in all search databases from 2010 to 2020. With the guidelines and keywords used, 271 studies were successfully screened. In addition, full-text analysis was carried out until finally, as many as 259 articles were eliminated because they did not meet the IC2 criteria—finally, a total of 13 articles were selected for review.

Table 1. Details of articles included in the review

Authors	**Country**	**Learning materials**	**N**	**Device**	**Result**
(Huang, 2019a),	USA	Cell	66	Samsung Gear VR & Smartphone	Experience
(Han et al., 2020)	China	Anatomy of the Liver	30	Gear VR & unity 3D	Experience
(Fahmi et al., 2020)	Indonesia	Anatomy	20	Vive controller, leap	Satisfaction

				motion controller &senso gloves	
(Kurniawati et al., 2020)	Indonesia	Anatomy of the kidneys	18	Google Cardbord & Smartphone	Experience
(Gochman et al., 2019)	USA	Evolution	8	VRTK (Virtual Reality Toolkit)	Satisfaction
(Hammang et al., 2018)	USA	Blood cells	83	Samsung Gear VR & Unity 3D	Satisfaction
(Sharma et al., 2018)	USA	DNA	8	VE	Satisfaction
(Zhang et al., 2020)	China	Nervous system	55	Gear VR	Satisfaction
(Makransky et al., 2020)	Denmark	DNA	131	Samsung Gear VR & Smartphone	Experience
(Mariana Iancu, 2018)	Bucharest	Nucleic Acids	180	Samsung Gear VR	Experience
(Silva et al., 2017)	Brazil	Cell	60	Samsung Gear VR	Satisfaction
(Parong & Mayer, 2020)	USA	Circulatory	60	Samsung Gear VR	Experience
(Bhattacharjee et al., 2018)	India	Anatomy	60	Google Cardbord	Experience

This meta-analysis provides insight into research focused on VR use in biology learning at the high school level. The three main topics discussed from the perspective of participants with the VR learning intervention are; 1) The use of VR in biology learning; 2) VR learning devices; 3) the results of participants' experiences with VR learning interventions.

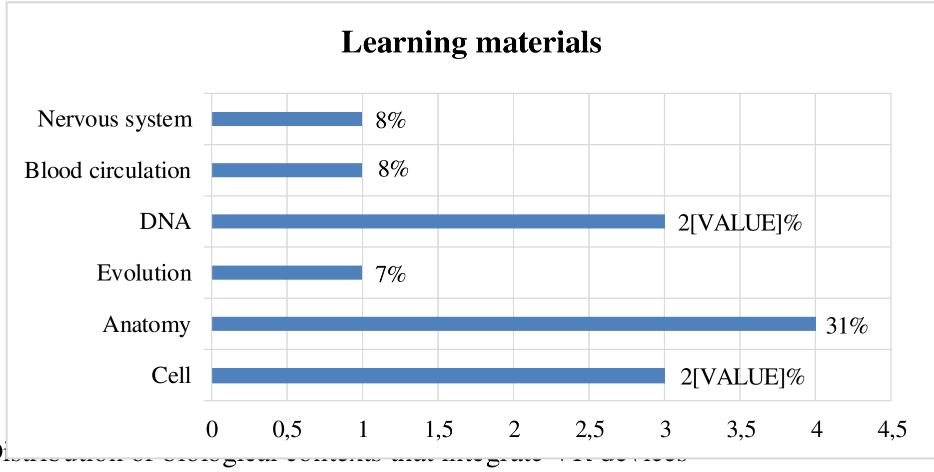


Figure 1. Distribution of biological contents that integrate VR devices

Figure 1 presents the context distribution of the reviewed learning materials. On the learning materials of four studies (31%) focusing on VR use in anatomical material. In addition, six studies (23%) were divided in two in cell matter and DNA. Lastly, there was one study (7%) conducted in Evolutionary material, as well as one study (8%) discuss blood circulation, and one study (8%) focusing on the material of the nervous system.

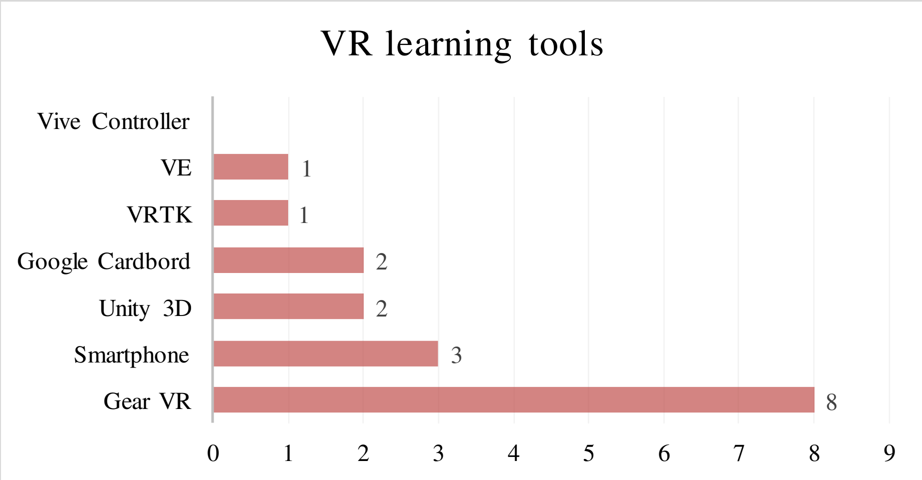


Figure 2. Results of a study on VR-based learning tools

In this review,seven types of VR technology are used for biology learning at the high school level (Fig. 2). Samsung Gear VR was found to be the most widely used technology for biological learning. The second most widely used device is a smartphone, where the smartphone can be said to be a component to optimize Gear VR or Google Cardbord. Simulation of the use of Gear VR is widely used in a variety of subject matter, including cells (Huang 2019; Hammang et al. 2018; Silva et al. 2017), anatomy (Han et al., 2020), DNA(Makransky et al., 2020; Mariana Iancu, 2018; Sharma et al., 2018), nervous system (Zhang et al., 2020), blood circulation(Parong & Mayer, 2020), Unity 3D and Google Cardbord(Bhattacharjee et al., 2018; Hammang et al., 2018; Han et al., 2020; Kurniawati et al., 2020). For other devices that are still rarely used in reviews areVRTK (Virtual Reality Toolkit) (Gochman et al., 2019), Virtual Environment (VE)(Sharma et al., 2018), andController along with Leap Controller and senso gloves(Fahmi et al., 2020).

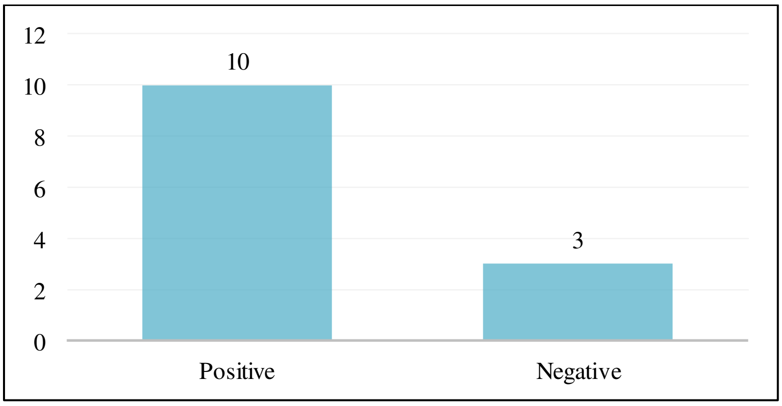


Figure 3. Number of study results of participants' experiences with VR learning interventions

In this review, there are seven devices in a VR environment: 1) gear VR, 2) smartphone, 3) unity 3D, 4) google Cardbord, 5) VRTK, 6) VE, and 7) Vive Controller, leap motion controller and senso gloves (Figure 2). Generally, in these seven devices, the usability and adoption of VR technology are classified as a positive experience. Only three studies were found with negative experience results with each device. Gear VR is the most common device in research (Hammang et al., 2018; Han et al., 2020; Huang, 2019a; Makransky et al., 2020; Parong & Mayer, 2020; Sharma et al., 2018; Silva et al., 2017; Zhang et al., 2020) and also showed a positive perception, where participants reported that VR simulations are considered exciting and valuable to acquire learning skills (Kurniawati et al., 2020). There were only three studies with negative experiences (Hammang et al., 2018; Huang, 2019a; Parong & Mayer, 2020).

Discussion

The purpose of this study was to analyze the use of VR in biology subjects at the high school level that differed in each device and material to the results of participants' perceptions/experiences with VR learning interventions. After reviewing all the included studies, seven types of devices are used for learning with the various subject matter. All studies written from 2011 to 2020 recorded that software and hardware development has overgrown over the past decade, enhancing the creation of realistic, immersive simulations. The most challenging task in this study is to identify scientific contributions through conceptual, empirical, and practical lenses. This requires us to survey relevant publications that support the claims or arguments of this review.

A total of 13 studies on VR in high school reviewed perceptions of VR use, with the results of studies showing that almost all studies observed were positive. Negative experiences are mostly related to insignificant abilities with learning activities (Huang, 2019a). These results are at odds with(Parmar 2017),where students have more significant abilities than traditional learning activities with the support of the VR environment.

In this review of the most frequently appeared subject matter of anatomy, as many as four studies reported satisfactory results against VR use. For example (Fahmi et al., 2020),with the help of Vive controller devices, leap motion controllers, and learning senso gloves, can be accepted by respondents as valuable tools and become interactive dick tools. Other findings, with the same material that is anatomy with google cardbord device, shows the existence of an approach that proved effective and satisfactory by participants (Bhattacharjee et al., 2018; Kurniawati et al., 2020). The VR learning system in the study (Han et al., 2020)on the anatomical material of the liver also provides a better operational experience and can increase students' learning interest.

Consistent results were also found in DNA material (Makransky et al., 2020; Mariana Iancu, 2018; Sharma et al., 2018)with varying device usage. The feedback of most participants was positive and felt that VR with VE became a helpful tool in DNA material learning(Sharma et al., 2018). The role of VR is considered successful in increasing students' interest and bringing cognitive and affective pluses in aspects of science education, specifically in biology (Makransky et al., 2020; Mariana Iancu, 2018).While three other studies(Hammang et al., 2018)found the perception that some students did not find the relevance of the VR environment to their experiences during the study of biology, specifically in blood cell matter. This is similar to the results(Huang, 2019b)in the use of VR gear devices that show insignificant capabilities with learning activities, after being analyzed physical movements become one of the important factors that determine the constant increase in capability. MeanwhileSilva et al., (2017)most students are satisfied after completing VR-based educational games with VR gear devices in cell material.

Gochman et al. (2019)developed a tarsier VR device to simulate visual sensitivity, sharpness, and colour blindness (red-green) with a positive user experience with a better understanding of natural selection. Using VR in nervous system materials is considered effective in improving the student learning experience, where it is thought that the use of VR makes the learning system easier(Zhang et al., 2020). Biological learning in VR interactive animation is considered significantly worse than the usual transfer of science, and students report an increase in cognitive load experienced and showed less involvement in learning(Parong & Mayer, 2020). This can be explained by the fact that some of these systems are not so easy to use.

Conclusion

VR applications for science education, specifically in biology learning at the top of the school level, will increase rapidly in the coming years. This study shows positive feedback on the development of VR technology that allows creating a comprehensive experience for its users. This is because VR systems make users feel completely immersed in the world as it was. This literature review is important to highlight more research needs in virtual learning environments. In the future, research should focus on testing the design and interaction effects of virtual learning.

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