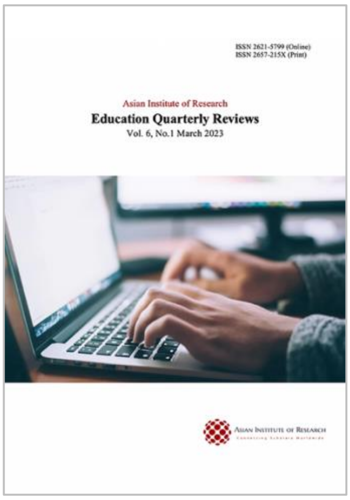

Education Quarterly Reviews

Jantakun, T., Jantakun, K., & Jantakoon, T. (2023). Systematic Review of Smart Classroom for Hard Skills Training in Augmented and Virtual Reality Environments. *Education Quarterly Reviews*, 6(1), 280-294.

ISSN 2621-5799

DOI: 10.31014/aior.1993.06.01.706

The online version of this article can be found at:
https://www.asianinstituteofresearch.org/

Published by:
The Asian Institute of Research

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The Asian Institute of Research
Education Quarterly Reviews
Vol.6, No.1, 2023: 280-294
ISSN 2621-5799

DOI: 10.31014/aior.1993.06.01.706

Systematic Review of Smart Classroom for Hard Skills Training in Augmented and Virtual Reality Environments

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Abstract
Advances in augmented and virtual reality (AVR) technology have allowed for the development of AVR interactive learning environments (AVR-ILEs) with increasing fidelity. When paired with a suitably capable computer tutor agent, such environments can permit adaptive and self-directed learning of procedural skills in some cases. We undertook a comprehensive review of published smart classroom (SC) solutions to facilitate hard skills training in AVR-ILEs. We established the learning context and implemented support for hard skills training for each of the seven solutions that qualified for the final analysis. Typically, AVR-ILEs mimic realistic work conditions or equipment. The aim of this study is to solutions featuring a smart classroom for hard skills training in an AVR-ILEs have been described. In the study, it is also aimed to types of AVR-ILEs from a smart classroom (SC) have been implemented to support hard skills training. This systematic review is based on the reporting criteria of PRISMA 2020 and the scope of the study consists of 9 academic studies including the keyword "smart classroom" and the keywords "augmented reality" or "virtual reality" in academic studies scanned in Scopus, IEEE Xplore, Eric, ScienceDirect and ACM Digital Library. In this study, the distribution of the studies used in the Smart Classroom for Hard Skills Training in Augmented and Virtual Reality Environments (SCHST-AVRE) by solution, domain, country, concept description, country, reviewed papers, learning objective(s), learning tasks, and the context of the technology used is included. In order to contribute to the research on the AVR-ILEs, it has been tried to determine the opportunities and risks that teaching in the SCHST-AVRE can offer to the field of education. In addition, it is thought that this study will shed a light on future studies.

Keywords: Smart Classroom, Augmented Reality, Virtual Reality, Hard Skills, Systematic Review

1. Introduction

Recent developments in augmented and virtual technology have made it feasible to teach professionals in hard skills in virtual settings. In addition, according to a meta-analysis done by Chun Xu and Linyue Zhang (2022), this technology facilitates the merging of the digital and physical worlds and produces a smart classroom where virtuality and reality coexist. We are interested in the combination of AVR and SC technologies in the context of developing AVR interactive learning environments (AVR-ILEs) for hard professional skills training. We expect that the study and development of AVR-ILEs will facilitate the self-study of professional hard skills. This study evaluates the numerous self-study training options for difficult skills that have been developed and assessed in the past. According to this view, professional hard skills are the technical competencies required to operate a variety of equipment and perform tasks associated with professional work. Applied training approaches typically consist of performance-based training programs administered by a qualified professional (Alsabbah & Ibrahim, 2018). Methods such as on-the-job training, master-apprentice teaching, and live-action simulations, whereby employees are trained in real working environments using a hands-on approach, represent popular means of hard skills training.

Augmented reality technology is utilized in a variety of educational contexts and learning levels, including preschool, elementary school, middle school, and high school (Palamar et al., 2021). Augmented reality techniques allow the transformation of curriculums, classrooms, and environmental elements in learning environments into multimedia opportunities, thereby enhancing the functional diversity of the environment and allowing multiple cognitive regions to operate during the learning process. It provides spaces where augmented reality facilitates the learning and teaching of abstract concepts and where students can share their knowledge (Erdem, 2017). Furthermore, it is said that these surroundings result in an improvement in students' learning (Di et al., 2013). Moreover, it was mentioned that augmented reality boosts students' interest, motivation, and experience, and plays a role in integrating the information and skills learned in the virtual world into the actual environment; hence, it is recommended (FernándezGarca, 2021).

Virtual reality environments are effective environments in terms of motivation. Users generally find these environments exciting and entertaining (Çoban & GOKSU, 2022). In addition, when individuals use VR settings, they might gain digital experiences and become more motivated to attain their objectives (Howard & Gutworth, 2020). Users may learn and feel motivated in virtual reality learning environments by having fun (Park & Kim, 2021; Holmberg & Hansen, 2008; Niemi et al., 2014). Increased student motivation guarantees their participation in learning activities (Ali et al., 2020). In addition, Makransky and Petersen (2019) underlined that students are motivated since they may do research in VR settings. Specifically, VR learning environments boost students' intrinsic motivation (Huang & Liaw, 2018).

Augmented reality (AR) and virtual reality (VR) have been highlighted as promising technologies for increasing the smart classroom educational experience (Elkoubaiti & Mrabet, 2018). AR and VR offer immersive and interactive learning environments that may engage students and promote the acquisition of new skills and information. Digital storytelling, which refers to the use of multimedia tools and techniques to narrate a tale or transmit information, is one educational use of augmented reality and virtual reality (Xu et al., 2011). Digital storytelling may be an excellent method for engaging students and enhancing their learning since it enables them to experience and interact with the subject in a more relevant and real manner. The purpose of this systematic review is to investigate the evidence on the usage of AR and VR interactive learning environments that combine digital storytelling in SMART classrooms.

Recent systematic reviews of the literature on VR have focused on its application to hard skills training (Laine et al., 2022). Learning classroom management has only rarely been integrated into VR due to the need for some type of VR tutor extension to their interface model (Lugrin et al., 2016). The combination of these emerging technologies has the potential to provide advantages for professional training, thus their incorporation into firms' training programs is anticipated to rise in the near future (Kukulska-Hulme et al., 2022).

In the present systematic literature review, we searched reputable databases for articles on AVR-based SCs, reviewed the pertinent articles, analyzed the review data in light of our research questions, and reported our findings. This investigation was intended to support our efforts with regard to developing an augmented and virtual reality-based smart classroom to train hard skills and observe immersed learners undergoing hard professional skills training within an AVR-ILE. Specifically, the study examined and catalogued published literature in an effort to answer the following questions:

1) What solutions featuring a smart classroom for hard skills training in an AVR-ILEs have been described in the literature?

2) What types of AVR-ILEs from a smart classroom (SC) have been implemented to support hard skills training?

2. Method

We discussed the purpose of this review paper and established the research questions, which we then used to develop the inclusion and exclusion criteria. The search was conducted in December 2022 and included articles published between January 2014 and December 2022. The following keywords were used: "augmented reality," "virtual reality," and "smart classroom." We performed comprehensive searches in Scopus, IEEE Xplore, ERIC, ScienceDirect, and ACM Digital Library and systematically narrowed the query down to one that could be repeated in all of the databases. This systematic review is based on the reporting criteria of PRISMA 2020 (Page et al., 2021).

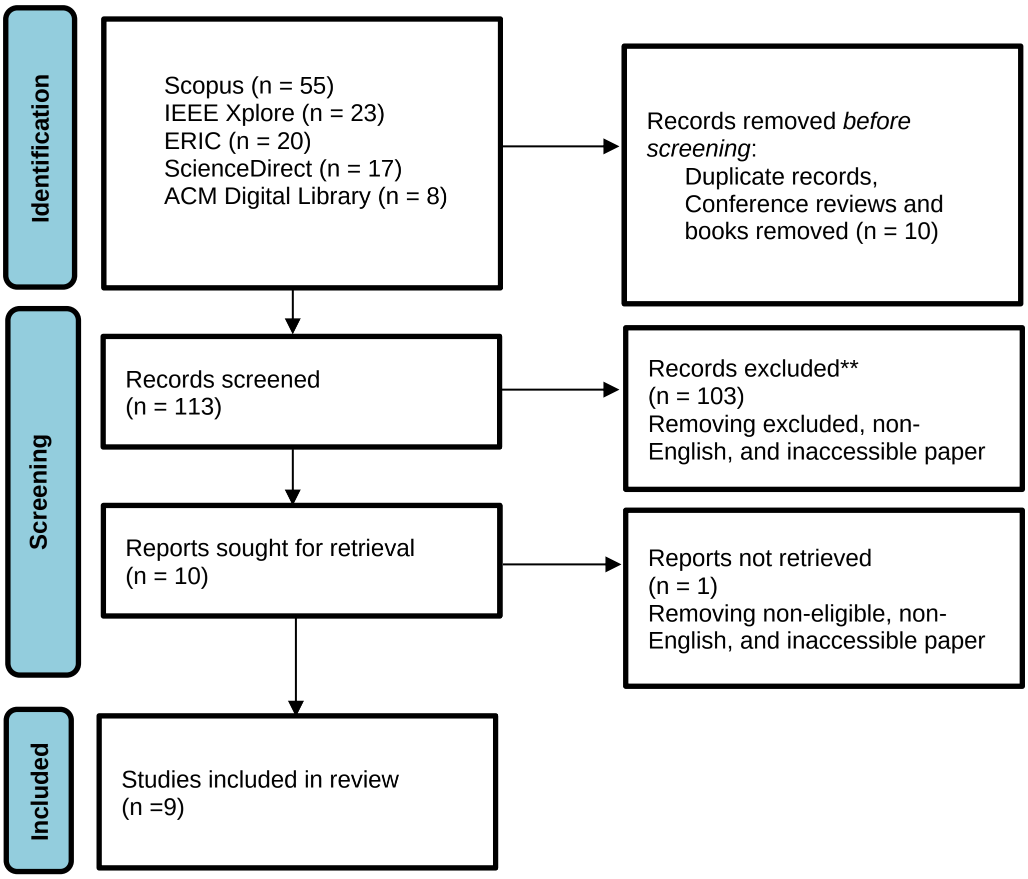

Figure 1: PRISMA guided systematic review procedure used for this study

We then moved on to the execution phase, which involved performing the query in a case-insensitive form using the title, abstract, and keyword fields of each database, with the exception of ACM Digital Library, where only the abstract field was available for the search. The query regarding “smart classroom” resulted in 228,342 papers being identified (see Table 1). As we were not interested in papers on smart classroom outside of the AVR context, we included the term “augmented reality” AND “virtual reality” in the search, which significantly reduced the number of results to 123. Scopus contributed the largest number of results. We then added five papers that we had previously identified as being potentially relevant when conducting the comprehensive queries. In addition, we removed all of the duplicate papers, conference reviews, and books from the results before reviewing the abstracts of the target articles.

Table 1: Number of Query Results in Each Database

Database	Target fields	Results for "smart classroom"	Results for "smart classroom" AND "augmented reality" AND "virtual reality"
Scopus	Article title, Abstract, Keywords	827	55
IEEE Xplore	"All metadata"	869	23
ERIC	Abstract, title	105	20
ScienceDirect	Title, abstract, or author specified keywords	126	17
ACM Digital Library	Abstract	226,415	8
ALL	-	228,342	123

2.1. Abstract Review

Next, we read through the abstracts of all the remaining papers (n=113) and assessed them based on the previously established inclusion and exclusion criteria (see Table 2). Papers that met at least two inclusion criteria and did not meet any exclusion criteria were accepted for a full-text review. In the case of all papers, merely reading the abstract was not enough to make a decision regarding their eligibility. We could not determine whether they had implemented an immersive form of AVR technology, what the exact training topic was, or whether a tutoring system was implemented. To address these issues, we performed an additional content-based inspection of the relevant papers. After the inspection, a total of 9 papers were approved for a full-text review, while 103 papers were removed. The removed papers did not meet the inclusion criteria, could not be retrieved, or were not available in English.

Table 2: Inclusion and Exclusion Criteria

Criteria	Action
Concerns hard skills training	Include
Describes a smart classroom	Include
The smart classroom guides learners towards achieving learning goals	Include
Describes the AR or VR context	Include
A framework proposition or a case study	Include
The training context is clearly non-immersive AR or VR	Exclude
Concerns training in soft skills or academic skills, such as communication or problem-solving	Exclude
The focus is different, such as authoring tool development, child development, etc.	Exclude
A review or a meta-analysis.	Exclude

2.2. Full-text Review

We performed a full-text review of the approved papers (n=9) after the abstract review. We re-visited our research questions and identified within them aspects that the papers should describe (see Table 3). The reviewed papers' eligibility for the final analysis was determined based on whether they discussed and described the proposed hard skills training solution integrating VR and SC.

Table 3: Reviewed Aspects of the AVR-ILEs and Smart classroom

RQ1 Overview	RQ2 AVR-ILEs from a smart classroom (SC) have been implemented
Authors	Technology
Domain	Solutions
Solutions	Learning objectives
Country	Learning tasks
Overall concept	-

The first author of the present work read each paper during the full-text review and marked all instances where they described the aspects of interest. More papers were linked together based on the studied training solutions. Thus, a total of 123 papers were fully reviewed. Prior to determining the final sample, two researchers re-reviewed the suggestions for the final analysis and discussed the papers' eligibility. Overall, 103 papers that could not be assessed (inaccessible or non-English) or did not provide an adequate description of using an AR or VR context were removed. The final accepted papers (n=9) provided the required descriptions of the utilized Smart classroom solution and tutoring solutions.

2.3. Final Analysis

During the final generic qualitative content analysis step, two researchers re-read and marked the accepted papers (n=9) individually. All of the marked phrases and paragraphs relevant to the tutoring systems and AVR-ILEs were entered into a Microsoft Excel sheet and organized according to the research questions. Furthermore, we collected images of each solution and used them to interpret aspects of the constructed AVR worlds and tutoring systems. After extracting and organizing the relevant material, we analyzed its content across each aspect category (see Table 3). More specifically, for each aspect category, we read through the material and established a general sense of it. Then, we began coding the descriptions with labels one aspect and one training solution at a time. Whenever a new label emerged, we rechecked the previous papers' descriptions for any instances of that label. The generated labels were inserted into landscape tables and more detailed tables that are broken down in the results section. A research question sometimes demanded descriptive answers that did not require such an in-depth content analysis. In such cases, we focused on achieving the correct interpretation of the extracted data. The reliability of the interpretations was assessed by means of discussions between the two researchers. Finally, all of the researchers assessed the results tables and made any necessary revisions.

3. Results

3.1 Solutions Described in the Literature

The nine papers included in our final analysis described seven separate solutions utilizing smart classrooms for hard skills within an AVR-LE (see Table 4). Among them, Solutions 1–6 were described in single papers, while Solutions 7–9 were discussed in more than one reviewed paper.

Table 4: Identified Solutions

Items	Solution	Domain	Concept description	Country	Reviewed papers
P1	Healthcare professionals	Clinical information	There are a lot of aspects that make digital learning approaches highly successful. It is possible to highlight the functions of recording a video lesson, engaging with different teachers and students from different cities and countries, creating an interactive learning environment, and using visual examples and 3D models to assist learners.	Russia-Kazakhstan	Omirzak et al., (2022)
P2	The steel structure construction technology	Civil engineering	A virtual training system that utilizes VR technology is an appropriate and cost-effective option.	China-United States	Xu et al., (2022)
P3	Develop interactive learning media	Developing teachers	The interactive learning media development model with augmented reality, employing the Imagineering process for SMART classroom comprises of the components of an interactive learning media development model with augmented reality, employing the Imagineering process for SMART classroom.	Thailand	Wannapiroon et al., (2021)
P4	Professional Development	Developing teachers	VR in teacher training programs, practicum and student teaching experiences, and a professional development event on how to implement VR in scientific classrooms. With the proper preparation and training, teacher candidates may become school leaders in the development of more participatory STEAM-based programs.	United States	Peterson & Stone (2019)
P5	Reading skills	Developing teachers	Implementation of the Living Book project and analysis of the program's core activities and deliverables. In addition, the document specifies the content and organization of the "Augmented Teacher" and "Augmented Parent-Trainer" training courses designed for the project. The paper concludes with a discussion of the key insights gathered from the pilot testing of the courses and the subsequent classroom experiments conducted in the project partner nations.	Cyprus	Meletiou-Mavrotheris et al., (2020)
P6	Programming Education	Situational teaching	VR goggles, the most fundamental virtual reality technology, are used to illustrate the sequencing process of abstract algorithmic knowledge and to apply innovative teaching tools to draw students' attention, boost classroom engagement, and deepen	China	Shen & Chen (2022)

Items	Solution	Domain	Concept description	Country	Reviewed papers
			their grasp of the learning topic. The creation of the application does not necessitate the use of specialized teaching equipment, and it has some practical value for ordinary instruction.		
P7	English Learning	Situational teaching	The emergence of fifth-generation (5G) and virtual reality (VR) technology gives substantial support for the reform of the new educational approach. Situational English training is enhanced by the immersive 5G+ VR smart classroom's smart education application scenario.	China	Ding & Qi (2022)
P8	English Learning	Situational teaching	The English augmented reality classroom is built using the system prototyping process and tested using semi-structured interviews. In order to implement an AR-enhanced curriculum, the framework is comprised of five primary components: instructors, themes, media, operational areas, and agents. Embedded interactive 3-D virtual elements in the learning environment provide an immersive learning experience. In the actual learning environment, students may interact with virtual items.	Taiwan	Kuo-Chen Li et al., (2016)
P9	English Learning	Situational teaching	AR, VR, and the combination of the two, known as mixed or extended reality, are umbrella words encompassing a variety of location, motion, and information technologies that enable augmenting reality with digital resources (in the case of AR) or creating wholly digital settings (in the case of VR).	Japan-New Zealand	Bonner & Reinders (2018)

In terms of the distribution of studies by country, the findings showed that the country with the highest number of studies was China (see figure 2). China was followed by the United States with one study, Thailand with one study, Cyprus with one study, and Taiwan with one study. One study was conducted in partnership with Russia and Kazakhstan; one study by the USA and the People's Republic of China together; and one study by Japan and New Zealand together. Only one study was found to have been conducted in the other countries mentioned above. Based on findings, one study was carried out in Russia and Kazakhstan, one in 2022. Moreover, studies in Japan and New Zealand carried out until 2018, no study after 2018 were found to be about AVR in SC.

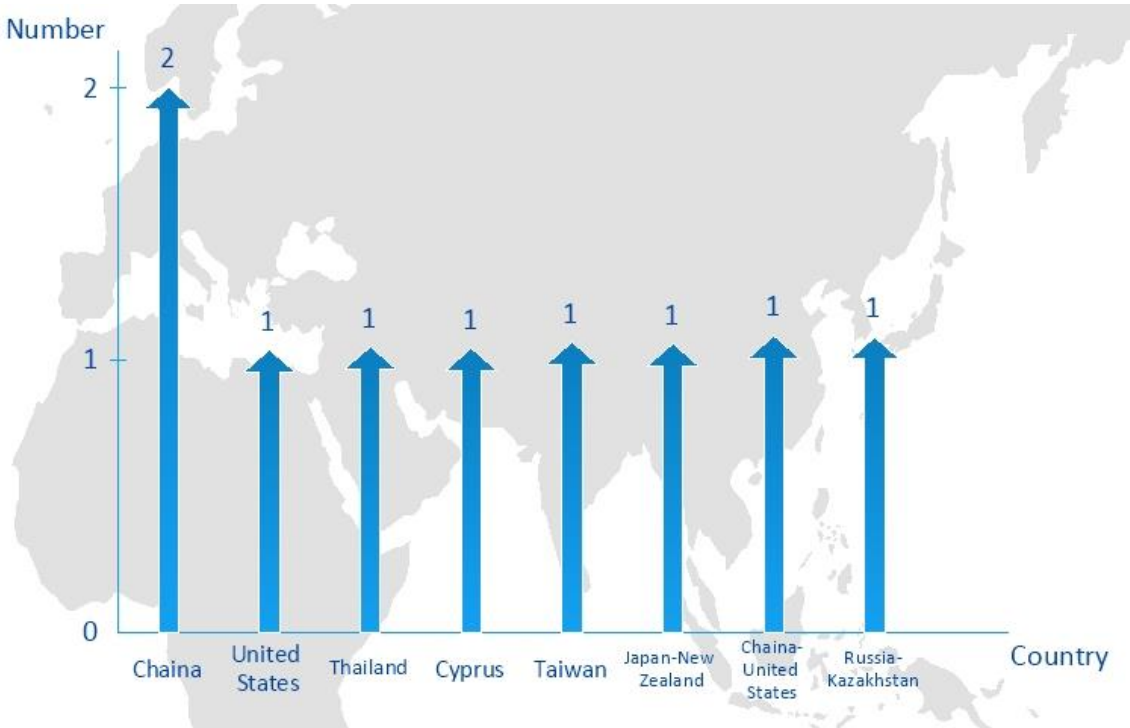

Figure 2: Distribution of Studies by Country

It is observed that the concept of SCHST-AVRE (from 2014 to 2022) has changed over the years from the perspective of 3D computer software or digital reality. On the other hand, no studies were found in 2017. It is seen that the largest number of studies (n=4) were done in 2022. It is also seen that the studies on SCHST-AVRE showed a steady but not growing trend after the first years, then a static increase in the number of studies, and growth again in 2022 (see Figure 3). Among the studies examined, the concept of AVR-ILEs has tended to be perceived as being based on either AR or VR technology in recent studies. In previous years, the concept of AVR-ILEs was handled in places such as situational teaching and teacher development.

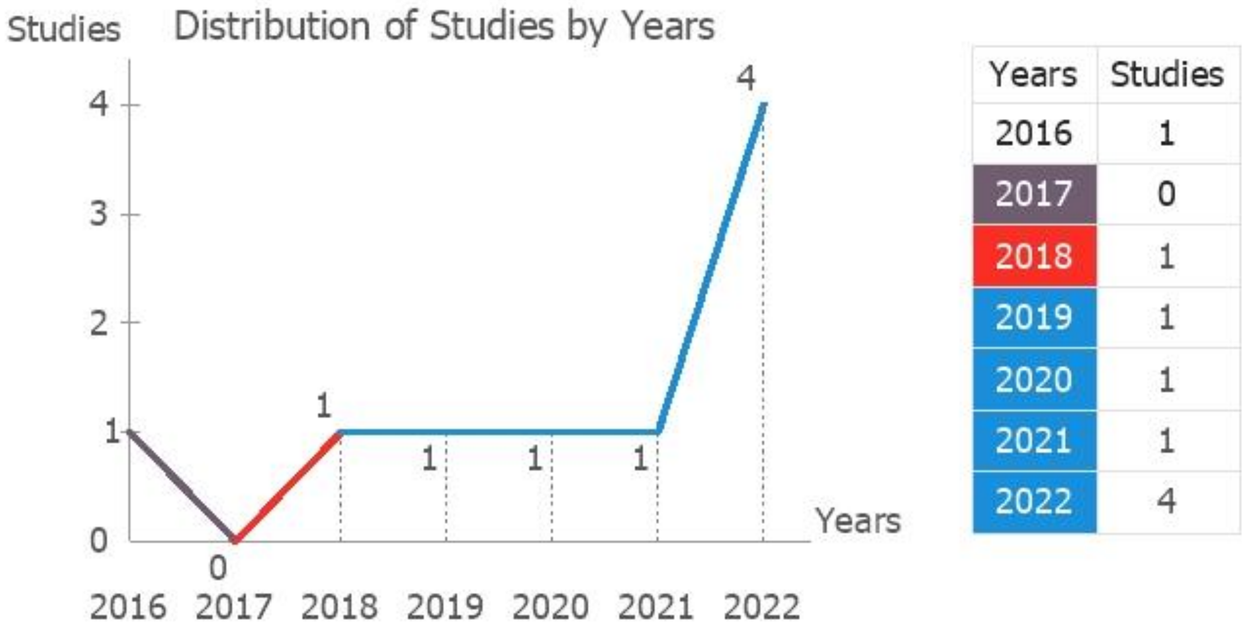

Figure 3: Distribution of Studies by Years

3.2 AVR-ILEs implementation

Learning Objectives and Learning Tasks

Each solution offered a description of the relevant technology. We collected and reviewed each solution’s learning objectives and tasks (see Table 5).

Table 5: Training Solutions’ Learning Objective and Tasks

Items	Technology	Solution	Learning objective(s)	Learning tasks
P1	AVR	Healthcare professionals	(a) evaluating the prevalence of technology solutions in the student population, the circumstances of the physical learning environment, and instructional activities within the Smart Classroom framework;	For decision-making at the point of treatment, healthcare providers require current clinical information and assistance. Smartphones give access to mainstream medical textbooks, community guidelines, pharmacological guides, and institution-specific therapeutic standards.
P2	AVR	The steel structure construction technology	(a) Development of cloud-based instructional resources utilizing augmented reality technology to facilitate reading, imitate real-world settings, and solve issues in theory and practice. There is a poor correlation between two-dimensional drawings and three-dimensional real-world situations. (b) Addressing the teaching challenges of Module 1, Steel Structure Drawing Recognition: Here, the primary aims are to facilitate the training of spatial thinking and to construct the "Steel Structure 3D Simulation Recognition Training Platform." As instructional material for two-dimensional design, we provide precise drawings of common steel structural joints. Afterwards, the three-dimensional model is produced and shown. The technology includes expert voice-over node explanations and simulated expert on-site instruction. In addition, we provide 3D models that are readily detachable and can be constructed step-by-step to facilitate one-click assembly and restoration of the overall components. (c) "one-click VR conversion" software is created with the goal of error checking the model and solving the teaching difficulties in steel structure BIM modelling in module 2. The student-created 3D model may be transformed by the software and transferred into the VR system for	In this mode, the steel structure hoisting construction project may be played and halted. This allows for unique observation and learning, which is perfect for instructor demonstrations. This mode is for interactive learning and training in a virtual reality environment. This approach integrates with the to-be-mastered knowledge points to provide practical training problems. The student can go to the next phase after answering the questions. The quantity and nature of the questions can be altered. The training and teaching management mode are available via a single interface for management. The primary duties consist of managing the VR equipment terminals, student accounts, the data resource package for the training course, and the task completion status and assessment scores of students. This mode also examines knowledge blind spots and gives comments on them.

Items	Technology	Solution	Learning objective(s)	Learning tasks
			inspection and modification. All of these phases constitute virtual building. d) The "steel structure VR training platform" is designed to address the lack of intuitive understanding of the building and installation processes and the difficulties in steel structure manufacturing and installation in module 3.	
P3	AR	Develop interactive learning media	To create the best practices of the Ministry of Education for instructors of information and communication technology in the creation of such learning materials.	a) Excellent teachers establish topic limits and develop activities that allow students to autonomously construct their own interactive learning materials based on their imagination and ingenuity. b) Teachers with outstanding practices conducted a six-step learning exercise based on the Imagineering Process. c) Students in higher education and vocational schools develop interactive learning materials using the Imagineering methodology. d) Using Imagineering, teachers evaluate the creativity and originality of their students. Evaluation instruments included the creativity assessment and the creative innovation quality assessment.
P4	VR	Professional Development	Use of VR in a teacher-training program	Using VR in teacher training programs, practicum and student teaching experiences, and offering a tutorial on how to integrate VR in scientific classrooms. With sufficient preparation and training, teacher candidates may become school leaders in the development of more participatory STEAM-based programs that employ cutting-edge technology such as virtual reality and augmented reality.
P5	AR	Reading skills	The pilot testing and follow-up classroom experiments that took done in four of the partner nations (Cyprus, Estonia, Portugal, and Romania) in order to assess the degree of effectiveness of the professional development program.	The purpose of the Augmented Teacher course is to promote reading instruction as a cross-disciplinary talent for all educators. The course introduces teachers to the Living Book approach and how it may be used to increase students' reading motivation and reading comprehension.

Items	Technology	Solution	Learning objective(s)	Learning tasks
P6	VR	Programming Education	Promoted programming education for students to learn to use computational thinking	This initiative incorporates virtual reality (VR) technology into middle school classrooms and creates VR-based teaching aid applications to assist students in improving their learning and developing algorithmic reasoning. In terms of platform design, direct human-computer interface learning, and the activation of appropriate functional buttons, the teaching aid apps do not need specialized teaching equipment and are realistically applicable to routine teaching.
P7	VR	English Learning	Abilities of a good English	From the standpoint of interacting subjects and objects, there are two situations: human-virtual object interaction and human-human interaction. Both interaction conditions in virtual space are crucial. The contact between people and virtual things can enrich the learner's experience, while human-to-human interaction can improve the learner's capacity for reflection.
P8	AR	English Learning	Abilities of a good English	Provides a demonstration of the tutor in the AR classroom. When students activate the mobile app to begin this lesson, the 3-D avatar tutor will appear above the tutor AR marker and begin the introduction. Since the example learning session is military-related, the tutor appears as a soldier to provide an immersive experience. After completing the introduction, the instructor will direct pupils to the subsequent region or move between scenarios.
P9	AVR	English Learning	Abilities of a good English	In order to illustrate how an AR or VR activity may function in the classroom, a sample activity with detailed implementation instructions is supplied. This paper outlines some of the decisions to be taken and processes to be followed, including which tools and applications are to be utilized. This also affords us the opportunity to teach unfamiliar technical jargon to the readership.

Nine studies (n=9) included in the study were examined according to their research technology. Studies were categorized as AR, VR, and AVR. It can be clearly seen that three studies were included in AR. three studies conducted VR, and three studies ARR technology (see figure 4).

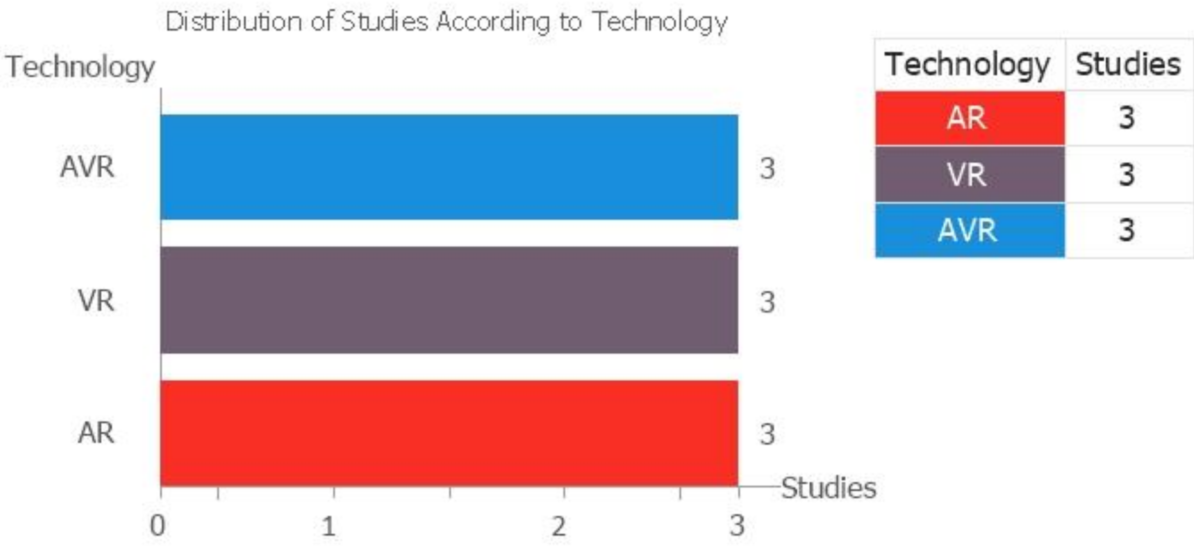

Figure 4: Distribution of Studies by Technology

4. Discussion

The present literature review has revealed that SC and AVR-ILEs technologies have only rarely been applied together in the context of hard skills learning over time and in different domains. The learning objectives within AVR-ILEs have generally focused on helping learners attain procedural knowledge. Learning objectives concerning declarative knowledge were exclusively realized in "Healthcare Professionals," "Steel Structure Construction Technology," "Developing Interactive Learning Media," "Professional Development," "Reading Skills," "Programming Education," and "English Learning" before the learner used the AVR-ILEs. However, various information augmenting methods were utilized by most of the classroom to display descriptions, explanations, and demonstrations as guiding actions within the AVR-ILEs. As such, learning objectives related to declarative knowledge also seem attainable within the studied AVR-ILEs.

The majority of the reviewed training solutions resembled tutorials with high regulation and an expected order of actions. One might even ask, where is the pedagogy and how impactful are these types of tutorials? The student models associated with the reviewed tutoring systems concentrated on the learner's capability to perform the correct actions and remain on the optimal path. However, AVR-ILEs technology can enable more detailed tracking capabilities and offer new possibilities for monitoring the learner. The objective of designing a tutoring system should be to create a system that is capable of offering both skill practice and social-emotional learning (Lertbumroongchai et al., 2020). In addition, Thongprasit and Piriyasurawong (2022, p. 112) argue that leading learners inside the context of a metaverse to acquire engineering competency requires three components: the metaverse, the metaverse platform, and future engineering competency. What if engineering students of the future could view a virtual building site, observe the flow of fluids in three dimensions, and choose to pursue their interests in the virtual world? It would save more time and money on the job front. If engineers are developing parts and seeing the disassembly of 3D parts in real time, it is as if they are actually producing them, or a construction site may mimic itself into a genuine structure, summarizing the construction without the need to travel to the site. This allows us to work from anywhere on the globe without having to physically travel there. The metaverse has made it feasible to cultivate an engineering-competent workforce capable of meeting the demands of future industrial firms. As a result of the metaverse's creativity, engineering is undergoing a profound transformation. By combining the notion of establishing a real-world environment with technology to form a "virtual world community," we may link the items around us and the environment as if we were living outside, engaging with strangers, and producing an event together in the actual location.

Finally, we acknowledge that only a small number of solutions met our inclusion criteria. In part, we consider this to be a fundamental issue associated with the literature review method, as authors may not include canonical terms within their keywords and abstracts. The majority of prior studies concerning SCs have focused on the education (formal schooling) domain, which we deliberately excluded due to our focus on the professional learning context. In addition, despite the work exhibiting many AVR-ILEs-like behaviors, may not be considered to incorporate a formal AVR-ILEs element.

5. Conclusion

We have reviewed papers that described training solutions in which SC technology was implemented in order to guide hard skills acquisition in an AVR-ILEs. While there is a long tradition of SC research, its implementation in AVR-ILEs remains a novel research branch. However, separate from this tradition, it is possible that some researchers have developed other adaptive smart classroom solutions for AVR-ILEs. The scope of our study only included papers featuring SCs for hard skills training.

This review indicated that the described hard skills training using AVR was exclusively completed either in realistic mock-ups of the learner’s real-life environment or using full mock-ups of the work equipment to be trained. A recent systematic review (Laine et al., 2022) proves that digital learning environments are generally made to resemble real-life working contexts in an effort to minimize the negative effects on performance transfer.

Overall, it appears that AVR-ILEs technology will be increasingly used to provide training through emulations of realistic situations. However, we should not ignore the fact that in its current phase of development, AVR-ILEs technology may increase inequality in relation to education. Indeed, not all learners can afford it, while some learners may not be able to use it. Yet, AVR-ILEs technology could help with rehabilitation, and it could also be harnessed to render certain practical training and manufacturing processes more sustainable. Ultimately, AVR-ILEs is a tool that needs to be combined with various technologies, and we can still influence its development and use.

Acknowledgments

This study was financially supported by a research grant from the Education Maintenance and Income Budget. The fiscal year 2022 Rajabhat Maha Sarakham University.

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