Online-Journals.org

iJIM International Journal of Interactive Mobile Technologies

iJIM | eISSN: 1865-7923 | Vol. 19 No. 16 (2025) | OPEN ACCESS

https://doi.org/10.3991/ijim.v19i16.54901

PAPER

Immersive and Interactive Learning: A Systematic Review of Virtual Reality in Primary Education

Cheng Lin,
Riyan Hidayat (✉),
Jazihan Mahat

Department of Science Technical Education, Universiti Putra Malaysia, Selangor, Malaysia

riyan@upm.edu.my

ABSTRACT

Virtual reality (VR) stands for the creation of a simulated environment. Over the last five years, VR, particularly mobile VR technology, has been applied in various educational settings. However, most research has focused on secondary and higher education, while few systematic analyses have focused on the use of VR in primary education. This study systematically reviews VR applications in primary education to address existing research gaps. Using a systematic review approach, we identified and screened studies, assessed their eligibility and inclusion, and used two key academic resources to analyze the data: Web of Science and Scopus. The final number of articles has reached thirty-nine. The results of these databases indicate that VR, particularly mobile VR technology, has a positive impact on learning engagement and teaching effectiveness in primary schools. Nevertheless, further research is needed to explore optimal strategies for integrating VR as an interactive tool in a wider range of educational environments in primary schools and to provide primary school teachers with effective strategies and suggestions for addressing current challenges.

KEYWORDS

immersive learning, interactive learning, primary education, systematic review, virtual reality (VR)

1 INTRODUCTION

Virtual reality (VR) is a form of computer technology that deals with the simulated environment of a virtual world [1]. The development of digital technology, including VR, has transformed teaching methods, providing students with immersive experiences that enable them to travel through past environments and gain a deeper understanding of complex concepts [2]. Many studies have begun to utilize mobile devices, including wireless sensors, tablets, head-mounted displays, and motion sensors, to access VR tools, confirming the feasibility and effectiveness of integrating mobile devices with VR [3], [8]. VR, as a new technology, can also truly restore the real world and attract students to experience it firsthand [9].

Lin, C., Hidayat, R., Mahat, J. (2025). Immersive and Interactive Learning: A Systematic Review of Virtual Reality in Primary Education. *International Journal of Interactive Mobile Technologies (iJIM)*, 19(16), pp. 163–188. https://doi.org/10.3991/ijim.v19i16.54901

Article submitted 2025-03-15. Revision uploaded 2025-05-25. Final acceptance 2025-06-05.

It is precisely because of the high reduction and powerful interactive function of VR that traditional learning methods are unmatched; therefore, VR brings more attraction, and students' participation improves [9]. Currently, new teaching strategies, teaching methods, and learning styles have emerged that lead students to an immersive experience of 3D and other virtual environments [10]. At the same time, VR is considered a powerful tool for learning due to its development. Thus, it can be used in elementary schools to promote students' enthusiasm for participation and increase their engagement and interest in learning through the unique visual impressions [11]. Visual appeal is very important for elementary school students. Therefore, the use of multisensory stimulation can enhance students' memory and understanding while also stimulating their thinking. The emergence of VR has become a valuable and novel learning tool for primary school students [12], [13]. To summarize, the increasing practice has also demonstrated that VR offers interesting and attractive thematic content, serves as a complex simplification, and can be better integrated into the real world [14]. In primary education, VR has changed students' enthusiasm for learning and learning methods, making it a new topic that warrants in-depth discussion [15].

Unfortunately, the promotion of VR is delayed in some countries or regions due to the lack of essential facilities and equipment, as well as the difficulty of introducing it in schools [11]. Moreover, in primary school practice, concerns often arise about whether the virtual environment created by the program in VR devices distracts students' attention and is not conducive to learning [16], [17]. Despite the obstacles and concerns, people have recognized the enormous educational potential that VR brings. VR enables future educators to immerse themselves in immersive learning experiences, make informed decisions, and explore virtual learning environments [18]. There is no doubt that VR technology plays a constructive role in increasing student enthusiasm and engagement in learning, enhancing student skills, and encouraging innovation and critical thinking [1]. Starting with the visualization of virtual technologies and how to increase student engagement, researchers can focus on how VR technology can be integrated into the primary classroom [19]. Current research is not yet prolific in terms of the effectiveness and depth of VR's impact on student engagement [20]. Furthermore, these potentially useful VRs are not yet widely utilized in various settings [21]. With its two major advantages of interactivity and immersion, VR will continue to prove its benefits in enhancing student enthusiasm, engagement, and achievement through thorough research. Therefore, VR should be widely used in further studies [22], [24].

In some developed countries, VR is widely used in secondary and tertiary education, drawing considerable attention. However, in developing countries and regions, the development is slow for various reasons. In primary education, several studies have utilized head-mounted VR technology [25], [26], which can enhance student engagement. In addition, many countries, including the United States, Singapore, and Thailand, have begun to explore the use of VR technology to train students' creativity and critical thinking, as well as to comprehensively develop their ability to collaborate and communicate, learn how to solve problems, and more [27].

In primary school, it is important to maintain students' attention, motivation to learn, and commitment. As the learning process changes, incorporating technology into the learning process is a possibility that needs to be explored [24]. Existing studies have focused on secondary and tertiary education students, leaving a significant gap regarding the application of VR for primary school students. To address this gap, this systematic review focuses specifically on VR applications in primary school settings. This review aims to analyze the current research on the use of VR in primary schools. This study addresses two key questions:

1. What types of VR are currently utilized in primary education?
2. How does VR impact the learning outcomes of primary school pupils?

2 THEORETICAL FRAMEWORK

Our systematic literature review (SLR) reveals that constructivism and cognitive load theory are among the most suitable theoretical frameworks for utilizing mobile VR in primary education. Constructivism is a theory that focuses on experiential, hands-on learning, in which students actively engage with the world around them to construct knowledge rather than passively receiving information [28]. Mobile VR is very much in this tradition. It provides immersive, interactive experiences that allow young learners to explore difficult or abstract ideas through rich, contextualized simulations. Movements such as manipulating objects in a virtual environment or navigating through a simulated 3D space encourage students to play, make decisions, and think—processes related to broader understanding and learning in a wider context. Just as cognitive load theory focuses on working memory by reducing extraneous cognitive load and supporting actual processing, mobile VR achieves this by providing information in spatial and dynamic formats and combining visual, auditory, and kinesthetic modalities to enhance access to abstract material [29]. For example, when students interact with virtual geometric figures or observe animated mathematical procedures in real time, they are relieved of the task of converting symbolic representations into mental images, thereby promoting schema construction and improving comprehension. In mobile VR geometry learning, students can visually view geometric objects within a simulated environment that incorporates visual, auditory, and tactile elements, thereby reducing their cognitive load for abstract thinking. This experiential learning approach reduces brain overload caused by excessive abstract thinking in traditional learning strategies, allowing students to focus more on a deeper understanding and application. It does not require students to imagine the change in their minds, so it is consistent with cognitive load theory [29], [38]. Similarly, in English VR simulations, students rehearse authentic dialogues within a virtual marketplace context. This process of experiential learning is typical of constructivist theory, as students actively construct knowledge by exploring rich, meaningful contexts [6], [8], [39].

3 LITERATURE REVIEW

3.1 Virtual reality

Virtual reality is a form of computer technology that deals with the environment in a simulated, virtual world [1]. VR mirrors the real situation or object and retains its physical characteristics [30]. In current research on VR technology in primary schools, VR is primarily categorized into three types: non-immersive VR, semi-immersive VR, and fully immersive VR, which can be used as an intervention for teaching and presented through various tools, including computer screens or mobile devices. VR rooms equipped with head-mounted displays are a key component of semi-immersive VR technology [31]. The possible use of semi-immersive VR in education is currently being researched [32], [33]. Semi-immersive VR and fully immersive VR often require more expensive external equipment [34]. To provide students with a more realistic experience, developers are working diligently to create fully immersive VR experiences [35]. The current fully immersive VR technology you can see is 360-degree video, also known as spherical video, which utilizes multi-sided lenses to capture the environment's characteristics and provide a unique video experience [21].

3.2 The potential of VR in primary education

To drive the realization of educational outcomes, VR, with its limitations, is sought and therefore rapidly developed and widely used [1]. In primary school, the application of VR primarily aims to enhance educational experience, with teachers seeking to help students better understand educational concepts through VR. Some studies also show that VR effectively increases students' and teachers' enthusiasm, improves students' understanding and increases efficiency in completing educational tasks [1]. From the perspective of influencing learning motivation, the emergence of VR enhances students' creativity, encourages active participation, improves learning engagement, and has a positive impact on education [1]. Existing data show that students who use traditional educational methods obviously lag behind those who try VR courses. The superiority of VR in primary education is obvious [13]. In primary education, VR has been shown to improve students' academic performance and engagement, and teachers also feel the tremendous benefits [1]. Although there are still some limitations that affect the development of VR, the above studies show that the implementation of VR in primary education has unlimited potential [1]. In China, for example, VR technology is developing rapidly [36]. In primary school classrooms, students often struggle to sustain attention, so VR interventions can help improve students' concentration and encourage their participation [37]. From a disciplinary perspective, VR in primary school physical education research has not only significantly improved the physical performance of primary school students through its innovation, but has also optimized physical education lessons for PE teachers, underscoring the application value of VR [1]. This is also confirmed in the field of math. VR clearly plays a crucial role in enhancing primary school students' understanding of mathematical modelling and other skills, demonstrating its significant benefits [7], [38]. In addition to physical education and math, English is not easy to understand, and VR also improves memory and understanding of grammar and vocabulary in spoken English [39]. Therefore, compared with traditional education and teaching methods, VR is indeed a new way to improve students' learning efficiency [40]. The potential of VR is now being recognized. Considering its great application potential, if VR can be effectively integrated into higher education levels at universities, it can also be utilized in primary education [19]. To summarize, the existing literature has confirmed the potential for VR development in primary education; however, a significant gap remains in the specific application of VR in primary schools and the improvement of learning outcomes in primary education.

3.3 Application of mobile VR technology in primary education

Take mobile VR technology as an example: mobile VR technology, including Google Cardboard and Class VR, used in conjunction with smartphones, provides students with an immersive experience. Primary school students favor this mobile VR technology due to its advantages, such as portability and low cost. It can fulfill the desire for interdisciplinary learning experiences and personalized learning of primary school students and also stimulate their creative thinking [41]. In addition, a study on the application of mobile VR technology in primary school art classes found that students using integrated Pico G2 4K VR headsets and HTC VIVE series devices for learning clearly experienced the convenience of operation. The immersive experience encourages student engagement and interactivity. It is, therefore, also suitable for elementary school. As the level of technical difficulty decreases, the costs also decrease, further emphasizing the significant advantages over other types of VR technologies [10]. In contrast, the use of desktop VR technology reveals its dependence on computers and the internet, which introduces technical barriers, connection limitations, platform access restrictions, and the disadvantage that students' needs for personalized interaction cannot be met [23]. In mobile VR technology, rural children can learn social etiquette and norms related to social learning skills by participating in VR navigation and virtual public activities via Cardboard VR, Meta Quest 2, and Tablet VR. The study found that the social skills of primary school students were significantly improved [6]. Currently, some studies suggest that mobile VR has a limited ability to provide feedback content. Current research often has a too small sample size, teachers' ability to design and use mobile VR is insufficient, students' attention is diverted, equipment and technology for mobile virtual displays are inadequate, and other challenges exist [24].

4 MATERIALS AND METHODS

In this review, the research questions were addressed through an SLR. The SLR enabled us to analyze the existing literature in a more structured way. The SLR helps to review and confirm previous research findings, identify gaps to be addressed in this study, and provide insights into future research directions that may inspire new ideas. This process supports decision-making [40]. The systematic approach and scientific methods help clarify and disseminate research findings effectively [42].

4.1 Systematic review

As the research topic involves examining the learning outcomes of VR in primary schools, this study chooses to systematically review the types of decisions that can be achieved with VR in the current context. We have elaborated on the types of VR used today, the design and application approaches of VR, and the research findings of VR, aiming to complement the possible shortcomings in previous studies. In these articles, we provided an overview of the use of VR on mobile devices, including tablets and smartphones [3], [7], [8], [20], [21], [27], [36]. The main databases used were Scopus and Web of Science. We used these two databases to collect and collate the baseline data. Scopus provides robust tools for searching, organizing and storing literature. Compared to Web of Science, Scopus offers a broader scope. Scopus is a scientific indexing database that provides access to a rich collection of publications, convenient search queries, comprehensive citations, and traceability dating back to the 1960s [43]. After defining the central research question, keywords were defined to find relevant journal articles using the two search engines. To ensure that all relevant articles were included, we conducted a comprehensive search of the database. Suitable search terms from the title are "VR," "primary school," or "elementary school." These search terms were then combined into a search string using the Boolean operators "OR" and "AND" for identification (refer to Table 1). The literature search strategies are summarized in Table 1 as part of the literature search plan.

Table 1. Keyword search strategy

Keyword	The Strings and Combinations of Keywords
Virtual reality Elementary education	"Virtual Reality" AND ("Elementary school" OR "Primary school")

We applied the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) method to extract relevant journal articles based on the flowchart [44]. PRISMA helps reduce errors in screening and analyzing the literature, improving the clarity and accuracy of the system's results [45]. This study strictly adhered to the PRISMA systematic review, ensuring transparency and standardization in the process of literature selection and analysis. The entire process comprises four steps: identification, screening, eligibility verification, and formal inclusion.

1. Identification: The Web of Science and Scopus, two major search engines, were used to identify relevant articles. These databases offer several options for customized search results. The keywords listed in Table 1 were used to find articles related to "virtual reality" and "elementary school" or "primary school." Scopus returned 484 results, and Web of Science 125; a total of 609 articles were reviewed. At this stage, only the specified keywords were considered when generating search engine results. The abstracts were the primary criterion for selecting relevant articles.
2. Screening: In this phase, the repetitions were removed from the results of the identification phase. 18 duplicates were identified from the 609 results and removed using the PRISMA protocol technique (see Figure 1). Subsequently, the remaining results were excluded if the title of the article was not qualified, it had been reviewed and excluded, the publication year was not in 2020–2024, the form of the article was not a journal, the language of the article was not English, or the open authority was not open. In this way, a total of 503 results were removed in this phase; the number of remaining articles is 88.
3. Eligibility: Then, in the remaining 88 articles, to determine the articles for the system, read each separate review at this stage to assess the eligibility and the application of manual inspection to ensure that the article in the PRISMA flowchart is in the exclusion criteria and finally guarantee that the article is closely related to the subject. The last two databases result in 41 articles. After eliminating articles that were not suitable for the current SLR reference, the authors examined 41 full-text articles.

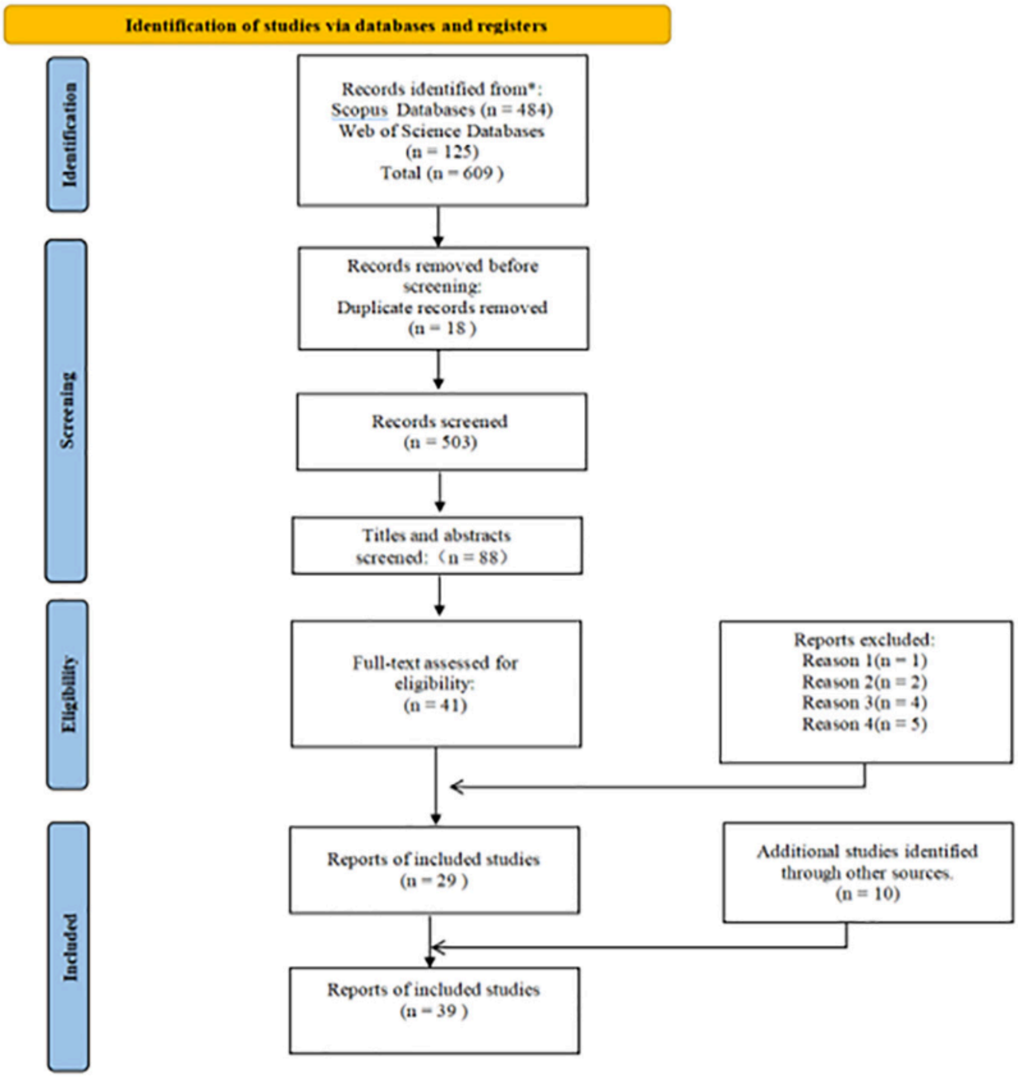

Fig. 1. PRISMA 2020 flow diagram showing the study selection process

4. Criteria for inclusion and exclusion: A comprehensive review of the full texts of the research papers revealed that one paper had been withdrawn, two papers were not eligible for systematic review, four papers focused on augmented reality, and five papers discussed multiple reality techniques without sufficiently addressing the learning outcomes that can be achieved through VR. Therefore, they were excluded from the review. In addition, 10 further related studies were identified through full-text screening using retrospective and extended tracking techniques. These 10 studies were considered relevant and included in the existing 29 studies, resulting in a total of 39 papers. Ultimately, 39 research articles that met the established criteria were included in this study. The principle of theoretical saturation was applied to the review, and the search was terminated if no new study characteristics were found after 10 consecutive searches. The data sources were compiled from secondary sources, including journals, books, and documents. In this systematic literature review, journal articles were selected as data sources because they offer a more innovative perspective than other sources and thus provide a reliable source of information. Table 2 contains guidelines for inclusion and exclusion.

Table 2. Inclusion and exclusion criteria

Criteria	Inclusion	Exclusion
Headline of the article and content	Title and meet study requirements	The topics were irrelevant and did not meet the study criteria
The year the book was issued	Works published between 2020 and 2024	Publications outside the specified range
Publication type	Only original studies and journal articles	Comments, editorials, and non-empirical studies
Spoken language	English-speaking	Others
Research area of the article	Primary school and student	Other than primary school and teachers
Accessibility	Complete-text documents	Pay or subscribe after browsing the article

Finally, the 39 articles selected for this study focused entirely on the applicability of the selected articles and the topic, based on the selection process, and closely adhered to the inclusion and exclusion criteria related to the results of applying VR in primary schools. This study provided useful information and conclusions. The study also duly discussed the research design, sample size, and number of participants, with a high degree of consistency in both content themes and quality. Furthermore, after including 39 articles in this study, the risk of bias was identified. Therefore, each article was reviewed and assessed separately by two reviewers, and the conflicting findings were analyzed and resolved by a third reviewer.

5. Data analysis: To create the system overview, we collected relevant data and findings from previous research and used them to answer the study's questions. This paper highlights the perspectives that integrate and connect many works, seeking ways to advance previous research. To further substantiate the validity of the systematic literature review, excellent coding consistency was achieved during the review of the papers. Prior to inclusion, the included studies were ranked, resulting in an overall selection of data from 39 publications. To obtain a broad perspective, we have collected published research articles. To ensure the validity of the existing work, themes were developed and categorized according to the generality and relevance of the data. After reading all of the remaining 39 articles, two main coding guidelines were used: the types of VR in primary schools, the creation and implementation of VR, and the impact of VR on learning effectiveness. Table 3 lists these two main categories. In some of the reviewed documents, ethical approval was not explicitly mentioned; therefore, they were excluded from the analysis and conclusions regarding ethics in this study.
6. Quality appraisal: To enhance the methodological value of this review, a quality appraisal was conducted for all studies included. The type of study, sample size, presence of a control group, and indication of ethical approval were examined. Table 3 summarizes the key features of the study design of the included studies, allowing the reader to critically appraise the strength and limitations of the available evidence.

Table 3. Evaluation of methodological quality

Study and Year	Scale Items				Total (Out of 4)
	1	2	3	4	
Xue and Wang. (2021)	✓	✓	✓	×	3
Xie et al. (2022)	✓	✓	×	✓	3
Wang et al. (2023)	✓	✓	✓	✓	4
Tarng et al. (2022)	✓	✓	✓	✓	4
Sulisworo et al. (2022)	✓	✓	×	✓	3
Sulisworo et al. (2024)	✓	✓	×	✓	3
Shim (2023)	✓	✓	✓	✓	4
Sandseter et al. (2023)	✓	✓	×	✓	3
Puig et al (2021)	✓	✓	✓	✓	4
Mills et al. (2022)	✓	✓	×	✓	3
Lee and Lee (2021)	✓	✓	✓	✓	4
Jalaluddin et al. (2024)	✓	✓	✓	✓	4
Iasha et al. (2023)	✓	✓	✓	×	3
Huang et al. (2021)	✓	✓	✓	×	3
Herwin et al. (2022)	✓	✓	×	✓	3
Garcia et al. (2023)	✓	✓	✓	✓	4
Chen et al. (2024)	✓	✓	✓	✓	4
Cardona et al. (2021)	✓	✓	✓	✓	4
Braren and Fels (2022)	✓	✓	×	✓	3
Bae (2023)	✓	✓	✓	✓	4
Asril and Arifin (2023)	✓	✓	×	✓	3
Asriadi et al. (2023)	✓	✓	×	✓	3
Amprasi et al. (2022)	✓	✓	✓	✓	4
Laine et al. (2023)	✓	✓	×	✓	3
Li et al. (2023)	✓	✓	✓	✓	4
Hui et al. (2022)	✓	✓	✓	✓	4
Dai et al. (2024)	✓	✓	✓	✓	4
Córcoles et al. (2023)	✓	✓	✓	✓	4
Van et al. (2024)	✓	✓	×	✓	3
Guan et al. (2024)	✓	✓	✓	✓	4
Xie & Zhang (2024)	✓	✓	×	✓	3
Digennaro et al. (2024)	✓	✓	×	✓	3
Chang et al. (2020)	✓	✓	✓	✓	4
Akman and Çakır, (2020)	✓	✓	✓	✓	4
Çakıroğlu et al. (2021)	✓	✓	✓	×	3

(Continued)

Table 3. Evaluation of methodological quality *(Continued)*

Study and Year	Scale Items				Total (Out of 4)
	1	2	3	4	
Molloy and Farrell (2024)	✓	✓	×	✓	3
Han (2020)	✓	✓	✓	✓	4
Lai (2024)	✓	✓	✓	✓	4
Xie et al. (2019)	✓	✓	×	✓	3

Note: Item 1: study type; Item 2: sample size; Item 3: control group presence; Item 4: ethical clearance.

4.2 Findings of SLR

This section contains information on data synthesis and analysis. A total of thirty-nine articles were carefully selected for inclusion in the systematic review following a thorough screening process in which specific eligibility criteria were applied to ensure relevance and quality. In this study, a thematic analysis was conducted in which all selected articles were analyzed based on two research questions. Table 4 contains a selection of articles that have been retained. Table 4 illustrates the countries to which the selected primary school research articles belong, provides basic information about the articles that used VR in this study, categorizes the VR category of the selected research articles, describes the specific design options, and outlines the topic areas and research findings of the selected research articles. Figure 2 shows that immersive VR tops the list with thirteen articles, followed by other hybrid VR technologies (12) and 360-degree video technology (3). Meanwhile, Cardboard VR, Tablet VR, and SVVR technologies each account for two articles. Other technologies, such as Zuo o-VR, HTC Vive Pro Eye, and VR agents, appeared less frequently. Figure 2 also illustrates the types of VR technologies employed in primary education, provides examples of inter-disciplinary applications of data statistics, and presents research findings on how VR can enhance learning outcomes in primary education. Table 5 provides a snapshot of the countries, regions, and education systems represented in the selected studies.

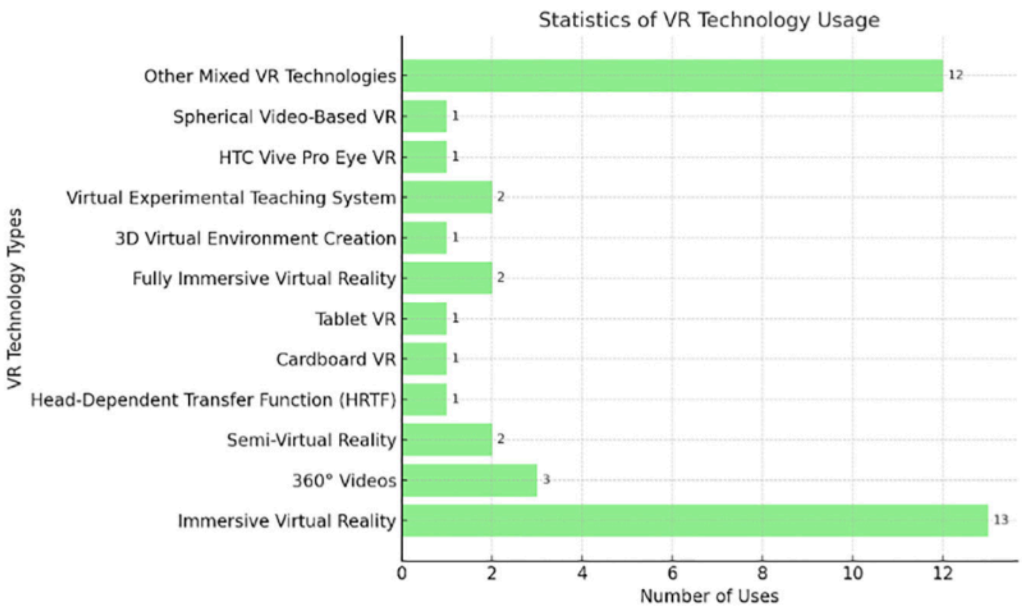

Fig. 2. Types of VR technologies applied in primary education

Table 4. Article summary

No (Country)	Author/Year	Types of VR	VR Design Used	Subject	Learning Outcomes
1 (Not mentioned)	Xue and Wang (2021)	Semi-immersive VR (Wireless sensing microprocessors combined with the technology of virtual)	Created VR dialogue, listened to virtual sounds, and experienced virtual scenes.	English	Task-driven, realistic, active English communication virtual environment.
2 (Not mentioned)	Xie et al. (2022)	Non-immersive VR	Three kinds of VR education auxiliary systems.	Mathematics	Three VR systems were used to help enhance students' interest in learning.
3 (China)	Wang et al. (2023)	Non-immersive VR (Cardboard VR, Meta Quest 2, Tablet VR)	Taught social skills with VR and improved social skills with Lego building blocks.	Social Competence	Cultivating them through VR and Lego. Social skills helped to improve their social skills and perceived social support.
4 (Taiwan, China)	Tarng et al. (2022)	Semi immersive (All-in-one virtual gaming system)	Employed the suggested VR system for concentration exercises.	Attention Process Training	VR training can effectively improve participants' focus while alleviating their learning anxiety and cognitive burden.
5 (Not mentioned)	Sulisworo et al. (2022)	Semi-immersive VR (Freely mobile zoo-VR)	Applied the virtual menu to experience the animal audio and text description.	Science	Zoo VR is suitable for application in real educational settings.
6 (Not mentioned)	Sulisworo et al. (2024)	Semi-immersive VR (Freely mobile zoo-VR)	In the cognitive load theory, the immersive experience of animals and their habitats was taken into consideration.	Science	Interest and learning outcomes were found to be positively correlated.
7 (South Korea)	Shim (2023)	Semi-immersive VR	VR ethics education programmes.	Morality Education	Educational programmes with VR can be simpler Strengthening moral awareness.
8 (Norway)	Sandseter et al. (2023)	Fully immersive VR	Developed VR scenarios and used virtual technology to measure risk variables.	Psychology, Science, Early Education and Family Coaching	The data will be used to explore behavioural patterns of children risk assessment, willingness, and processing.
9 (Spain)	Puig et al. (2021)	Non-immersive VR	Immersed in two- and three-dimensional virtual environments to play the architect, making objects.	Mathematics (geometry)	Students' interest in mathematics learning has improved, and teachers and students speak highly of them.
10 (Australia)	Mills et al. (2022)	Semi-immersive VR	Using a head-mounted display and a motion sensor to analyse multimodal data.	Drawing	Students' creative expression ability has improved.
11 (South Korea)	Lee and Lee (2021)	Semi-immersive VR	A study on the individual and class influence of sports cognition combining football curriculum and VR technology.	Soccer	VR classes improved students' confidence and focus, and they also experienced a greater sense of flow.

(Continued)

Table 4. Article summary *(Continued)*

No (Country)	Author/Year	Types of VR	VR Design Used	Subject	Learning Outcomes
12 (Malaysia)	Jalaluddin et al. (2024)	Semi-immersive VR	Applied VR technology to experience the flipped classroom and observe the improvement of rural students' writing ability.	Physical and English	In the VR flipped classroom, rural students' vocabulary accumulation and learning ability improved.
13 (Indonesia)	Iasha et al. (2023)	Semi-immersive VR	Developed a VR cultural tourism model and assessed student interest in cultural learning.	Cultural learning	This mode stimulated students' enthusiasm for learning and improves students' cultural identity.
14 (China)	Huang et al. (2021)	Semi-immersive VR (All-in-one SVVR experiential learning system)	Provided a virtual scene experience and guided the students to imitate the expression mode of metaphors in the model writing examples.	Writing	Students' interest in writing and writing self-expression skills were improved.
15 (Indonesia)	Herwin et al. (2022) [56]	Non-immersive VR	Developed the VR learning management system.	Development and application of a learning management system.	The system optimized the teaching process and has improved students' learning, understanding and retention ability.
16 (Philippines)	Garcia et al. (2023)	Semi-immersive VR	Used 360-degree video to conduct a virtual field investigation in travel.	Natural Science, History, and Culture	360-degree videos provided an enjoyable and immersive experience.
17 (Not mentioned)	Chen et al. (2024)	Non-immersive VR (Movable 3D Modelling Course)	Developed immersive 3D VR modelling.	3D Modelling	A 3D modelling approach based on IVR has significantly improved creative thinking of primary school students and reduced cognitive burden in the learning process.
18 (China)	Cardona et al. (2021)	Semi-immersive VR	The user experience was evaluated in an interactive environment.	ADHD (Attention Deficit Hyperactivity Disorder)	Helped special children experience education. Implemented in VR scenarios.
19 (United States)	Braren and Fels (2022)	Non-immersive VR	The head-related transfer functions (HRTFs) were measured using VR, and high-resolution 3D scans of the head and upper semi-stem were recorded for each participant.	Science (Acoustics)	Revealed significant differences between pediatric head-related transfer functions and adult or standard artificial heads. The characteristics of the child's head and auricles have an important impact on the temporal and frequency response of HRTF.
20 (South Korea)	Bae (2023)	Semi-immersive VR	Weekly, an 8-week VR physical education course, three times.	Physical Education	After participating in the virtual physical education course, the physical health of the students improved, and the children also showed differences.

(Continued)

Table 4. Article summary *(Continued)*

No (Country)	Author/Year	Types of VR	VR Design Used	Subject	Learning Outcomes
21 (Malaysia)	Asril and Arifin (2023)	Non-immersive VR	Development of VR-based education modules for teaching.	Islamic Religious Education	This VR-based learning approach improved the learning process's authenticity, enjoyment, adding new dimensions and experiences for students.
22 (Indonesia)	Asriadi et al. (2023)	Non-immersive VR	Utilize VR to design materials for the Social Sciences in elementary schools.	Social Sciences	VR integration has a significant positive effect on learning activities.
23 (Greece)	Amprasi et al. (2022)	Full Immersive	Developed a comprehensive VR gaming programme and a standard training curriculum.	Selective Attention (SA)	Video games improved students' choice and focus.
24 (Finland)	Laine et al. (2023)	Semi-immersive VR (Mobile VR goggles)	Utilized the I-VR teaching system to comprehend the student experience, assess the impact of learning, and gauge the demand for educational I-VRS.	Environment	I-VR experiences that affect students' motivation and methods of learning and content experience.
25 (China)	Li et al. (2023)	Fully immersive VR	Understanding the impact of Video-Based VR (SVVR) and Traditional Video on pupils' writing proficiency and inspiration.	Writing	SVVR developed virtual encounter scenarios, thereby enhancing pupils' abilities.
26 (China)	Hui et al. (2022)	Semi-immersive VR (Integrated Pico VR)	VR and head-mounted displays were introduced into teaching activities to evaluate the impact of VR on the effectiveness of elementary school art instruction.	Art	VR simplified the process and enhanced learning engagement.
27 (Netherlands)	Dai et al. (2024)	Non-immersive VR	Synthetic sounds aided students in perceiving and remembering TTS sounds in VR agents.	K-12 classroom technology	Adding VR agents improves the perception of TTS sound.
28 (Spain)	Córcoles et al. (2023)	Non-immersive VR	Designed the integration of the virtual environment to understand its impact on achievement.	History	In the VR background, academic performance and inspiration have improved.
29 (Netherlands)	Van et al. (2024)	Semi-immersive VR	Experience in immersive VR where elementary school students make self-statements on drawings.	Drawing	I have a deeper experience and understanding of how to reflect self-transcendence in painting.

(Continued)

Table 4. Article summary *(Continued)*

No (Country)	Author/Year	Types of VR	VR Design Used	Subject	Learning Outcomes
30 (China)	Guan et al. (2024)	Fully immersive VR	A VR collaborative painting tool was developed and used in elementary art classes to assess its impact.	Art	In VR teaching, students can have a higher level of cooperation, presentation, and a two-way sharing strategy.
31 (China)	Xie and Zhang (2024)	Semi-immersive VR	A VR-integrated STEM course called "Bird Feeder" was conducted.	STEM education	VR-based STEM programmes were both practical and impactful in addressing the challenges of STEM education in primary schools.
32 (Italy)	Digennaro et al. (2024)	Fully immersive VR (Virtual reality combined with mobile social media)	Developed an engaging and interactive educational setting that conveys theoretical ideas, allowing children to actively engage with and absorb the material.	Body image	Encouraged comprehensive development and welfare during the age of VR and social media impact.
33 (not mentioned)	Chang et al. (2020)	Non-immersive VR	Non-immersive VR teaching systems aided students master the relevant knowledge of geology.	Geology class	Enhanced students' learning capability in the field of natural science and stimulates their enthusiasm for learning.
34 (Turkey)	Akman and Çakır, (2020)	Fully immersive VR	Developed VR games for teaching, the impact on primary school students' academic performance and participation in Mathematics.	Mathematics	Increased academic achievement and maintained the level of student engagement in mathematics.
35 (Turkey)	Çakıroğlu et al. (2021)	Semi-immersive VR	Designed a learning environment that combines a virtual environment and animated painting.	Biology Health Education Science	A high level of interaction between the student and the subject also brings with it some unrealistic students' perceptions of their learning.
36 (Ireland)	Molloy and Farrell (2024)	Semi-immersive VR	Designed a menu of immersive technology learning experiences.	Autistic	VR technology has certain potential application advantages, which are reflected in this research.
37 (not mentioned)	Han (2020)	Semi-immersive VR	Designed virtual field trips based on the geography curriculum.	Science	Immersive VFTs have significant advantages in terms of increased attention, emotional engagement, and engagement.
38 (not mentioned)	Lai (2024)	Semi-immersive VR	VR creates immersive learning scenarios, incorporates multimodal input and interactive elements.	Science	Students learn to apply what they have learnt in highly interactive and immersive VR games.
39 (not mentioned)	Xie et al. (2019)	Fully immersive VR	VR Primary School Mathematics Teaching System Based on GIS Data Fusion.	Mathematics	The virtual lab education system has greatly increased interest in learning.

Table 5. The country and geographical distribution

Selected Study Number (as in Table 3)	Country	The Continent to Which the Country Belongs	Belong to the Education System	Quantity
3, 4, 14, 17, 25, 26, 30	China	Asia		8
7, 11, 20	South Korea	Asia		
8	Norway	Europe		1
9, 28	Spain	Europe		2
10	Australia	Oceania		1
12, 21	Malaysia	Asia		2
13, 15, 22	Indonesia	Asia		3
16	Philippines	Asia		1
19	United States	North America		1
23	Greece	Europe		1
24	Finland	Europe		1
27, 29	Netherlands	Europe		2
31	Italy	Europe		1
34, 35	Turkey	Asia		2
36	Ireland	Europe		1
1, 2, 5, 6, 18, 33, 37, 38, 39	Not mentioned	Not mentioned	Primary school	9

5 RESULTS

5.1 Types of VR that are currently utilized in primary school education

This systematic review analyzes the application of VR in primary schools across two databases, focusing on the types of VR use in primary schools, the design and implementation approaches, and the key findings. 39 different articles on the use of VR learning in primary schools were selected for analysis. The systematic review reveals that the primary technologies employed in VR for primary education encompass fully immersive, semi-immersive VR, and non-immersive systems. Among them, mobile virtual reality technology is the most widely used and common. In general, semi-immersive VR technologies, including mobile virtual reality, are widely used, which shows their applicability in education. These include Google Cardboard or other mobile VR apps that serve to streamline the process, make it more vivid, and improve VR engagement.

5.2 VR impact on the learning outcomes of primary school pupils

These articles illustrate the extensive use of VR in primary school lessons and with primary school students. This also includes a certain number of mobile device apps for VR exercises. It is clear from 39 articles that the application potential of VR in primary schools is enormous, especially for mobile virtual reality technology, and that its portability makes it readily adopted and appreciated by teachers and students. Through the integration of different disciplines and the mobile VR experience, primary school students have experienced a significant increase in their eagerness to learn and their academic performance. In addition, the experience of mobile VR can better address the challenges in actual teaching, meet the needs of students with diverse levels and characteristics, and reflect more interactivity and personalization.

1. Non-immersive VR: The 39 articles, including 2D surfaces, 3D graphics, virtual teaching systems, TTS integration, and 3D modelling, generally make much use of semi-immersive VR technology and demonstrate its applicability in education. Some of these studies mainly focus on the effects of VR on student engagement in learning. For example, Munn et al. [42] present examples of virtual experimental teaching systems and intelligent supportive teaching systems that have been shown to significantly increase student interest and engagement in learning. Some studies suggest that they should promote students' social participation and enhance their learning abilities in specific areas. For example, Wang et al. [6] used Cardboard VR, meta-tasks, and Tablet VR to introduce a combination of VR and Lego-based social skills education, aiming to improve social skills and perceived social support in primary school children. Sulisworo et al. [3] also suggested analyzing Zoo VR in more detail to improve learning skills. Some research trends and the positive impact of VR on a subject in primary school, as noted by Puig et al. [46], suggest that creating buildings with 2D and 3D shapes has led to increased learning and interest in mathematics. Iasha et al. [47] developed a model for a VR cultural journey to identify students' needs and interests in cultural learning and to stimulate their inspiration. Several studies have investigated the impact of VR on the immersion and authenticity experienced by primary school students in various activities. For example, Asril et al. [48] confirmed that the application of VR in the classroom enhances the sense of realism, authenticity, and entertainment in the learning experience, providing students with a new learning perspective and a more engaging experience. Makassar et al. [49] also demonstrated a significant positive effect of integrating VR into learning activities.
2. Semi-immersive VR: Semi-immersive VR technology is becoming increasingly prevalent in primary education, with students being more familiar with 360 videos, the virtual field trip model, semi-VR experiences, and multimedia integration, which allows them to experience the profound effects of semi-immersive VR. The introduction of the combination of external media and VR has led to many research results. For example, Xue and Wang [8] primarily guided students in integrating wireless sensor microprocessors and VR to facilitate English language acquisition through interactive activities in a virtual environment. Another example: In primary schools, VR-based STEM programs are both practical and effective in addressing STEM teaching challenges [49]. Tarng et al. [50] utilized the proposed VR system. Concentration exercises are designed to improve individuals' concentration and effectively reduce learning stress and mental effort. Sulisworo et al. [3] noted that the Zoo VR program was designed to accommodate various learning models, providing opportunities that can be experienced both inside and outside the classroom. According to Shim [51], VR education initiatives can strengthen moral awareness. Mills et al. [5] investigated a multimodal combination using a head-mounted display and a motion sensor. A multimodal analysis of video and other sensory input was also conducted. Capturing data and thinking aloud represent new forms of creativity. Jalaluddin et al. [52] investigated the use of VR to improve the writing skills of students in rural primary schools. Huang et al. [53] taught students to imitate figurative expressions using writing models. They encouraged students to observe and

create virtual scenarios. Those who used SVVR showed significant improvement in figurative expression in descriptive writing. Herwin et al. [54] found that VR significantly improves teaching and learning by making it more engaging and interactive. The VR-based learning management system enhances the teaching process, promotes the understanding and retention of learning material, and provides students with a customized learning experience. Garcia et al. [55] conducted a virtual tour using 360-degree videos and found that they can provide an enjoyable and immersive experience. Semi-immersive virtual reality technology, including mobile VR, was found to provide students with a rich experience and enhance their learning ability.

3. Fully immersive VR: Current research is also investigating the learning outcomes that can be achieved through fully immersive VR in primary education. Fully immersive VR technologies encompass games that enable full immersion, body roll simulations with multi-sensory integration, and devices such as HTC VIVE, PICO VR, SVVR, and others, offering a range of innovative ways to explore the application of VR in primary education. Sandseter et al. [57] investigated VR scenes, developed eye-tracking techniques and motion capture algorithms to assess variables related to risk management, and examined children's risk assessments, preferences, and behavioral patterns. Additionally, research [58] has demonstrated that VR is an effective means of enhancing selective attention, comparable to traditional training methods. There are also studies [4], [59], [60] that use different VR games to influence the interaction and participation of primary school students. In addition, some studies focus on the cooperation of primary school students [61] and the overall development [2].

5.3 Advantages of mobile VR in primary education, obstacles to implementation and curricular integration into the curriculum

The application of VR technology in schools holds great promise for enhancing the learning experience by creating more opportunities for interdisciplinary learning and stimulating students' creativity through interactive virtual worlds. Mobile VR provides primary school teachers with the latest equipment to enhance their support in the teaching and learning process. It enables teachers to introduce abstract ideas in subjects such as math using dynamic visualizations, making them easier and more interesting for children to understand. This technology facilitates mastery of concepts, supports different learning styles, and enables more effective differentiated instruction. For example, VR can mimic real-world environments, making language learning more realistic and authentic, increasing learner engagement and motivation, promoting creative language use, and providing greater cultural sensitivity [62]. However, there are challenges in implementing VR, particularly the lack of sufficient teacher training in VR skills. It is crucial to continuously improve teachers' competence in planning, developing, and teaching students how to use VR, deepen their knowledge of the technology, and promote its adoption in the classroom. Improving professional development, increasing the availability of VR, and reducing costs are ways to remove these barriers and realize the full educational potential of VR. In the past, concerns about the excessive cost and low quality of VR have deterred some from believing that mass adoption is not possible [63]. There are also concerns about the compatibility of VR content with national curricula, as most available materials do not always meet the required learning standards or outcomes. Without thoughtful customization or creation of VR materials that are aligned with the curriculum, there is a risk that VR solutions will be more of a distraction than an educational tool.

6 DISCUSSION

6.1 The value of virtual reality in primary schools

Virtual reality is gradually being used in primary education, with the main type being semi-immersive VR, including mobile VR [6], [8], while other types serve as supplements. Several innovative practices have emerged in the design and development of this technology, such as the development of interactive modules, the application of 360-degree videos [18], [44], body roll simulation [2], and task-based design [8]. Research has shown that VR significantly increases attention, interest in learning, creativity, and academic performance in primary school students, promoting comprehensive improvement in their skills. Semi-immersive VR, represented by mobile VR, leverages its portability and flexibility to deliver more personalized and richer learning content [48], [57] at a lower cost, enabling students to experience cultural and historical contexts anytime, anywhere, and achieve broader applications through the implementation of immersive learning [20], [50].

It has been proven that VR enhances students' concentration, motivation, creativity, and performance, promoting the development of their entire personality. However, to realize its full potential for education, it must be consciously integrated into the learning process. Teachers need to develop meaningful VR learning activities that not only align with curriculum objectives but also promote higher-level skills such as teamwork and creative thinking and address students' physical and mental development needs [1], [6].

6.2 Current challenges and implementation strategies

Currently, there is a lack of specialized training, weak design skills among teachers, insufficient or inappropriate mature content in course development, and generally high costs of using the devices [1], [51], [64], all of which lead to a mismatch between application and actual teaching, as well as difficulties in implementation. In the future, more investment will be needed in mobile VR to continuously reduce development and utilization costs, promote targeted and systematic teacher training, and design mature teaching resource packages that meet the curriculum standards of primary schools in different countries.

For the more commonly used subjects, such as science, math, and PE in primary school, further in-depth research [50], [65], [66] is needed to promote the integration of virtual environments with history and combine them with multiple subjects, such as art and PE. For the less common Chinese language teaching in primary school, actively engaging students' senses through immersive experiences compensates for the lack of hands-on writing exercises. By incorporating stories into virtual scenarios, students are guided to participate in meaningful events, transforming situational interest into motivation to learn [67], [68].

Table 6 lists the main challenges schools encounter when utilizing VR technology, including cost, teacher training, and resource availability, and discusses the key implications of VR technology in practice. Finally, there are fundamental issues of equity, access, and sustainable impact. Country and regional differences in technology, curricula, and research facilities emphasize the need for international collaboration and locally adapted plans for implementation.

Table 6. A summary of the challenges of VR and the educational benefits

Selected Study Quantities and Numbers (in Table 3)	Challenge/ Benefit Types	Key Findings
7 (3, 4, 12, 19, 27, 30, 37)	Costs	The costs are high, and it is not easy to fulfil them at the same time. Consider whether the infrastructure can fulfil the requirements.
5 (5, 9, 11, 31, 32)	Teacher Training	Strengthen teachers' creativity and skills to guide students towards VR experiences and empower teachers to deliver personalized VR experiences and project design.
8 (1, 2, 3, 10, 11, 13, 25, 36)	Accessibility	Accessibility has been improved, but it still needs further improvement, and most VR applications or systems have development potential.
8 (1, 6, 14, 18, 22, 24, 25, 27)	Educational benefits	Creation of a positive learning environment.
11 (2, 6, 9, 11, 13, 15, 21, 27, 33, 37, 39)		Enhance students' interest in learning.
1 (3)		Reducing inequalities in education.
5 (4, 11, 17, 23, 37)		Reduce students' burden and anxiety, and improve students' concentration.
8 (5, 9, 12, 13, 14, 15, 22, 28)		Students perform better academically.
1 (7)		Promote students' moral awareness.
1 (8)		Instructor's pedagogical problems.
3 (24, 26, 34)		Increase student engagement and motivation.
5 (20, 25, 29, 30, 38)		Improve students' physical fitness and ability.
1 (35)		Generating negative educational benefits (generating unrealistic perceptions)

6.3 Emerging directions and opportunities

While existing research based on leading databases suggests that VR, especially mobile VR, enhances the quality of learning and teaching in primary schools, the discipline would greatly benefit from additional research on less explored but highly promising applications. Focusing on less explored areas such as the use of mobile VR for inclusive learning (e.g., supporting students with special educational needs), children's emotional regulation (e.g., using immersive environments to build socio-emotional skills), and low-cost, mass-produced VR solutions for poor or remote schools would make the work much more original and relevant. Furthermore, future research should not only confirm the benefits of VR but also analyze pedagogically appropriate, context-specific integration approaches that empower primary school teachers to respond effectively and reliably to prevailing issues such as curriculum relevance, teacher training deficits, and infrastructural constraints. Future research must seek to fill important gaps in existing practice in education by identifying how mobile VR can be strategically utilized to promote equity, accessibility, and interdisciplinary learning in primary education. While much of the existing literature addresses interaction and teaching skills, there is a lack of empirical work that examines how mobile VR can support marginalized learners, such as students in rural areas, those with limited resources, or those with learning difficulties. Further research is also needed to explore how VR can facilitate cross-curricular connections. Studies such as those by Papadakis [69], [70], which uncover the synergy between cloud technologies and immersive technologies such as AR and simulation, suggest that future VR research should examine this technological convergence to create more inclusive, scalable, and pedagogically robust solutions. Ultimately, future studies should investigate inclusive design principles for creating VR content that is suitable for diverse learners and aligns with various pedagogical objectives [71], [72].

7 CONCLUSION

The study, based on the systematic integration of 39 studies, demonstrates the significant potential of mobile VR in primary school education. Extensive empirical research has demonstrated that mobile VR technology can enhance student engagement, creativity, and academic achievement through immersive and interactive learning experiences. Although primary school educators have recognized the potential of mobile VR technology, issues such as inadequate teacher training, the high costs associated with using VR devices, and a lack of appropriate curriculum resources in primary schools have hindered extensive research. In the future, educators must be guided to further explore this technology. Through professional training, teachers of each subject will be instructed to select the appropriate VR equipment based on the subject's characteristics and develop training plans and corresponding course content using this technology. The aim is to alleviate the academic burden on students and increase the participation and enthusiasm of primary school teachers in research. In the future, the application of mobile VR technology in primary education will be realized on a larger scale through joint efforts in the development of VR curriculum content, the professional development of primary school teachers, technological innovation, and the strengthening of international cooperation. To illustrate the findings of this study, the final summary, Figure 3, shows the relationship between VR type, mobile accessibility, and learning outcomes.

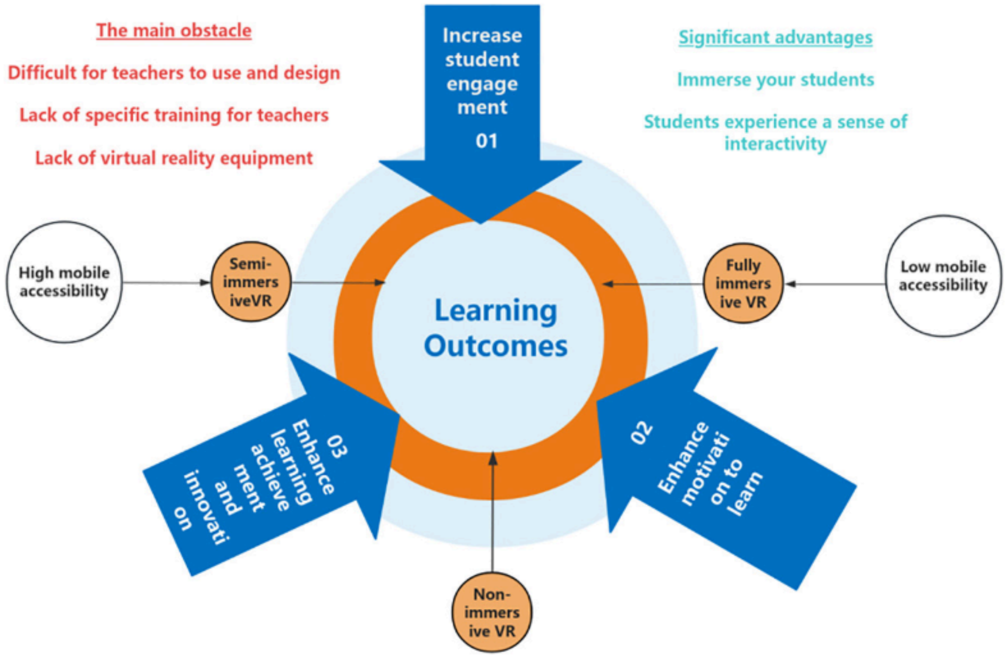

Fig. 3. Relationship between VR type, mobile accessibility, and learning outcomes

8 LIMITATIONS

A small proportion of the articles selected in this study did not contain an explicit reference to ethical approval. Therefore, they were excluded from the analysis and conclusions regarding ethics in this study. As shown in Table 5, the articles discussed in this study also have some limitations and are relatively unevenly distributed, which may impact the general applicability of the results presented in this study. Future studies should therefore cover more regions, such as Africa, South America, and Eastern Europe. Current studies are rather biased; the negative challenges and dilemmas are not thoroughly discussed, and there is a notable lack of long-term studies. Future studies can try to conduct randomized controlled trials and long-term studies.

The articles analyzed in this study also have certain limitations, namely that most of the review articles focus on Asia and China in particular, resulting in a rather uneven geographical distribution of studies. This concentration may limit the generalizability and transferability of the study's findings to other regions with different socio-technical systems, policy frameworks and teacher education systems. In different parts of the world, differences in technological infrastructure, such as access to a stable internet connection, availability of VR hardware and technical support, influence the feasibility and effectiveness of implementation in primary schools. The policy environment is also significantly different: some countries have established national policies and funding initiatives to support the introduction of educational technology, while others lack clear guidelines or adequate financial support to strengthen VR in schools. Teacher education programs also differs widely; nations that have extensive professional development programs for digital pedagogy is more likely to have a smooth incorporation of VR, as teachers can plan, teach, and sustain VR-supported lessons. For nations where teacher education is poor or teachers have increased workloads, the adoption of VR technology tends to be slow and irregular. These disparities underscore the need for more representative, regionally diverse research to better comprehend the problems and promise of mobile VR implementation globally, and to develop context-dependent policies and training programs that can more effectively assist educators and students in various learning settings.

9 FUNDING

This study has not been supported by any specific grants provided by official funding bodies, private groups, or non-profit organizations.

10 REFERENCES

[1] Y. Erita, Y. Miaz, J. Jupriani, S. Hevria, and R. Fauzi, "Using virtual reality to enhance twenty-first-century skills in elementary school students: A systematic literature review," *Open Education Studies*, vol. 6, no. 1, 2024. https://doi.org/10.1515/edu-2024-0030

[2] S. Digennaro and A. Visocchi, "Nurturing body literacy: Transforming education in the virtual reality era to shape children's identities and redefine educator roles," *Educ. Sci. (Basel)*, vol. 14, no. 3, p. 267, 2024. https://doi.org/10.3390/educsci14030267

[3] D. Sulisworo, V. Y. Erviana, B. Robiin, Y. Sepriansyah, and A. Soleh, "The feasibility of enhancing environmental awareness using virtual reality 3D in the primary education," *Educ. Res. Int.*, vol. 2022, no. 1, pp. 1–10, 2022. https://doi.org/10.1155/2022/4811544

[4] E. B. H. Sandseter *et al.*, "Virtual Risk Management—exploring effects of childhood risk experiences through innovative methods (ViRMa) for primary school children in Norway: Study protocol for the ViRMa project," *JMIR Res. Protoc.*, vol. 12, p. e45857, 2023. https://doi.org/10.2196/45857

[5] K. A. Mills, L. Scholes, and A. Brown, "Virtual reality and embodiment in multimodal meaning making," *Writ. Commun.*, vol. 39, no. 3, pp. 335–369, 2022. https://doi.org/10.1177/07410883221083517

[6] X. Wang, G. W. Young, A. Plechatá, C. Mc Guckin, and G. Makransky, "Utilising virtual reality to assist social competence education and social support for children from under-represented backgrounds," *Comput. Educ*, vol. 201, no. 104815, 2023. https://doi.org/10.1016/j.compedu.2023.104815

[7] Y. Xie, Y. Hong, and Y. Fang, "Virtual reality primary school mathematics teaching system based on GIS data fusion," *Wirel. Commun. Mob. Comput.*, vol. 2022, no. 1, pp. 1–13, 2022. https://doi.org/10.1155/2022/7766617

[8] Y. Xue and J. Wang, "English listening teaching device and method based on virtual reality technology under wireless sensor network environment," *J. Sens.*, vol. 2021, no. 1, pp. 1–11, 2021. https://doi.org/10.1155/2021/8261861

[9] D. Hamilton, J. McKechnie, E. Edgerton, and C. Wilson, "Immersive virtual reality as a pedagogical tool in education: A systematic literature review of quantitative learning outcomes and experimental design," *J. Comput. Educ.*, vol. 8, pp. 1–32, 2021. https://doi.org/10.1007/s40692-020-00169-2

[10] J. Hui, Y. Zhou, M. Oubibi, W. Di, L. Zhang, and S. Zhang, "Research on art teaching practice supported by virtual reality (VR) technology in the primary schools," *Sustainability*, vol. 14, no. 3, p. 1246, 2022. https://doi.org/10.3390/su14031246

[11] N. Alalwan, L. Cheng, H. Al-Samarraie, R. Yousef, A. I. Alzahrani, and S. M. Sarsam, "Challenges and prospects of virtual reality and augmented reality utilization among primary school teachers: A developing country perspective," *Stud. Educ. Eval*, vol. 66, no. 100876, 2020. https://doi.org/10.1016/j.stueduc.2020.100876

[12] A. Çöltekin *et al.*, "Extended reality in spatial sciences: A review of research challenges and future directions," *ISPRS Int. J. Geoinf.*, vol. 9, no. 7, p. 439, 2020. https://doi.org/10.3390/ijgi9070439

[13] R. Liu, L. Wang, J. Lei, Q. Wang, and Y. Ren, "Effects of an immersive virtual reality-based classroom on students' learning performance in science lessons," *Br. J. Educ. Technol.*, vol. 51, no. 6, pp. 2034–2049, 2020. https://doi.org/10.1111/bjet.13028

[14] Afnan, K. Muhammad, N. Khan, M.-Y. Lee, A. Imran, and M. Sajjad, "School of the future: A comprehensive study on the effectiveness of augmented reality as a tool for primary school children's education," *Appl. Sci.*, vol. 11, no. 11, p. 5277, 2021. https://doi.org/10.3390/app11115277

[15] J. Laine, T. Korhonen, and K. Hakkarainen, "Primary school students' experiences of immersive virtual reality use in the classroom," *Cogent Educ.*, vol. 10, no. 1, 2023. https://doi.org/10.1080/2331186X.2023.2196896

[16] A. F. Di Natale, S. Bartolotta, A. Gaggioli, G. Riva, and D. Villani, "Exploring students' acceptance and continuance intention in using immersive virtual reality and metaverse integrated learning environments: The case of an Italian university course," *Educ. Inf. Technol.*, vol. 29, pp. 14749–14768, 2024. https://doi.org/10.1007/s10639-023-12436-7

[17] S. M. Noble, J. D. Saville, and L. L. Foster, "VR as a choice: What drives learners' technology acceptance?" *Int. J. Educ. Technol. High. Educ.*, vol. 19, 2022. https://doi.org/10.1186/s41239-021-00310-w

[18] O. Østerlie, H. Frantzen, and A. Portals Riomao, "'It's like being there, but not in the way'. Exploring the use of virtual reality tools to stimulate reflection in Norwegian physical education teacher education," *Sport Educ. Soc.*, pp. 1–15, 2024. https://doi.org/10.1080/13573322.2024.2417070

[19] A. F. M. S. Saif, Z. R. Mahayuddin, and A. Shapi'i, "Augmented reality based adaptive and collaborative learning methods for improved primary education towards fourth industrial revolution (IR 4.0)," *Int. J. Adv. Comput. Sci. Appl. (IJACSA)*, vol. 12, no. 6, 2021. https://doi.org/10.14569/IJACSA.2021.0120672

[20] F.-R. Sun, L.-F. Pan, R.-G. Wan, H. Li, and S.-J. Wu, "Detecting the effect of student engagement in an SVVR school-based course on higher level competence development in elementary schools by SEM," *Interact. Learn. Environ.*, vol. 29, no. 1, pp. 3–16, 2021. https://doi.org/10.1080/10494820.2018.1558258

[21] A. Alqarni, J. Wang, and A. Abuhussein, "I-tech: Empowering educators to bring experimental learning to classrooms," *Int. J. Adv. Comput. Sci. Appl. (IJACSA)*, vol. 15, no. 2, 2024. https://doi.org/10.14569/IJACSA.2024.0150258

[22] S. A. Barab, T. D. Sadler, C. Heiselt, D. Hickey, and S. Zuiker, "Relating narrative, inquiry, and inscriptions: Supporting consequential play," *J. Sci. Educ. Technol.*, vol. 16, pp. 59–82, 2007. https://doi.org/10.1007/s10956-006-9033-3

[23] N. Neulight, Y. B. Kafai, L. Kao, B. Foley, and C. Galas, "Children's participation in a virtual epidemic in the science classroom: Making connections to natural infectious diseases," *J. Sci. Educ. Technol.*, vol. 16, pp. 47–58, 2007. https://doi.org/10.1007/s10956-006-9029-z

[24] S. van Ginkel *et al.*, "Fostering oral presentation competence through a virtual reality-based task for delivering feedback," *Comput. Educ.*, vol. 134, pp. 78–97, 2019. https://doi.org/10.1016/j.compedu.2019.02.006

[25] K.-H. Cheng and C.-C. Tsai, "A case study of immersive virtual field trips in an elementary classroom: Students' learning experience and teacher-student interaction behaviors," *Comput. Educ.*, vol. 140, p. 103600, 2019. https://doi.org/10.1016/j.compedu.2019.103600

[26] I. Han, "Immersive virtual field trips in education: A mixed-methods study on elementary students' presence and perceived learning," *Br. J. Educ. Technol.*, vol. 51, no. 2, pp. 420–435, 2020. https://doi.org/10.1111/bjet.12842

[27] C. L. Lai and G. J. Hwang, "Effects of mobile learning time on students' conception of collaboration, communication, complex problem-solving, meta-cognitive awareness and creativity," *Int. J. Mob. Learn. Organ.*, vol. 8, nos. 3/4, 2014. https://doi.org/10.1504/IJMLO.2014.067029

[28] Z. H. Putra, "Development of computational thinking tasks based on Riau Malay culture: A study of fifth-grade public school students in Pekanbaru, Indonesia," *Educ.*, vol. 13, no. 8, pp. 1387–1397, 2024. https://doi.org/10.1080/03004279.2022.2150063

[29] P. Kannadass, R. Hidayat, P. S. Siregar, and A. P. Husain, "Relationship between computational and critical thinking towards modelling competency among pre-service mathematics teachers," *TEM J.*, vol. 12, no. 3, pp. 1370–1382, 2023. https://doi.org/10.18421/TEM123-17

[30] J. H. Murray, "Virtual/reality: How to tell the difference," *J. Vis. Cult.*, vol. 19, no. 1, pp. 11–27, 2020. https://doi.org/10.1177/1470412920906253

[31] J. Zhao, X. Xu, H. Jiang, and Y. Ding, "The effectiveness of virtual reality-based technology on anatomy teaching: A meta-analysis of randomized controlled studies," *BMC Med. Educ.*, vol. 20, 2020. https://doi.org/10.1186/s12909-020-1994-z

[32] A. Parmaxi, "Virtual reality in language learning: A systematic review and implications for research and practice," *Interact. Learn. Environ.*, vol. 31, no. 1, pp. 172–184, 2023. https://doi.org/10.1080/10494820.2020.1765392

[33] H. A. Santos Garduño, M. I. Esparza Martínez, and M. Portuguez Castro, "Impact of virtual reality on student motivation in a high school science course," *Appl. Sci.*, vol. 11, no. 20, p. 9516, 2021. https://doi.org/10.3390/app11209516

[34] H.-L. Huang, G.-J. Hwang, and C.-Y. Chang, "Learning to be a writer: A spherical video-based virtual reality approach to supporting descriptive article writing in high school Chinese courses," *Br. J. Educ. Technol.*, vol. 51, no. 4, pp. 1386–1405, 2020. https://doi.org/10.1111/bjet.12893

[35] L. Jensen and F. Konradsen, "A review of the use of virtual reality head-mounted displays in education and training," *Educ. Inf. Technol.*, vol. 23, pp. 1515–1529, 2018. https://doi.org/10.1007/s10639-017-9676-0

[36] Y. Zhang, Y. Zhao, Y. Wu, and X. Zhang, "Digital communication of folk art in urban scenes based on vision sensor images," *Mob. Inf. Syst.*, vol. 2022, no. 1, pp. 1–13, 2022. https://doi.org/10.1155/2022/2800496

[37] M. A. M. Algerafi, Y. Zhou, M. Oubibi, and T. T. Wijaya, "Unlocking the potential: A comprehensive evaluation of Augmented Reality and Virtual Reality in education," *Electronics*, vol. 12, no. 18, p. 3953, 2023. https://doi.org/10.3390/electronics12183953

[38] A. K. Kenedi, A. U. Akmal, C. Handrianto, and Sugito, "The effect of using virtual reality media on the geometric skills of elementary school students," *JPI (Jurnal Pendidikan Indonesia)*, vol. 12, no. 3, pp. 427–435, 2023. https://doi.org/10.23887/jpiundiksha.v12i3.60735

[39] Y.-H. S. Wu and S.-T. A. Hung, "The effects of virtual Reality infused instruction on elementary school students' English-speaking performance, willingness to communicate, and learning autonomy," *J. Educ. Comput. Res.*, vol. 60, no. 6, pp. 1558–1587, 2022. https://doi.org/10.1177/07356331211068207

[40] C. A. Lara-Alvarez, E. F. Parra-González, M. A. Ortiz-Esparza, and H. Cardona-Reyes, "Effectiveness of virtual reality in elementary school: A meta-analysis of controlled studies," *Contemporary Educational Technology*, vol. 15, no. 4, p. ep459, 2023. https://doi.org/10.30935/cedtech/13569

[41] H. Cardona-Reyes, J. E. Guzman-Mendoza, and O. P. García-Coronado, "Virtual reality environments as a support in elementary school," in *Handbook of Research on Adapting Remote Learning Practices for Early Childhood and Elementary School Classrooms*, IGI Global, 2022, pp. 463–481. https://doi.org/10.4018/978-1-7998-8405-7.ch027

[42] Z. Munn, M. D. J. Peters, C. Stern, C. Tufanaru, A. McArthur, and E. Aromataris, "Systematic review or scoping review? Guidance for authors when choosing between a systematic or scoping review approach," *BMC Med. Res. Methodol.*, vol. 18, p. 143, 2018. https://doi.org/10.1186/s12874-018-0611-x

[43] N. Çinar, "İyi Bir Sistematik Derleme Nasıl Yazılmalı?" *Online türk sağlık bilim. derg.*, vol. 6, no. 2, pp. 310–314, 2021. https://doi.org/10.26453/otjhs.888569

[44] F. Boyle and D. Sherman, "Scopus™: The product and its development," *Ser. Libr.*, vol. 49, no. 3, pp. 147–153, 2006. https://doi.org/10.1300/J123v49n03_12

[45] H. A. Shaffril, S. F. Samsuddin, and A. A. Samah, "The ABC of systematic literature review: The basic methodological guidance for beginners," *Qual. Quant.*, vol. 55, pp. 1319–1346, 2021. https://doi.org/10.1007/s11135-020-01059-6

[46] A. Liberati *et al.*, "The PRISMA statement for reporting systematic reviews and meta-analyses of studies that evaluate health care interventions: Explanation and elaboration," *PLoS Med.*, vol. 6, no. 7, p. e1000100, 2009. https://doi.org/10.1371/journal.pmed.1000100

[47] A. Puig, I. Rodríguez, J. Baldeón, and S. Múria, "Children building and having fun while they learn geometry," *Comput. Appl. Eng. Educ.*, vol. 30, no. 3, pp. 741–758, 2022. https://doi.org/10.1002/cae.22484

[48] V. Iasha, M. Japar, A. Maksum, and B. Setiawan, "Let's go on a virtual reality trip!: The effect on the students' literacy, interest, and satisfaction in cultural learning," *TEM J.*, vol. 12, no. 4, pp. 2488–2499, 2023. https://doi.org/10.18421/TEM124-61

[49] Z. Asril, S. Syafril, E. Engkizar, and Z. Arifin, "Advancing educational practices: Implementation and impact of Virtual Reality in Islamic religious education," *J. Pendidik. Islam*, vol. 9, no. 2, pp. 199–210, 2023. https://doi.org/10.15575/jpi.v9i2.20567

[50] U. N. Makassar, “Virtual reality technology for elementary school students: A study of effectiveness in learning,” *P. Sci. Edu.*, vol. 66, no. 6, pp. 565–577, 2023. https://doi.org/10.32744/pse.2023.6.33

[51] Y. Xie and X. Zhang, “Research on the design and implementation of primary school STEM project based on VR coursewares,” *Int. J. Technol. Des. Educ.*, vol. 34, pp. 939–955, 2024. https://doi.org/10.1007/s10798-023-09848-4

[52] W. Tarng, I.-C. Pan, and K.-L. Ou, “Effectiveness of virtual reality on attention training for elementary school students,” *Systems*, vol. 10, no. 4, p. 104, 2022. https://doi.org/10.3390/systems10040104

[53] J. Shim, “Investigating the effectiveness of introducing virtual reality to elementary school students’ moral education,” *Computers & Education: X Reality*, vol. 2, p. 100010, 2023. https://doi.org/10.1016/j.cexr.2023.100010

[54] I. Jalaluddin, R. Darmi, and L. Ismail, “Implementing mixed augmented and virtual reality in an animated flipped classroom for low-achieving writers in rural primary schools,” *Issu. Lang. Stud.*, vol. 13, no. 1, pp. 215–232, 2024. https://doi.org/10.33736/ils.6217.2024

[55] Y.-P. Huang *et al.*, “Towards figurative expression enhancement: Effects of the SVVR-supported worked example approach on the descriptive writing of highly engaged students,” *Sustainability*, vol. 13, no. 21, p. 12260, 2021. https://doi.org/10.3390/su132112260

[56] H. Herwin, A. Shabir, and A. Asriadi, “Learning management system based on virtual reality technology in elementary school,” *World J. Educ. Technol. Curr. Issues*, vol. 14, no. 5, pp. 1506–1517, 2022. https://doi.org/10.18844/wjet.v14i5.7922

[57] M. B. Garcia, L. S. Nadelson, and A. Yeh, “‘We’re going on a virtual trip!’: A switching-replications experiment of 360-degree videos as a physical field trip alternative in primary education,” *Int. J. Child Care Educ. Policy*, vol. 17, 2023. https://doi.org/10.1186/s40723-023-00110-x

[58] E. Amprasi *et al.*, “Effect of a full immersive virtual reality intervention on selective attention in children,” *Int. J. Instr.*, vol. 15, no. 1, pp. 565–582, 2022. https://doi.org/10.29333/iji.2022.15132a

[59] E. Akman and R. Çakır, “The effect of educational virtual reality game on primary school students’ achievement and engagement in mathematics,” *Interact. Learn. Environ.*, vol. 31, no. 3, pp. 1467–1484, 2020. https://doi.org/10.1080/10494820.2020.1841800

[60] C.-J. Lai, “Enhancing multimodal output in CLIL education: The impact of VR games on fourth-grade students’ English poster designs and presentations in Taiwan,” *Humanit. Soc. Sci. Commun.*, vol. 11, 2024. https://doi.org/10.1057/s41599-024-03999-y

[61] J.-Q. Guan, W.-Z. Wang, X.-F. Wang, J. Zhu, and G.-J. Hwang, “Effects of a VR-based collaborative painting approach on primary students’ creativity and collaborative quality in art courses,” *Educ. Technol. Res. Dev.*, vol. 72, pp. 2187–2211, 2024. https://doi.org/10.1007/s11423-024-10371-z

[62] K. W. Lau and P. Y. Lee, “The use of virtual reality for creating unusual environmental stimulation to motivate students to explore creative ideas,” *Interact. Learn. Environ.*, vol. 23, no. 1, pp. 3–18, 2015. https://doi.org/10.1080/10494820.2012.745426

[63] S. C. Hayes and S. G. Hofmann, “The third wave of cognitive behavioral therapy and the rise of process-based care,” *World Psychiatry*, vol. 16, no. 3, pp. 245–246, 2017. https://doi.org/10.1002/wps.20442

[64] J. Wang, “Intelligent education based on mobile learning: Transitioning from traditional classrooms to adaptive learning environments,” *Int. J. Interact. Mob. Technol. (iJIM)*, vol. 19, no. 11, pp. 51–65, 2025. https://doi.org/10.3991/ijim.v19i11.56057

[65] B. Brown, G. Pérez, K. Ribay, P. A. Boda, and M. Wilsey, “Teaching culturally relevant science in virtual reality: ‘When a problem comes, you can solve it with science’,” *J. Sci. Teacher Educ*, vol. 32, no. 1, pp. 7–38, 2021. https://doi.org/10.1080/1046560X.2020.1778248

[66] M.-H. Bae, "The effect of a virtual reality-based physical education program on physical fitness among elementary school students," *Iran. J. Public Health*, vol. 52, no. 2, pp. 371–380, 2023. https://doi.org/10.18502/ijph.v52i2.11890
[67] F. Li, L. Cheng, X. Wang, X. He, and Y. Wang, "The effects of Spherical Video-Based Virtual Reality and Conventional Video on students' descriptive writing achievement and motivation: A comparative study," *SAGE Open*, vol. 13, no. 3, 2023. https://doi.org/10.1177/21582440231193822
[68] M. R. Mohd Saad, S. Mamat, R. Hidayat, and A. J. Othman, "Integrating technology-based instruction and mathematical modelling for STEAM-based language learning: A sociocultural and self-determination theory perspective," *Int. J. Interact. Mob. Technol. (iJIM)*, vol. 17, no. 14, pp. 55–80, 2023. https://doi.org/10.3991/ijim.v17i14.39477
[69] S. Papadakis *et al.*, "Revolutionizing education: Using computer simulation and cloud-based smart technology to facilitate successful open learning," in *Joint Proceedings of the 10th Illia O. Teplytskyi Workshop on Computer Simulation in Education, and Workshop on Cloud-Based Smart Technologies for Open Education (CoSinEi and CSTOE 2022) co-located with ACNS Conference on Cloud and Immersive Technologies*, 2023, pp. 1–18. https://doi.org/10.31812/123456789/7375
[70] S. Papadakis *et al.*, "Unlocking the power of synergy: The joint force of cloud technologies and augmented reality in education," in *AREdu 2022: 5th International Workshop on Augmented Reality in Education*, 2023. https://elibrary.kdpu.edu.ua/bitstream/123456789/7399/1/paper00.pdf
[71] R. Rattanakha, P. Chatwattana, and P. Piriyasurawong, "AI-powered smart classrooms for C-PBL: Enhancing mobile and virtual learning technologies," *Int. J. Interact. Mob. Technol. (iJIM)*, vol. 19, no. 10, pp. 4–31, 2025. https://doi.org/10.3991/ijim.v19i10.54623
[72] Y. Shen, "Design principles and practices for mobile user interfaces in high-fidelity virtual reality environments," *International Journal of Interactive Mobile Technologies (iJIM)*, vol. 19, no. 7, pp. 44–57, 2025. https://doi.org/10.3991/ijim.v19i07.54975

11 AUTHORS

Cheng Lin (surname: Cheng) is a PhD student at the Department of Science Technical Education, Universiti Putra Malaysia, Selangor, Malaysia.

Riyan Hidayat is with the Department of Science Technical Education, Universiti Putra Malaysia, Selangor, Malaysia (E-mail: riyan@upm.edu.my).

Jazihan Mahat is with the Department of Science Technical Education, Universiti Putra Malaysia, Selangor, Malaysia.