Review Article

Trends in Use of Virtual Reality (VR) Technology in Science Education: A Systematic Review

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Abstract

The purpose of this review was to systematically identify the general trends in the use of virtual reality technology in science education. For this study, two databases ERIC and Web of science were selected for review of related articles. PICO framework was used as a review protocol. Based on inclusion-exclusion criteria 22 articles were found to be eligible for the present study. The content analysis method was employed to analyze and synthesize the data into findings. Finally, the results regarding the study objectives are graphically presented and discussed. The findings of the present review throw light into the gaps or inconsistencies in the literature as well as provide insight on the overview of the use of virtual reality in science education.

Keywords: Virtual reality in Science, Science Education, Systematic review, Trends in virtual reality

Introduction

Virtual reality is a computer generated three-dimensional learning environment that allows interaction and visualization of the non-observable imagined physical world. According to Christou (2015), it replaces the user's sensory input with a computer-generated 3-dimensional simulation. Burdea and Coifett (2003) define virtual reality as real-time interactive graphics with three-dimensional models mixed with a display technology that allows the user to manipulate the model world directly and immerse him or herself in it. Virtual reality is not a new concept; rather it has existed since the early 19th century in the form of panoramic paintings. These paintings were created to give the illusion of being somewhere we are not, such as a historical event or a scenic location. The popular stereoscopes were based on this idea. Morton Heilig in 1956 invented a sensorama and gave the basic idea of immersiveness experience which is still alive today and used as a key feature of modern virtual reality technology. Since 1962, government agencies, contractors and software and hardware companies have been researching and developing virtual reality technology for research, administrative, and training purposes. Ivan Sutherland, a computer scientist, introduced interactive computer graphics in 1963 with his sketchpad application and in 1965 with his Ultimate Display, which allows users to interact with objects in an artificial environment that defies the laws of physics. From 1990 onwards, virtual reality-based gaming machines appeared along with various types of headsets. Palmer Luckey developed the first prototype of the modern, lightweight Occulus Rift in 2010 for gaming purposes which was thought to be a truly immersive virtual reality headset which was later purchased by Facebook in 2014. In 2014 Google announced their cardboard stereoscopic headset for smartphones, aptly named Google Cardboard and in 2015; Samsung released their Samsung

Gear VR headsets which were compatible only with Samsung smartphones making VR more accessible to a larger population (Yadav & Tomar, 2017).

An immersive experience is a key feature of this technology created by mixing computer graphics, interface devices, and visual screen displays (Pan, et al., 2006). Adding to the immersive experience of VR systems are interactivity and multimodal feedback. Immersion means being fully immersed in the environment. With immersion, you feel physically present in the stated reality. By moving one's body, interactivity allows one to control events in a simulation. This makes the experience more believable and engaging (raising a sense of presence), and reduces ambiguity and uncertainty. There are three basic forms of virtual reality technology: immersive, non-immersive, and semi-immersive (Verma et al., 2021). The user must be surrounded by GPS beacons or haptic devices to fully immerse them in virtual reality. A desktop or PC is required for non-immersive VR. The virtual world is controlled by a mouse, trackball, keyboard, or joystick. Widescreen projection is a typical framework in semi-immersive VR systems. Stereographic imaging is possible with particular shades of glasses and a broader field of view. It is emerging as a new educational tool for kids that have the ability to improve and alter student education (Pantelidis, 1993). As a result of its wide potential, virtual reality is being utilized to teach in fields as diverse as medical and education. Virtual reality is expected to help in many ways. One of its defining advantages is its ability to assist students to learn and visualize abstract scientific concepts (Youngbult, 1998). To participate in laboratory simulations or virtual trips that would be otherwise impractical or dangerous. It can simulate those dangerous science experiments. Using virtual reality in chemistry, for instance, allows users to experience completely immersive, interactive, and three-dimensional chemical procedure simulations (Georgiou et al., 2007). Previous educational research has shown the value of virtual reality technology in the teaching-learning process (Pantelidis, 2009). Virtual reality simulations, for example, have been shown to improve students' understanding of complex scientific concepts and increase their interest in science. Several advantages have been documented in research on the use of virtual reality for educational purposes, which are listed below (Table 1).

Table-1: Advantages of virtual reality in education

Advantages of VR	**Researchers**
Increases Achievement	Maloney (2005), Kim (2006), Parmar (2013), Dhamija and Kumari (2016), Aggarwal (2018)
Improves Retention	Moreno and Mayer (2002), Pérez-López and Contero (2013)
Enhances Interest and Motivation	Mei and Sheng (2011), Bowen (2018), Parong and Mayer (2018)
Develops scientific attitude	Kim (2006), Sarioglu and Girgin (2020)

Table-1 shows the benefits of virtual reality in science teaching. These advantages may allow virtual reality technology to be utilized to teach science. Future studies in education could use virtual reality studies as a paradigm. To explain the existing status and guide future research, a systematic

review is needed. Prior research can assist identify gaps, difficulties, and study design. Several comprehensive reviews have identified patterns in the usage of technology in education (Kucuk et al., 2013; Pardamean & Suparyanto, 2014; Crompton et al., 2016; Soni & Dubey, 2018; Unal, 2019 and Sabiri, 2019). But only a few rigorous reviews of virtual reality in education have been undertaken (Kavanagh et al., 2017; Kurniawan et al., 2019 and Pirker et al., 2020). There is a paucity of research on virtual reality in science teaching (Radianti et al., 2019 and Durukan et al., 2020). As a result, further research is needed to uncover patterns in virtual reality in science. Due to the lack of comprehensive reviews, this study examines all virtual reality studies found in chosen databases (ERIC and Web of sciences).

Review of Literature

Over the years, several learning techniques have been designed and effectively utilised in the classroom. Virtual reality technology, for example, has grown in popularity among educators, students, and researchers. Bernsten et al. conducted a comprehensive literature review to assess the commercial impact of virtual reality technology and the most prevalent subject of study (2016). The findings came from a careful review of several articles that questioned the commercial impact of virtual reality technology. There was a lot of research in the "presentation and entertainment department," which is concerned with the future of daily life being transformed and computerised. Similarly, Kavangh et al. (2017) reviewed virtual reality in education from 2010 to June 2017. Various databases were searched for relevant papers. The researchers studied 99 publications that employed virtual reality to create software. Higher education accounted for 51 per cent of virtual reality software implementations. Research revealed that numerous publications had identified software usability concerns due to poor programme design and hardware usability issues due to lack of training. Cankaya, 2019 looked at 49 studies to see what trends emerged in the use of VR in education. The number of research articles published annually increased from 2014 to 2019. The findings show that quantitative methods were used in over half of the investigations. Pretest posttest and questionnaires were the most regularly utilised data collection tools, with undergraduates and adult students being the most common study participants. Kurniwan et al. reviewed a large amount of material (2019). 32 papers were found and assessed. This research sought to understand the purpose, equipment, and user experience of virtual reality in education. The majority of studies use virtual reality to enhance the user's learning experience by using a head-mounted display rather than a wide screen projector for all four objectives. Luo et al., on the other hand, evaluated scholarly literature on virtual reality in primary and secondary education over 20 years (2021). However, most of the VR treatments reviewed in this study were managed by computers or projectors, with low levels of immersion, engagement, and creativity.

Methodology

This systematic study examines articles published between 2015 and 2020 to determine trends in the usage of virtual reality in science education. The five steps provided by (Uman, 2011) are considered and adopted in this review study.

Defining the Research Questions

The researchers framed the research questions initially. These questions were framed using the PICO framework.

PICO acronym stands for "Participant-Intervention-Context-Outcomes". In this study, a participant is a population found through advanced database searches. This study's intervention is the researcher's preferred technology. Context refers to the study's shortcomings. The outcomes pertain to the review's objectives.

- P – The number of articles obtained after selecting the time frame and type of document.
- I – Virtual reality technology used in science education.
- C – Context is a science subject.
- O – Trends in terms of years of publication, country origin, research methodology used and data collection tools, etc.

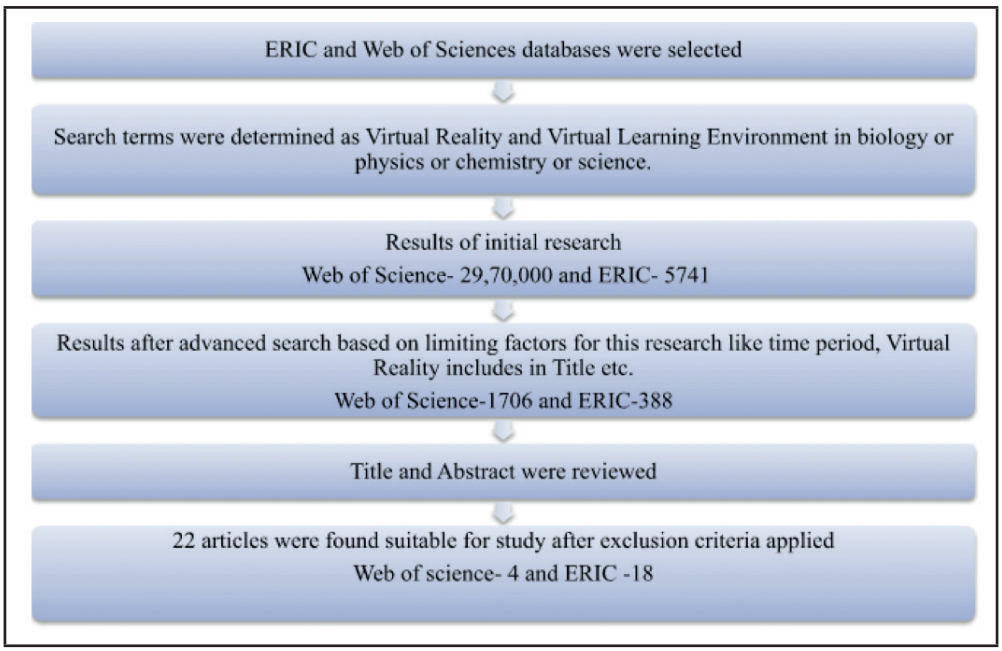
Virtual reality in science education: Where are we now? This study intended to answer these and other related topics.

1. What numbers of studies are published each year?
2. In which countries the studies are most commonly carried out?
3. What research methods are most commonly employed in the studies?
4. What sample group is most commonly preferred in the studies?
5. What data collection tools are most commonly used in the studies?
6. Which science domain is most commonly selected for studies?
7. What variables do the studies most commonly investigate?
8. What type of hardware devices are used in the studies?
9. What findings do the studies report?

Searching the Database

After formulating the research questions, the researcher chose the databases to search for relevant publications. The search was limited to two databases, ERIC and Web of Science, to find relevant studies. The selection of these two databases was based on their availability of relevant and high-quality papers on the study topic. They also make full-text document retrieval simple. Moreover, past reviews of instructional technology use have used only two databases. For example, (Ünal, 2019) uses the Web of Science and ERIC. The topic-related keywords were found using Boolean operators (and, or) for a more precise and advanced search. A virtual reality and virtual learning environment in Biology, Physics, Chemistry, or Science was the keyword. Searches were limited to peer-reviewed full-text documents published since 2015. The researchers chose 2015-2020 because, according to the literature, most studies on virtual reality were published after 2015 (Durukan, Artun & Temur 2020). The steps followed in data collection are illustrated in Figure 1:

Figure-1: Data Collection Process



Selection of Articles

For the third step, the researchers selected the articles which were relevant to answering research questions. In this step, the researchers accept or reject the articles for literature review analysis based on inclusion-exclusion criteria (Table 2).

Table-2: Inclusion-Exclusion criteria

Inclusion	Exclusion
Articles that are peer-reviewed and with access to full-text were included in the study.	Conference papers, editorials, book chapters, reports, or articles with only abstract or summaries were excluded from the study.
Articles in which only Virtual reality technologies were used in science subjects with no other environment were included.	Articles which are using augmented reality or mixed reality along with virtual reality were excluded from the study.

Data Extraction

In this step, the researchers extracted the information from articles according to the research questions of the study. For examining the selected articles in detail the researchers developed an article review form. For the current study, the article review form developed by Unal (2019) was adapted and revised for its appropriateness according to the research questions of the present study. The data collection tool in this study was cross-examined by two experts in the educational field. Based on the expert's suggestions the final data collection tool was prepared which consists of 10 sections: Title of the study included for analysis, year of publication, country origin, sample, research domain,

research method, data collection tool, dependent variables investigated, and findings of the study. Each of the sections of the article review form and their corresponding categories are explained in Table 3:

Table-3: Data Collection Tool

Section	Category
Title of the study	Research Articles selected for analysis
Year of publication	2015-2020
Country origin	As per the authors affiliation and institution in which the study conducted
Sample	Primary school students Elementary school students Middle school students High school students Secondary school students Undergraduate students Teachers
Research domain	Natural Science Biology Physics Chemistry
Research Method	Experimental Survey Qualitative Mixed Research and Development
Data Collection Tools	Questionnaires Interviews Test (Achievement test, descriptive test, knowledge test, conceptual understanding test etc.) Scale (Attitude scale, Opinion scale etc.) Observation
Variable Investigated	Achievement Motivation Interest Other
Devices used	Desktop VR Mobile VR headsets Standalone VR headsets Handheld VR headsets
Findings of the study	Most commonly reported

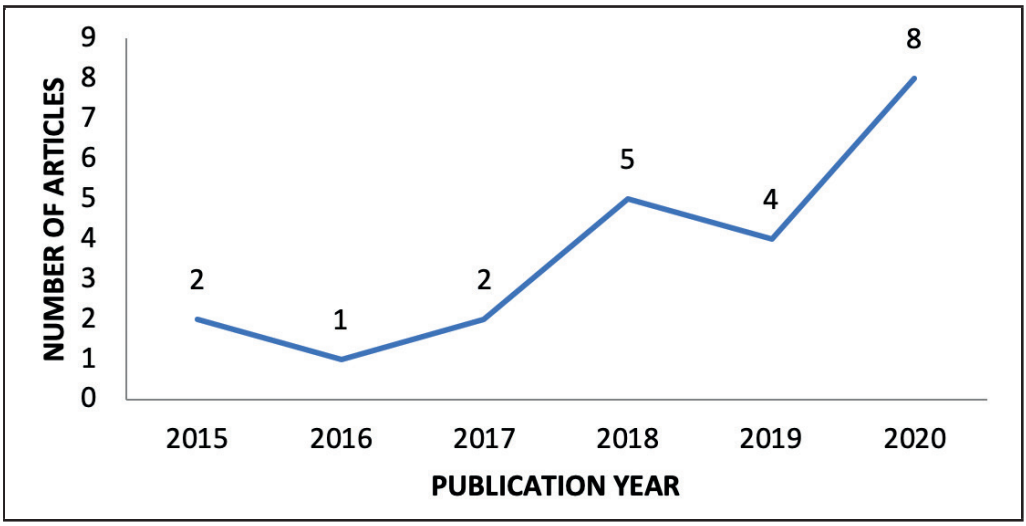
The articles were then categorically analyzed and systematically examined based on the content analysis method for reducing information into more manageable data. Researchers sought two experts' views for the article review process to ensure the reliability of the data assessment. Finally, the result of the data was presented graphically.

Results

What numbers of studies are published each year?

The distribution of research publications published by year is depicted in Figure 2. From 2019 to 2020, there is a significant increase in the number of studies published. Two studies were published in 2015, one research was published in 2016, two studies were published in 2017, five studies were published in 2018, four studies in 2019, and eight studies were published in 2020. Between 2015 and 2020, the researcher discovered inconsistencies, such as an increase and decrease in the number of studies completed and published. Furthermore, more papers were published in 2020, with the least in 2016.

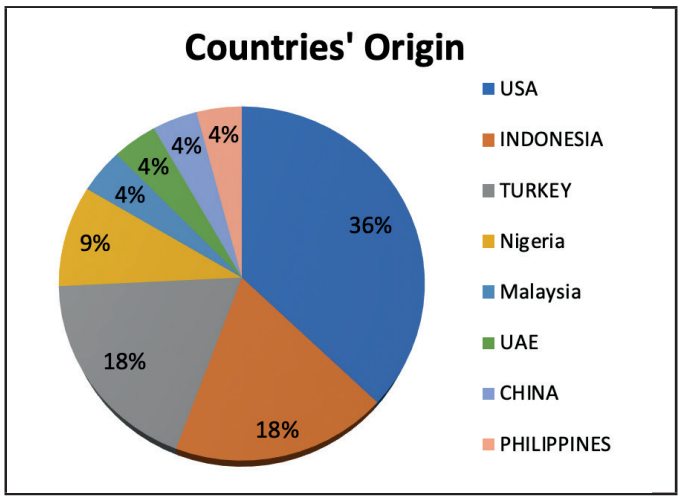
Figure-2: Number of articles by publication year.



In which countries the studies are most commonly carried out?

The distribution of research by country of origin is depicted in Figure (3). The authors' institution at which the study is being done is taken into account when determining the origin of the study in a country. As shown in Figure 3, the USA ranked first with a total of eight studies (36 per cent) conducted, followed by Indonesia and Turkey, which ranked second in terms of number with four studies each (18 per cent) conducted, Nigeria with two studies (9 per cent), and Malaysia, China, the United Arab Emirates, and the Philippines with one study each (4 per cent).

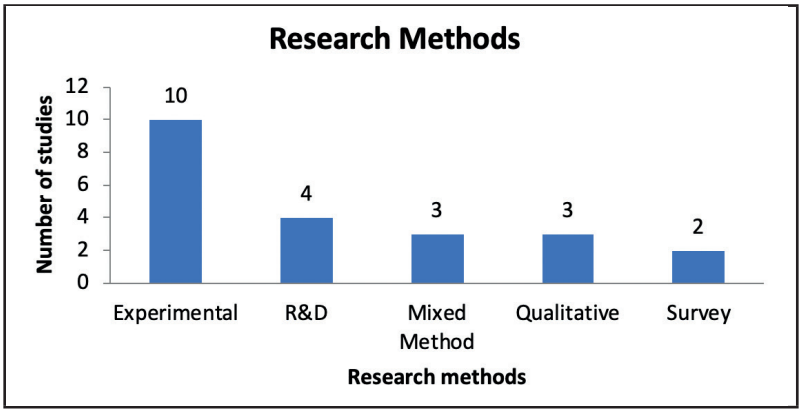
Figure-3: Studies according to their countries' origin



What research methods are most commonly employed in the studies?

According to Figure (4), the most commonly used research methods in studies of virtual reality technology in science were experimental, which accounted for 45 per cent, followed by R&D, which accounted for 18 per cent, mixed-method and qualitative methods, which each accounted for 13 per cent, and survey method, which accounted for only 9 percent. The experimental approach was used in the majority of the investigations.

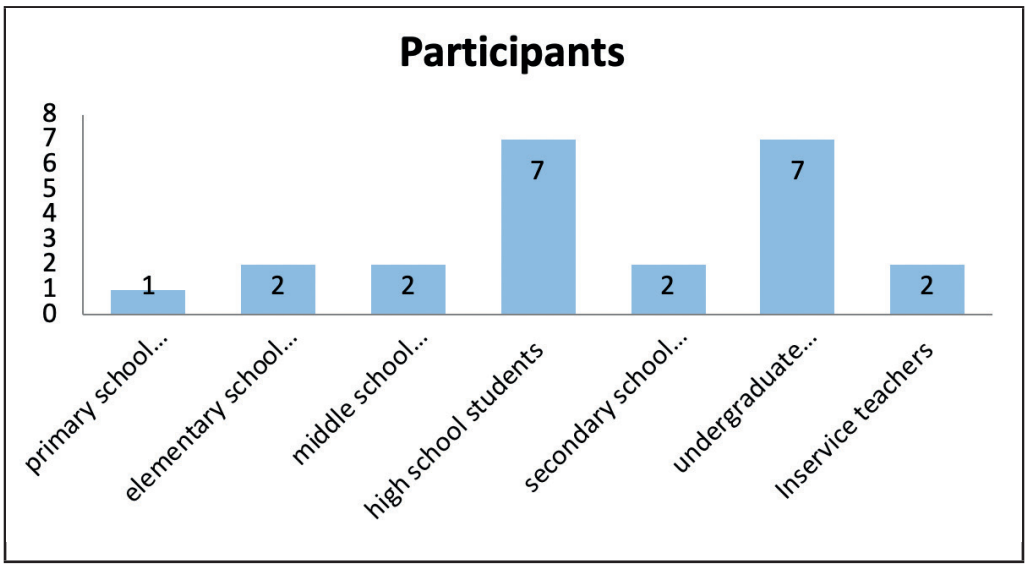
Figure-4: Research Methods used in Virtual Reality studies in Science



What sample groups are most commonly preferred in the studies?

The distribution of virtual reality studies based on sample size is shown in Figure (5). In general, it shows that undergraduate and high school students made up the majority of the study samples, accounting for 31 per cent. Middle school, high school, and elementary school children are each sampled in two studies (for a total of 9 per cent), while primary school students are only included in one study (for a total of 4 per cent). Primary school pupils were the least studied group, while undergraduate and high school students were the most studied.

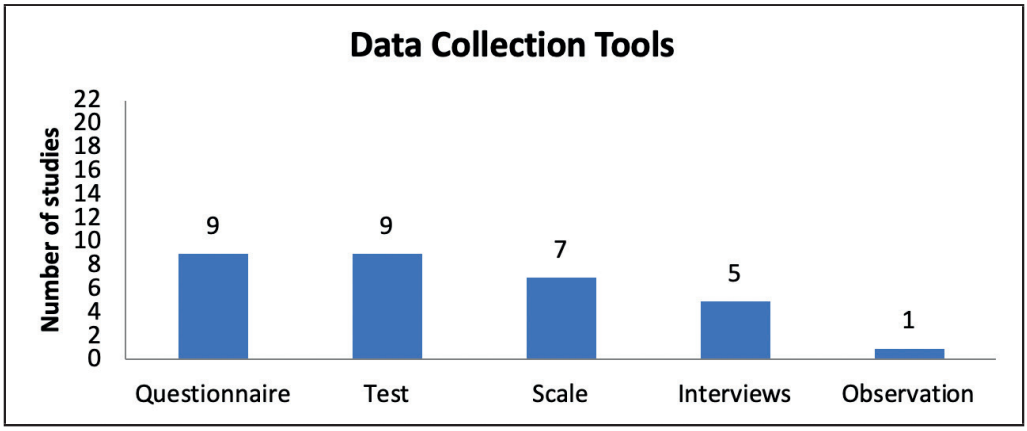
Figure-5: Most preferred Sample group in Virtual Reality Studies



What data collection tools are most commonly used in the studies?

It was found that the most common data collection tools used in virtual reality studies in science were Questionnaires and Tests and the least commonly employed data collection tool was the observation method.

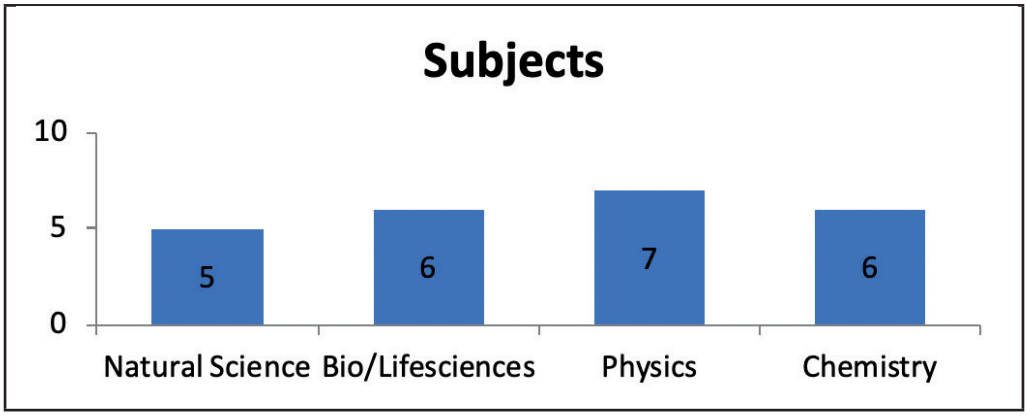
Figure-6: Most preferred Data Collection Tools



Which science domain is most commonly selected for the studies?

Figure (7) depicts the distribution of virtual reality studies across various science streams. It may be determined that physics has the highest number of studies (31 per cent) and followed by chemistry and biology (27 per cent). Natural science has the fewest studies, accounting for only 22 per cent of all studies.

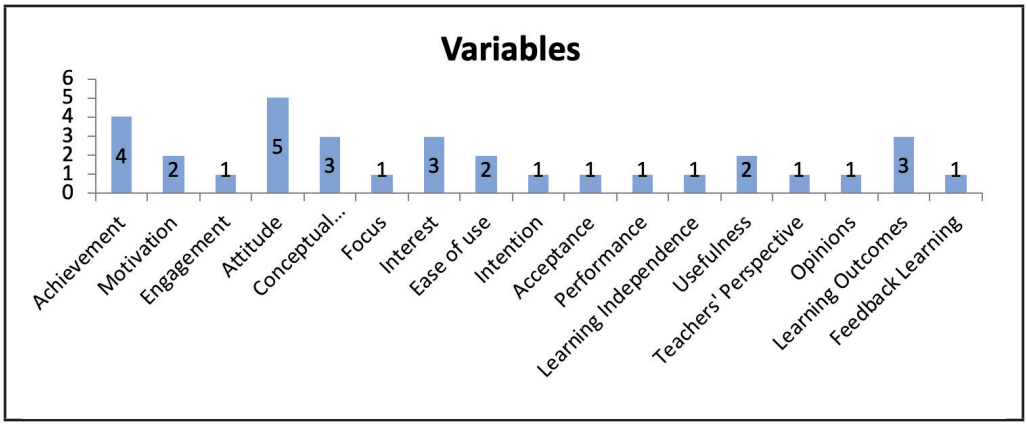
Figure-7: Virtual Reality Studies by different domains of Science



What variables do the studies most commonly investigate?

According to Figure (8), five studies looked into students' attitudes towards virtual reality in science, four looked into achievement, three looked into interest, learning outcomes and conceptual understanding and two looked into engagement, motivation, perceived ease of use, perceived usefulness and one looked into focus, intention, acceptance, performance, learning independence, teachers' perspective, opinion, and feedback. It has been observed that the most investigated variable is an attitude towards virtual reality.

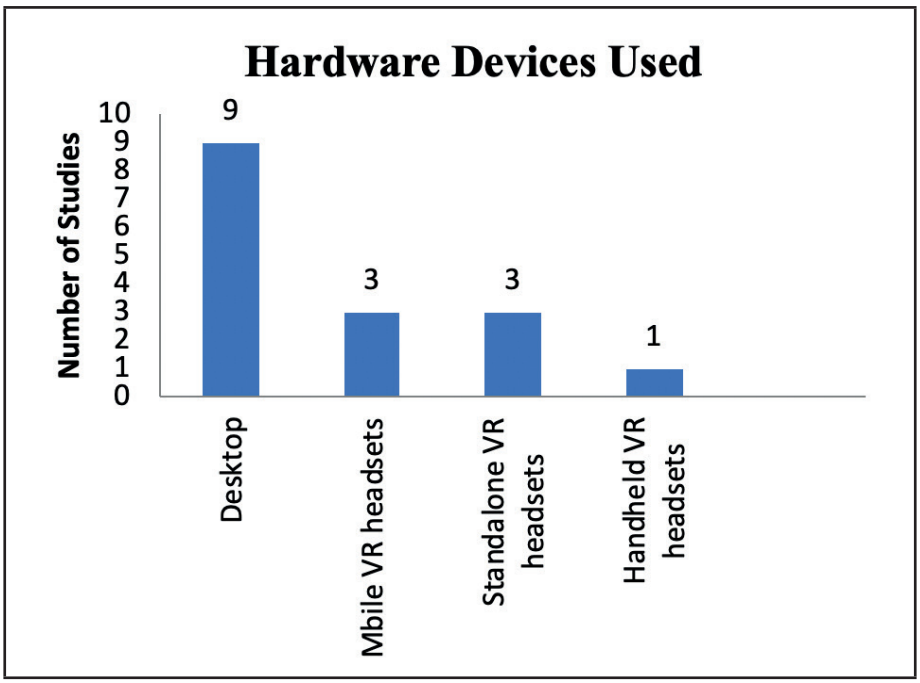
Figure-8: Most commonly investigated variables.



What type of hardware devices are used in the studies?

According to figure (9), it was observed that maximum studies used desktops for experiencing virtual environments i.e. 40 per cent. Mobile VR headsets were used in 3 studies and standalone VR headsets are also employed in 3 studies i.e. each contributes 13 per cent in the studies and only 1 study uses handheld VR headsets like Google Cardboard i.e. 4 per cent. The remaining 27 per cent of studies were found that have not clearly mentioned the kind of hardware devices used.

Figure-9: Hardware devices used in the studies



What findings do the studies report?

The findings of the reviewed articles revealed that the learning content developed by three-dimensional virtual reality technologies is viable and feasible to use in the teaching-learning process (Arista & Kuswanto, 2018; Bakar, Sugiyarto & Ikhsan, 2019 and Suleman, Sugiyarto & Ikhsan, 2019). There are plentiful studies that reported a significantly positive impact of a virtual environment on achievement (Haris & Osman, 2015; Goff, et al., 2017; Gambri, Kawu & Falode, 2018; Alneyadi, 2019 and Sarioglu & Girgin, 2020) and learning outcomes (Saputro & Setyawan, 2020 and Klash & Simmons, 2020). The studies also found that virtual reality allows the passive learner to actively participate (Bakar, Sugiyarto & Ikhsan, 2019) and engage in the learning process (Alneyadi, 2019 and Stone et al., 2020) for better enhancement of conceptual understanding in science (Arista & Kuswanto, 2018; Faour & Ayoubi, 2018 and Gabunilas et al., 2018). Moreover, learning with virtual reality assists in development of scientific skills (Gambri, Kawu & Falode, 2018 and Klash & Simmons, 2020), enhancement of students' autonomous or independent learning ability (Arista & Kuswanto, 2018 and Wang, 2019). The studies conducted on pre-service and in-service science teachers as samples showed their positive attitude (Falode, 2018; Sarioglu & Girgin, 2020 and Mutlu & Acarsesen, 2020) towards the use of virtual reality technologies in the realm of educational settings. Teachers perceive virtual reality as an effective pedagogical tool for teaching science difficult concepts. However, only one study reported no significant difference in attitude towards virtual reality and conventional teaching method groups (Faour & Ayoubi, 2018). This can be attributed to the finding of previous research on virtual reality studies which found that this technology is as effective as the traditional approach (Tatli &Ayas, 2013; Smith, et al., 2016). There are myriad of studies that revealed various other

benefits of contemporary technology like increase in interest (Huynh, Hou & Wang, 2016; Wang, 2019 and Stone et al., 2020), motivation, and knowledge (Saritas, 2015; Alneyadi, 2019 and Stone et al., 2020) among learners and provides encouragement to opt science and engineering for learning and career purposes (Huynh, Hou & Wang, 2016). Despite numerous advantages, one study found that virtual reality has few barriers in the implementation of content in classrooms. These barriers may be related to the poorly designed virtual environment or lack of realism in learning material as promised by this contemporary pedagogical tool (Lamb, Lin & Firestone, 2020). Overall, virtual reality is found to be an effective instructional strategy for teaching science.

Discussion

An overview of important studies using virtual reality technology is provided in this systematic review. This study reviewed research publications published between 2015 to 2020, as this is the peak period for virtual reality studies. Similar results were found in earlier research when the researcher studied the literature. Durukan, Artun, and Temur (2020) observed that the majority of virtual reality studies were published after 2015. The researchers discovered anomalies in the number of studies performed and published between 2015 and 2020. However, this research found a significant increase in virtual reality studies in 2020, with a decrease in 2016 and 2019. Virtual reality has become an increasingly prevalent instructional technique for conveying scientific concepts. Virtual reality is becoming more affordable and accessible with smartphones, tablets, and video games (Gutierrez et al., 2017). The USA and Indonesia have the most research articles on the use of virtual reality technology in science, followed by Turkey. Malaysia, Nigeria, UAE, China, and the Philippines also have few studies. The majority of scientific investigations on virtual reality are undertaken in the USA. Examining the literature revealed comparable findings in earlier educational technology research (Yildiz, Cengel &Alkan, 2020). China, UAE, and Philippines have the least.

Moreover, the results show that experimental research methodology is most usually used in publications released after 2015. A prior evaluation of virtual reality found that the most recommended research approach is experimental (Durukan et al., 2020 and Kalogiannakis et al., 2021). This study also revealed that qualitative research and surveys are the least usually used research approaches. Examining the literature revealed similar findings in earlier studies (Pellas, Mystakidis, & Kazanidis, 2021). The systematic review also found that the most common data-gathering technique employed is the questionnaire, as most studies used experimental approaches. Previous studies have found similar results (Egmir et al., 2017; Kalogiannakis et al., 2021 and Keser & Ozcan, 2011). Also, the target audience is undergraduate students. The literature review identified similar results from numerous educational technology researches, revealing that undergraduate students are the recommended sample (Kucck et al., 2013, Sirakaya & Sirakaya, 2018). These researches support our results that the least targeted participation level is lower grade school kids. The most popular subjects for using virtual reality technology were physics, followed by Chemistry and Biology, which relate to the participants' desired levels. Other characteristics addressed in virtual reality scientific investigations included attitude and achievement. The study undertaken by Pellas, Mystakidis, & Kazanidis, (2021) backed our findings.

Despite the availability of high-end VR devices on the market, the bulk of studies employed desktop VR technology. (Saritas, 2015; Haris & Osman, 2015; Huynh, Hou & Wang, 2016; Hite et al., 2017; Falode, 2018; Gambri, Kawu & Falode, 2018; Mutlu & Acarsesen, 2020; Saputro & Setyawan, 2020 and Klash & Simmons 2020). The researchers believe this is because most VR interventions are utilised for material delivery, requiring minimum involvement, immersion, and imagination. Luo et al., 2021 published a comprehensive review of virtual reality in K-12 and higher education from 2000 to 2019 with similar findings. Finally, the articles evaluated proved virtual reality's instructional potential. This systematic study also indicated that virtual reality can improve students' achievement, knowledge, comprehension, learning outcomes, interest, motivation, and abilities.

Limitations, Suggestions and Conclusion

This research is based on publications gathered from ERIC and Web of Science, two major databases. However, because the chosen databases contain high-quality publications from the relevant study activity, potential deviations are thought to be minor. For future research, it is advised that more datasets be reviewed so that a more comprehensive picture of the area may be formed. This evaluation discovered a dearth of comprehensive reviews on the use of virtual reality in science education, which can serve as a resource for future researchers, educators, and administrators. Because the majority of research has utilized quantitative approaches, it is critical to advise that more qualitative studies on lower grade sample groups are needed to fill the gap in the literature and investigate the educational potential of virtual reality technology in more depth. Furthermore, the concerns, obstacles, and potential solutions that arise when using virtual reality technology in science education settings are not addressed in this study. Future research should also include and explore the concerns, challenges, and potential solutions linked with virtual reality, according to the authors. The findings of this systematic review, which are significant and add to the relevance of this study in guiding emerging research in the relevant subject, are deemed to have addressed potential gaps in the literature.

References

Aggarwal, P. (2018). *Effect of multimedia approach on achievement in biology of IX grade students in relation to their learning styles*. *International Journal of Research in Social Sciences, 8*(3), ISSN: 2249-2496.

Alneyadi, S. S. (2019). *Virtual lab implementation in science literacy: Emirati science teachers' perspectives. Eurasia Journal of Mathematics, Science and Technology Education*, *15*(12). https://doi.org/10.29333/ejmste/109285

Arista, F. S., & Kuswanto, H. (2018). *Virtual physics laboratory application based on the android smartphone to improve learning independence and conceptual understanding. International Journal of Instruction, 11*(1), 1-16. https://doi.org/10.12973/iji.2018.1111a

Bakar, I. S. A., Sugiyarto, K. H., & Ikhsan, J. (2019). *The utilization of virtual reality on development of three dimensional visualisation on chemistry subject. International Journal on New Trends in education and their implications*, *10*(3), 47–54.

Bernsten, K., Palcios, R.C., & Herranz, E. (2016). *Virtual reality and its uses – a systematic literature review. Fourth International Conference on Technological Ecosystems for Enhancing Multicultarity.* DOI:http://dx.doi.org/10.1145/3012430.3012553

Bowen, M. M. (2018). *Effect of virtual reality on motivation and achievement of middle- school students. The university of memphis, ProQuest Dissertation Publishing*.

Burdea, C. G., & Coiffet, P. (2003). Virtual reality technology (2nd ed., p.35). New Jersey: Wiley & Sons.

Çankaya, S. (2019). *Use of VR headsets in education: a systematic review study. Journal of Educational Technology & Online Learning*, 2(1), 74-88.

Christou, C. (2010). *Virtual reality in education. In affective, interactive and cognitive methods for e-learning design: Creating an optimal education experience,* IGI global, Hershey, 228-243. https://doi.org/10.4018/978-1-60566-940-3.ch012.

Crompton, H., Burke, D., Gregory, K.H., & Catharina, G. (2016). *The use of mobile learning in science: A systematic review. Journal of Science Education and Technology, 25*, 149-160.

Dhamija, N., & Kumari, M. (2016). *Effectiveness of computer assisted instruction on the academic achievement in mathematics of secondary school students*. *International Journal of Engineering Science and Computing*, *6*(9), 2127-2131.

Durukan, A., Artun, H., & Temur, A. (2020). *Virtual reality in science education: A descriptive review. Journal of Science Learning, 3*(3).132-142. DOI: 10.17509/jsl.v3i3.21906

Egmir, E., Erdem, C., & Kocyigit, M. (2017). *Trends in educational research: A content analysis of the studies published in international journal of instruction. International journal of instruction, 10*(3), 277-294.

Falode, O. (2018). *Preservice teachers, perceived ease of use, perceived usefulness, attitude and intentions towards virtual laboratory package utilization in teaching and learning of physics. Malaysian online journal of educational technology, 6*(3), 63-72. Doi: 10.17220/mojet.2018.03.005

Faour, M.A. & Ayoubi, Z. (2018). *The effect of using virtual laboratory on grade 10 students' conceptual understanding and their attitudes towards physics*. *Journal of Education in Science, Environment and Health (JESEH)*, 4(1), 54-68. DOI:10.21891/jeseh.387482

Gabunilas, L.M., Adlao, E., Burns, K., Chiu, J.s., & Sanchez, S.S.A. (2018). *Utilizing portable virtual reality in teaching chemistry. Sci.Int. (Lahore), 30*(2), 263-266. ISSN 1013-5316.

Gaddis, T. (1997). *Using virtual reality to bring your instruction to life. Retrieved on 13th march 2021 from*: https://files.eric.ed.gov/fulltext/ED413961.pdf

Gambari, A. I., Kawu, H., & Falode, O. C. (2018). *Impact of virtual laboratory on the achievement of secondary school chemistry students in homogeneous and heterogeneous collaborative environments.* Contemporary *educational*

technology, *9*(3), 246–263. https://doi.org/10.30935/cet.444108

Georgiou, J., Dimitropoulos, K., & Manitsaris, A. (2007). *A virtual reality laboratory for distance education in chemistry. International journal of social Science, 2*(1), 34–41.

Goff, E. E., Reindl, K. M., Johnson, C., McClean, P., Offerdahl, E. G., Schroeder, N. L., & White, A. R. (2017). *Efficacy of a meiosis learning module developed for the virtual cell animation collection. CBE life sciences education, 16*(1).

Gutierrez, J. M., Mora, C. E., Diaz, B . A., & Marrero, A. G. (2017). *Virtual technologies trends in education. EURASIA journal of mathematics science and technology education, 13*(2), 469-486.

Haris, N., & Osman, K. (2015). *The effectiveness of a virtual field trip (VFT) module in learning biology. Turkish online journal of distance education*, *16*(3), 102–117. https://doi.org/10.17718/tojde.13063

Hew, K. F., & Cheung, W. S. (2013). *Use of web 2.0 technologies in k-12 and higher education: The search for evidence-based practice*. *Educational research review, 9*, 47-64.

Huynh, T., Hou, G., & Wang, J. (2016). *Communicating wave energy: An active learning experience for students. American journal of engineering education, 7*(1), 37-46.

Kalogiannakis, M., Papadakis, S., & Zourmpakis, A-L. (2021). *Gamification in science education: A systematic review of the literature. Education sciences, 11*(1), 22. https://doi.org/10.3390/edusci11010022

Kavanagh, S., Luxton-Reilly, A., Wuensche, B. & Plimmer, B. (2017). *A systematic review of virtual reality in education*. *Themes in Science and Technology Education, 10*(2), 85- 119. Retrieved on March 12, 2021 from https://www.learntechlib.org/p/182115/

Keser, H., & Ozcan, D. (2011). *Current trends in educational studies presented in world conferences on educational sciences*. *Procedia Social and Behavioral Sciences, 15*. Doi: 10.1016/j.sbspro.2011.04.403

Kim, P. (2006). *Effects of 3D virtual reality of plate tectonics on fifth grade students' achievement and attitude towards science interactive learning environments*. *14*(1), 25-34.

Klash, E. F., & Simmons, K. D. (2020). *The virtual avatar lab (VAL): Tapping into virtual live environments to practice classroom feedback conversations*. *Journal of curriculum and teaching*, *9*(3), 149. https://doi.org/10.5430/jct.v9n3p149

Kucuk, S., Aydemir, M., Yildirim, G., Arpacik, O., & Goktas, Y. (2013). *Educational technology research trends in Turkey* from 1990 to 2011. *Computers & Education*, *68*, 42–50. http://doi.org/10.1016/j.compedu.2013.04.016

Kurniawan, C., Rosmansyah,Y., & Dabarsyah, B. (2019). *A systematic literature review on virtual reality for learning. IEEE 5th international conference on wireless and telematics,* 1-4. Doi: 10.1109/ICWT47785.2019

Lamb, R., Lin, J., & Firestone, J. B. (2020). *Virtual reality laboratories: A way forward for schools?. Eurasia journal of mathematics, science and technology education, 16*(6).

Luo, H., Li, G., Feng, Q., Yang, Y., & Zuo, M. (2021). *Virtual reality in K-12 and higher education. A systematic review of the literature from 2000-2019. J Compt Assist Learn*, 37, 887-901.

Maloney, R. (2005). *Exploring virtual fetal pig dissection as a learning tool for female high school biology students. Educational Research and Evaluation*, *11*(6), 591-603.

Mei, H. H., & Sheng, L. S. (2011). *Applying situated learning in a virtual reality system to enhance learning motivation. International journal of information and education technology, 1*(4), 298-302.

Moreno, R. & Mayer, R.E. (2002). *Learning science in virtual reality multimedia environments: Role of methods and media. Journal of educational psychology*, *94*(3), 598-610.

Mutlu, A., & Acarsesen, B. (2020). *Comparison of inquiry based instruction in real and virtual laboratory environments: Prospective science teachers' attitudes. International journal of curriculum and instruction, 12*(2), 600-617.

Pan, Z., Cheok, A. D., Yang, H., Zhu, J., & Shi, J. (2006). *Virtual reality and mixed reality for virtual learning environments. Computers & Graphics*, 30, 20-22

Pantelidis, V. S. (1993). *Virtual reality in the classroom. Educational technology, 33*(4), 23–27. http://www.jstor.org/stable/44428033

Pantelidis, V. S. (2009). *Reasons to use virtual reality in education and training courses and a model to determine when to use virtual reality*. *Themes in Science and Technology Education,* 2, 59–70.

Pardamean, B., & Suparyanto, T. (2014). *A systematic approach to improving e-learning implementations in high schools. The turkish online journal of educational technology,13*(3),19-26.

Parmar, G. (2013). *An impact of teaching through virtual reality based multimedia package on achievement in chemistry subject of students of standard-XI. International journal for research in education, 2*(3), 96-102.

Parong, J., & Mayer, R. E. (2018). *Learning science in immersive virtual reality. Journal of educational psychology*. http://dx.doi.org/10.1037/edu0000241

Pellas, N., Mystakidis, S., & Kazanidis, I. (2021). *Immersive virtual reality in k-12 and higher education: A systematic review of the last decade scientific literature*. *Virtual reality*, 25, 835-861.

Perez-Lopez, D. & Contero, M. (2013). *Delivering educational multimedia contents through an augmented reality application: A case study on its impact on knowledge acquisition and retention. The Turkish online Journal of Educational Technology*, *12*(4), 19-28.

Pirker, J., Dengel, A., Holly, M., & Safikhani, S. (2020). *Virtual reality in computer science education: A systematic review. In 26th ACM symposium on virtual*

reality software and technology. Association for computing machinery, New York, USA, Article 8, 1-8. https://doi.org/10.1145/3385956.3418947

Radianti, J., Majchrzak, T. A., Fromm, J. & Wohlgenannt, I. (2019*). A systematic review of immersivevirtual reality applications for higher education: Design elements, lessons learned, and research agenda. Computers & education*, 147.

Rodrigues, H., Almeida, F., Figueiredo, V., & Lopes, S.L. (2019). *Tracking e-learning through published papers: A systematic review. Computer education*, 136, 87–98.

Sabiri, A. K. (2019). *ICT in EFL teaching and learning: A systematic literature review. Contemporary educational technology, 11*(2), 177-195. Doi: 10.30935/cet.665350

Sang, G., Valcke, M., Braak, J. and Tondeur, J., 2010. *Student teachers' thinking processes and ICT integration: Predictors of prospective teaching behaviors with educational technology*, *Computer and Education*, vol. 54, pp.103-112

Saputro, S. D., & Setyawan, A. (2020). *The effectiveness use of virtual reality media in physics education of solar system towards cognitive learning outcomes. JPI, 9(3), 389. https://doi.org/10.23887/jpiundiksha.v9i3.23105*

Sarioglu, S. & Girgin, S. (2020). *The effect of using virtual reality in 6th grade science course the cell topic on students' academic achievements and attitudes towards the course*. *Journal of turkish science education, 17* (1), 109-125.

Saritas, M. T. (2015). *Chemistry teacher candidates' acceptance and opinions about virtual reality technology for molecular geometry. Educational research and reviews, 10*(20), 2745-2757.

Shim, Park & Kim (2003). *Application of virtual reality technology in biology education, Journal of biological education, 37*(2), 71-74.

Sirakaya, M., & Sirakaya, D.A. (2018). *Trends in augmented reality studies: A systematic review. Malaysian online journal of educational technology, 6*(2).

Smith, S.J., Farra, S., Ulrich, D.L., Hodgson, E., Nicely, S., & Matcham, W. (2016). *Learning and retention using virtual reality in a decontamination simulation. Nurs Educ Perspect*, *37*(4), 210-214.

Soni, S., & Dubey, S. (2018). *Towards systematic literature review of e-learning*. *International journal of scientific research in computer science, engineering and information technology, 3*(3).

Stone, H., Li, M., Ritter III, K.A., & Chambers, T.L.(2020). *Virtual reality: Authentic and immersive learning in the science classroom. International Journal for Innovation Education and Research, 8*(8), 101-111. https://doi.org/10.31686/ijier.vol8.iss8.249

Suleman, M., Sugiyarto, K.H., & Ikhsan, J. (2019). *Development of media three-dimensional (3D) visualization using virtual reality on chemistry education*. *Journal of physics: conference series*. doi:10.1088/1742-6596/1397/1/012034

Tatli, Z., & Ayas, A. (2013). *Effect of a virtual chemistry laboratory on students' achievement. Educational technology & society, 16*(1), 159-170.

Uman L. S. (2011). *Systematic reviews and meta-analyses*. *Journal of the Canadian academy of child and adolescent psychiatry, 20*(1), 57–59.

Ünal, E. (2019). *Web 2.0 technologies supporting problem-based learning: A systematic literature review. Journal of problem based learning in higher education*, *7*(1), 25–50. https://doi.org/10.5278/ojs.jpblhe.v7i1.2845

Verma, P., Kumar, R., Tuteja, J., & Gupta, N. (2021). *Syatematic review of virtual reality and its challenges. Proceedings of the Third International Conference on Intelligent Communication Technologies and Virtual Mobile Networks (ICICV 2021).* IEEE Xplore Part Number: CFP21ONG-ART; 978-0-7381-1183-4

Wang, H. (2019). *Application of virtual reality technology in physics experiment teaching. Journal of physics: conference series, 1345*(6), 266-271. Doi 10.1088/1742-6596/1345/6/062013

Yildiz, E. P., Alkan, A., & Cengel, M. (2020). *Current trends in education technologies research worldwide: Meta-analysis of studies between 2015 and 2020. New Trends and Issues Proceedings on Humanities and Social Sciences, 7(1),* 47–62. https://doi.org/10.18844/prosoc.v7i1.4867 (Original work published July 2, 2020)

Yadav, A., & Tomar, S. (2017*). Virtual reality: A technology of illusion. International journal of engineering research and technology, 5(3).*

Youngblut, C. (1998). *Educational uses of virtual reality technology (Technical Report No. IDA Document D-2128). Institute for defense analyses.*