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The Potential of Virtual Reality Technology in Children's Learning Success

RIA ANDRYANI,[1*] RAHMAT GERNOWO[2], AND EDI SURYA NEGARA[3]

Abstract

Learning technology for children often does not have a positive impact on improving children's learning abilities and achievements. So that an appropriate approach is needed for the development of learning technology for children. The article examined the application and implications of the success of virtual reality-based learning for children from the perspective of human-computer interaction. This study used a literature study method from previous scientific publications regarding the potential of virtual reality technology for children's learning success. This literature review was conducted using an exploratory approach. The results of the literature study showed that various studies had been conducted in this domain, the main direction in development is the user-centered design and participatory design approach with the principles of child-computer interaction (CCI).

Keywords
Children, education, learning, virtual reality

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[1*]Doctoral student of information system, Universitas Diponegoro, Semarang, Indonesia and Faculty member at Universitas Bina Darma, Indonesia; Corresponding author: ria.andryani@binadarma.ac.id
[2]Professor at Universitas Diponegoro, Semarang, Indonesia
[3]Professor at Universitas Bina Darma, Indonesia.

Introduction

Currently, new educational technologies continue to emerge and develop, one of which is virtual reality (VR). The use of VR technology in the teaching and learning process is considered to have high potential in achieving student learning success (Kuna, Hašková, & Borza, 2023). This technology contains three-dimensional (3D) visualization so as to increase students' understanding of lesson material obtained through a multisensory environment (Heverton et al., 2016). Multisensory environments are environments that allow the integration of more human senses (Lloyd, 2014), and learning objects that are conveyed through visual experiences that can be combined with teacher explanations about the images displayed (Heverton et al., 2016), (Kaufmann, & Papp, 2006). The use of VR in the teaching and learning process places users in environmental conditions that are similar or even the same as those specified in the learning material (Bias et al., 2014; Barbieri, Bruno, & Muzzupappa, 2018; Romero et al., 2022).

VR technology enables a participatory, collaborative, and exploratory teaching and learning process followed by a pleasant learning atmosphere with good student involvement and attention during the teaching and learning process (Farahmand et al., 2013). The use of VR technology in Ausbrun's research (Ausburn & Ausburn, 2008) on engineering study program students proved that students who were supported by VR technology had a high level of motivation in learning, and they even had a significant tendency to use their free time to study. The same thing was also stated by medical students, VR technology provides a high level of understanding, experience, and training to learn surgery with a method that is faster, safer, and does not require high costs for learning (Stevens et al., 2005; Lee et al., 2015; Pelargos et al., 2017). Based on these references, it shows that VR technology has high potential to be used as a pedagogical tool to improve the student learning process, providing students with an authentic context within the scope of learning with real three-dimensional (3D) visualization (Chen, 2016; Huang et al., 2010; Ibáñez et al., 2011).

The use of VR technology fulfills participatory, collaborative, and exploratory principles in learning. These principles adopted in the development of VR technology enable the creation of more meaningful learning experiences, allowing students to develop control over the content, sequence, and learning strategies to build their knowledge, as well as providing them with authentic, contextual activities (Baker et al., 2019). Fulfillment of the principles of participatory, collaborative, and exploratory learning encourages students to have various ways of learning, thinking, and generating intrinsic motivation (Lee et al., 2010).

In its implementation, most of this VR technology is used by adults. However, several studies have shown the benefits of using VR technology in various disciplines regarding its use in children (Gabyzon et al., 2016; Gershon et al., 2004; Passig et al., 2016). The use of VR technology also continues to grow rapidly in children's daily lives (Chiţu et al., 2023), but in its implementation, the function of this technology is often not directly proportional to the expected implications, namely increasing children's learning abilities. This is because in general children's understanding of technology is still limited (Livingstone & Third, 2017; Long & Magerko, 2020). This means that there is a significant imbalance between the importance of emerging technologies and children's ability to understand these technologies and their consequences for successful learning.

The phenomenon of low levels of learning success in children who use VR technology opens up interesting discussions and research. This has caused many related fields to conduct research related to the positive and negative impacts of this technology, especially the field of psychology. Many studies have been conducted to analyze the impact of using VR technology on student learning achievement (Lee et al., 2015; Newman et al., 2010; Wilson & Soranzo, 2015). The development of VR technology must also pay attention to social aspects with the diversity of social characteristics that exist in each region (Buana, 2023; Phelan et al., 2023).

Therefore, to illustrate the potential of VR technology as a learning tool, this paper will focus on literature studies that provide explanations of the use and application of VR technology in children, especially the ideas behind the potential of VR technology being used as a learning tool in children. children, current use and research on VR technology for learning and envisioning learning success, and the obstacles and limitations of its application in the school environment.

Methodology

This study uses a literature review approach to explain the potential use of VR technology in the successful learning of children in elementary schools. A literature review is an important stage in research activities, where this stage will become a strong basis for knowing the state of the art in the development of technology and information systems (Negara et al, 2021). This study provides a strong conceptual and theoretical basis for understanding the state of the art regarding the potential of VR technology in the learning process and learning success of children in elementary schools. To explore it completely, researchers in this literature review were divided into four stages. The first stage reviews the research objectives and protocol. The second stage is a literature search by filtering using specified keywords. The third stage assesses the quality of the article and carries out data extraction. The fourth stage is to analyze the findings.

Planning phase

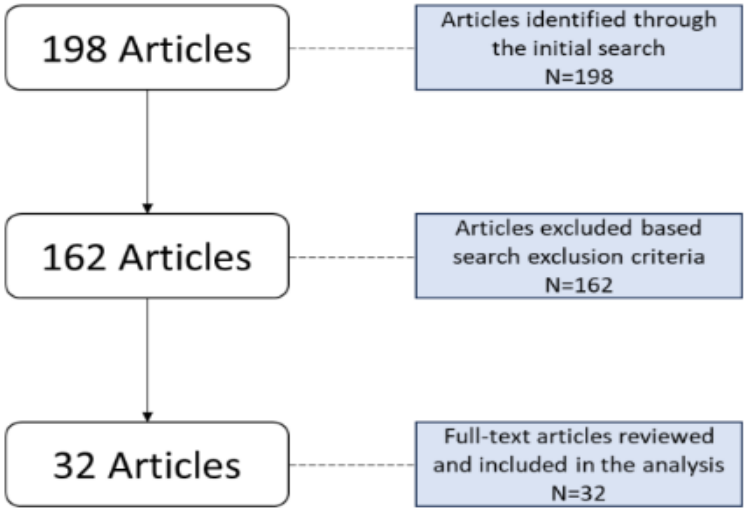
In this first stage, a review of the research objectives and protocol was carried out. The aims and protocol of this study contain important elements that must be carried out in a literature review (Plakkal, 2023). A clear review protocol can reduce bias in the research plan. At this stage, the purpose of the literature review, protocol design, literature criteria, data extraction methods, data analysis, and presentation of the review results are discussed.

Selection phase

In this second stage, scientific articles used in the study are selected. The scientific articles used are articles sourced from the Scopus and Google Scholar databases for 2018-2023. The scientific articles taken as review material are articles that are similar and close to the topic of study, namely: virtual reality technology and the learning success of children in elementary schools. The article search carried out included articles that had been published in international journals, conference papers, and white papers. In searching for articles that have similarities and closeness to the topic, keywords with Boolean operators are used as follows:

virtual reality + children education, virtual reality + children + model + learning, virtual reality + children + acceptance + technology, virtual reality + children + emerging + possibilities + challenges. These keyword pairs are used independently in each search. After obtaining article results that match the keywords, a filtering process is carried out to ensure that the articles obtained are suitable. The filtering process is carried out by eliminating articles that are not relevant to the topic. This filtering process also eliminates duplicate articles and articles for which the full text cannot be obtained. The article selection process is shown in Figure 1.

Figure 1. *Article selection*



Exclusion and inclusion criteria

In this third stage, articles are selected based on exclusion criteria. This stage eliminates articles that do not have suitability and relevance to the research topic. Then, at this stage, articles were also eliminated that did not comply with the specified publication year, namely 2018-2023, and articles that were incomplete with full text. The next step is to select article criteria with inclusion criteria, namely: quality journals, conference papers, and white paper articles.

Synthesis

In the fourth stage, which is the final stage of this literature study, data and information are extracted from articles that have been determined to be used as material for study, analysis, and identification of the potential of virtual reality technology on the learning success of children in elementary schools. At this stage, extraction is carried out using qualitative techniques and continues with the data analysis stage and reporting it in the literature review report.

Results and Discussion

Child–computer interaction (CCI)

Child–Computer Interaction (CCI) is a field of study concerned with children's interactions with computer technology, including hardware and software (Netta et al., 2023). CCI aims to understand and improve the design of computing interfaces, applications, and experiences to be appropriate and beneficial for children. Children have unique needs, characteristics, and capabilities that need to be considered in the development of technology to provide educational, safe, and enjoyable experiences. Research in CCI covers a wide range of aspects, including child-friendly interface design, educational game development, analysis of children's interaction patterns with digital devices, and evaluation of the impact of technology on children's cognitive and social development (Netta et al., 2023).

The main concepts in CCI involve understanding the characteristics of children, their user needs, and the psychological and developmental aspects that influence their interactions with computers. One key concept is child-oriented design. The design of interfaces, software, and hardware must take into account children's intelligence, motor skills, and understanding of the world. This design often adopts participatory principles, involving children in the development process to ensure that the resulting product truly suits their needs and preferences (Kristin et al., 2022).

Children's involvement in the design process is one of the core concepts of CCI. Children's participation in designing the technology they use can increase their sense of ownership and involvement in the use of that technology. This concept views children as active co-designers, rather than passive users. Children's participation can include creative activities such as prototyping, providing feedback, and even being involved in design decision-making. Some participatory methods, such as co-design or participatory design, are often used to include children's voices in the design process (Kristin et al., 2022). Another concept that involves children's participation is universal learning design, which emphasizes flexibility and adaptability in devices and applications so that they can accommodate the diverse needs of children in ways that are most supportive for them (Kristin et al., 2022).

In addition, another important concept in CCI is the context of technology use. See Figure 2.3 which shows a visualization of the method and technique map in CCI. In designing technology for children, it is necessary to consider where, when, and how the technology is used. For example, in a school or home environment, during formal learning time, or in a play context. The availability and accessibility of technology are also important considerations, given the differences in technology access and infrastructure across geographic locations. Overall, these concepts underscore the importance of integrating children's perspectives in technology development, while considering the context of use and other aspects that may influence children's experiences with computer technology (Kristin et al., 2022).

The main dimensions of the methods and techniques used in CCI are divided into two, namely the level of user involvement (children) and design focus. User involvement can be measured from bottom to top with low involvement levels to high involvement levels. While

the design focus is measured from left (User-Centred Design) to right (Participatory Design). There are also additional aspects such as Learner-centred Design and Co-Design with children.

Technology for learning

The development of research on Virtual Reality (VR)-based learning technology models reflects ongoing efforts to understand the potential and challenges of utilizing VR in educational contexts. These models are designed to design, implement, and evaluate learning experiences that focus on the use of VR technology. One of the main directions in this development is the user-centred design approach that incorporates the principles of child-computer interaction (CCI). By detailing children's needs in the design process, this model ensures that VR learning experiences truly meet children's developmental characteristics and learning preferences (Jalal, Abolghasem, & Soo-Mi, 2021).

These models also increasingly pay attention to the concept of learning in the form of a virtual environment that is collaborative and interactive. This approach creates a more contextual and real-world learning experience. In addition, new models incorporate the concept of adaptive learning in VR, where content and difficulty levels are adjusted to each student's level of understanding and progress. VR-based learning technology can monitor student activity and responses in real-time, provide immediate feedback, and adjust the learning journey to maximize its effectiveness (Jalal, Abolghasem, & Soo-Mi, 2021). This research development also highlights ethical and security issues. With the increasing use of VR in learning, it is important to consider data security, student privacy rights, and the psychological impact of using this technology. Development models must take into account a solid ethical framework to address privacy concerns and maintain the security of student data. This is also relevant to the development of VR learning models that are accessible to different socio-economic levels and educational environments, to ensure inclusivity and accessibility.

Overall, the development of research on VR-based learning technology models reflects an effort to combine innovative elements such as user-based design, project-based learning, adaptive learning, and ethical aspects in a holistic model by continuously updating and detailing the virtual reality (VR) technology model based on child-computer interaction (CCI) in education towards a more inclusive, adaptive, and pedagogical future. The development of this research can be seen in Table 1 Development of Research on Virtual Reality-Based Learning Technology Models.

Table 1. *Development of research on virtual reality-based learning technology models*

No	Years	Titles	Authors	Methods	Results	Strengths	Weakness
1	2023	Systematic literature review on critical success factors in implementing augmented reality for science learning environment (2006–2021) (Gopalan et al., 2023).	Valarmathie Gopalan; Juliana Aida Abu Bakar; Abdul Nasir Zulkifli	Systematic Literature Review Method	This analysis reveals several critical success factors for AR in science learning environments such as rich learning experiences, effective learning outcomes, and viable inherent characteristics.	This study has determined critical success factors that provide guidelines or measurements for educational stakeholders, academics, and AR developers in implementing AR in science learning environments.	Source references are limited to only six databases: IEEE Xplore, Elsevier, ACM Digital Library, SpringerLink e-journal, Taylor & Francis, and Wiley Online Library. The fundamental limitations of any systematic review are

							bias in the selection of studies and possible imprecision in the extraction of data from various sources.
2	2020	Challenges and prospects of virtual reality and augmented reality utilization among primary school teachers: a developing country perspective (Alalwan et al., 2020).	Nasser Alalwan; Lim Cheng; Samer Muthana Sarsam	Interviews with 29 Science Teachers & using thematic content analysis to sort and capture categories or themes that emerged from the interviews.	It was determined that lack of competency, limited instructional design, lack of focused attention, lack of time, and limited environmental resources were common challenges in the utilization of VR and AR. Additionally, we found that both technologies can be used to encourage exploration behavior and perceived benefits and develop positive attitudes.	The results of this research can provide insights for administrators and policy makers to set priorities for the use of VR and AR in school practices to carry out various reflective and exploratory tasks.	First, this research only examines the challenges and prospects of using VR and AR from the perspective of science teachers. This research is also limited to teachers from certain schools.
3	2019	Adoption of augmented reality technology by university students (Cabero-Almenara et al., 2019)	Julio Cabero Almenara; José María Fernández Batanero; Julio Barroso Osuna	Multiple choice tests for analyzing student performance after interaction, Technology Acceptance Model (TAM) diagnostic instruments, and "ad hoc" instruments created by Davis (1989)	Not only the production of AR objects is required, but also the creation of guides indicating how they should be utilized, guidelines for their use, etc. No significant relationship was found between students' assessment of the objects and their academic performance, or demonstrated level of technology acceptance.	This study allows us to expand scientific knowledge about TAM by Davis, to understand that AR objects can be utilized in university teaching, and to find out that student gender does not affect learning.	This research was only carried out in certain fields. It needs to be expanded to other fields of science.
4	2019	A critical outlook at augmented reality and its adoption in education (De Lima et al., 2022).	Carlos Baptista De Lima; Sean Walton; Tom Owen	The review Methodology is based on the PRISMA strategy	AR research in education has largely focused on the student-centered aspect which is understood to be one of the least important factors for adoption.	A total of 169 papers were identified for use in this study and this group of papers was evaluated using content analysis.	This research does not see AR being widely adopted as an educational technology.
5	2021	Integrating TTF and UTAUT2 theories to investigate the adoption of augmented reality technology in education: Perspective from a developing country (Faqih & Jaradat, 2021).	Khaled M. S. Faqih; Mohammed-Issa Riad Mousa Jaradat	Integration of Task-Technology Fit (TTF) and UTUAT2	The positive influence of task technology suitability, performance expectancy, effort expectancy, social influence, facilitating conditions, and hedonic motivation on behavioural intention (BI) in the process of augmented reality adoption in an educational environment, where price value was found to be influential. little influence on behavioural intentions.	This model explains 49% of the variation in intentional behaviour for adopting AR technology in educational contexts.	First, the current analysis has considered behavioural intention to adopt AR technology as an outcome construct. However, not incorporating actual behavior as an endogenous construct may provide interesting conclusions.

6	2022	Exploring the factors influencing the adoption and usage of Augmented Reality and Virtual Reality applications in tourism education within the context of COVID-19 pandemic (Shen et al., 2022).	Shiwei Shen; Kexin Xu; Yuejiao Wang;	Technology Acceptance Model (TAM)	The findings show that perceived usefulness, hedonic motivation, and price value are important predictive factors for the adoption and use of these apps by Chinese students. This research shows that the main issue is to approach and consider these digital applications in an adequate way and manage their implementation well. To achieve this strategic goal, universities and educational practitioners must gain an in-depth understanding of student perceptions.	These findings contribute to the expansion of TAM theory and the effective application of digital technologies in university settings.	The context of the Empirical investigation is the first limitation. China has several specialties and privileges. Future research efforts should investigate research models in other countries / continents. Another limitation is the research approach chosen. It is believed that the real impact of digital technology tools/applications in education is better understood with an experimental research approach that will help determine the level and nature of the impact of their adoption and use in learning.
7	2023	Design and evaluation of an augmented reality cyberphysical game for the development of empathic abilities (López-Faican, & Jaen, 2023).	Lissette López; Faican Javier Jaen	Using scenario design that produces affective, cognitive, reflective and social experiences that support the expression of prosocial behaviour. To verify the effectiveness of our Empathy AR game, the evaluation was applied to the experimental group vs the experimental group. control.	The game was rated positively by players on the levels of usability (utility, ease of use and learning and satisfaction) and game experience (positive affect, competence and immersion). Compared with the control group who used traditional strategies, Empathy AR had a positive impact as a learning strategy on 2 dimensions of the Interpersonal Reactivity Index (IRI) for empathy, namely fantasy and empathic concern. For the remaining two IRI dimensions (perspective taking and personal stress) although they did not provide statistically significant differences, the results show that Empathy AR improves the scores obtained on these dimensions. At the end of the experimental study, the players showed higher levels of prosocial behaviour than those who did not play the game.	The main emphasis of this research is designing scenarios that produce affective, cognitive, reflective and social experiences to improve empathy skills such as prosocial behaviour at school	Experimental design, limiting tasks in each session, without the option to choose, and duplicating their execution within sessions can affect the challenge and flow, because in the last session the players know how the tasks work, which does not provide any results. new and more challenging scenarios. The statistically significant validity of some scales in the IRI and PBQ questionnaires in the school context may be limited by the small number of participants.
8	2023	Utilizing virtual reality to assist social competence education and social	Xining Wang; Gareth W. Young; Adela	Using three representativ e pedagogies	VR and Lego social competence education promoted children's social	Research was specifically conducted that investigated	This study focuses only on educational disparities and children

		support for children from under-represented backgrounds (Wang et al., 2023)	Plechata; Conor Mc Guckin; Guido Makransky	(Technology Pedagogy, Play-Based Learning, and Traditional Pedagogy), by designing three approaches to social competency education – virtual reality (VR) assisted social competency education, Lego social competency education, and traditional classroom learning	competence and perceived social support in elementary school children (Study 1). Additionally, VR social competence education resulted in significantly greater social competence and subjective sense of social support than traditional classroom learning with middle school children (Study 2). The results show that VR-assisted social competency education (Technology Pedagogy) can be a potential tool for reducing educational disparities in underdeveloped countries and regions.	whether VR and Lego social competence education could improve rural children's social competence and perceived social support.	from underrepresented backgrounds. This study used limited VR equipment.
9	2023	Using a mobile Virtual Reality and computer game to improve visuospatial self-efficacy in middle school students (Kuznetcova et al., 2023).	Irina Kuznetcova; Michael Glassman; Shantanu Tilak; Ziye Wen; Marvin Evans; Logan Pelfrey; Tzu-Jung Lin	Experiment with predefined scenarios	Results indicated that the intervention significantly increased students' VS self-efficacy but did not improve their VS performance or STEM performance.	The [name withheld for peer review] intervention game was created by a research team using principles of self-efficacy theory and visuospatial research findings. After the two-week intervention, participants' visuospatial self-efficacy increased significantly but visuospatial and STEM performance did not.	Testing is only carried out in certain fields, namely visuospatial and STEM. Needs to be expanded to other fields.
10	2022	Effects of virtual reality on learning outcomes in K-6 education: A meta-analysis (Villena-Taranilla et al., 2022).	Rafael Villena Taranilla; Sergio Tirado Olivares; José Antonio González Calero	Meta Analisis / SLR	In 2021, 21 experimental studies were finally included in the meta-analysis. The results showed that, on average, VR promoted students' learning better compared to the control condition (ES =0.64). Moreover, this effect was even greater when immersive VR (ES = 1.11) was used compared to semi-immersive (ES = 0.19) and non-immersive (ES = 0.32) systems. This effect was independent of educational level (kindergarten (ES = 0.59), 1–3 (ES = 0.69), 4–6 (ES = 0.70)), and most knowledge domains in which	This study focused on K-6 students and analysed the influence of several variables: level of experience, length of intervention, and domain knowledge.	Reference sources for this research are limited to references from the Scopus database.

					VR is used. In addition, short-term interventions – less than 2 hours – (ES = 0.72) were more effective than those lasting longer (ES = 0.49).		
11	2022	The potential of immersive virtual reality to enhance learning: A meta-analysis (Coban et al., 2022).	Murat Coban; Yusuf Islam Bolat; Idris Goksu	Meta Analysis / SLR	This meta-analysis investigates the magnitude of the overall impact by combining the results of primary experimental studies that reveal the influence of I-VR on learning outcomes. In addition, effect sizes were calculated based on measurement moment, measurement type, educational level, educational field, educational resources of the control group, and immersion type subgroup.	As a result of the meta-analysis, it was determined that the overall effect size on I-VR learning outcomes was small (g = 0.38). Additionally, based on the results of subgroup analysis, it was revealed that I-VR significantly differentiated effect sizes based on educational level, educational field, and computer-based/traditional sources.	In this research, there was no inspection and adjustment of computer hardware and software to run the I-VR system so that it met the recommended requirements.
12	2023	Creation of Virtual Reality for Education Purposes (Kuna, Hašková, & Borza, 2023).	Peter Kuna, Alena Hašková, L'uboš Borza	SWOT	Analysing the suitability and usability of various VR systems and camera systems to create VR software products designed for vocational schools.	VR provides a more immersive and engaging learning experience, the potential for virtual visits to replace or complement face-to-face visits, and the development of students' skills for analysing problems and researching new concepts.	The high cost of some systems, the technical requirements for using the systems, and the need for teachers to effectively integrate virtual reality into their teaching practices.
13	2022	Hoope project: user-centered design process applied in the implementation of augmented reality for children with ASD (Romero Pazmiño et al., 2022)	Romero, Harari, Diaz, & Macas	User Cantered Design Proving the concept through prototype implementation	Analysis, design and implementation of software that uses augmented reality in a playful environment with the aim of strengthening educational aspects of children diagnosed with ASD	In this investigative work, a study of techniques related to the user-cantered design of DCUs in children with ASD has been carried out, a little studied space due to the complexity of planning for the implementation of usability tests, in addition to exploring usability and accessibility. in software products.	

Conclusion

Virtual reality technology allows for a participatory, collaborative and exploratory teaching and learning process followed by a pleasant learning atmosphere with good student involvement and attention during the teaching and learning process. As an exploratory study, this literature study shows studies conducted by various researches in this domain, including

the determinants of success in implementing VR, factors influencing the adoption and use of VR, and the design of VR technology for learning based on human-computer interaction.

Declaration of Conflicting Interests

The authors declared no potential conflicts of interest.

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Biographical Notes

RIA ANDRYANI is a doctoral student of information system, Universitas Diponegoro, Semarang, Indonesia and faculty member at Universitas Bina Darma, Indonesia; Corresponding author: ria.andryani@binadarma.ac.id.

RAHMAT GERNOWO is a Professor at Universitas Diponegoro, Semarang, Indonesia.

EDI SURYA NEGARA is a Professor at Universitas Bina Darma, Indonesia.