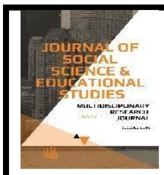

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INTEGRATING AUGMENTED REALITY WITH COGNITIVE CONSTRUCTIVIST THEORY: A SYSTEMATIC REVIEW OF ENHANCING LEARNING IN EDUCATION

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ABSTRACT

This paper investigates the integration of AR with cognitive constructivist theory in education. AR facilitates enhanced student engagement and comprehension through immersive learning experiences, while cognitive constructivism predicated on Piaget's theory, emphasizes active knowledge construction through experience. Notwithstanding AR potential, challenges such as financial constraints, technological barriers, and the necessity for pedagogical adaptation impede its broader adoption in educational settings. The study sought to examine the alignment of AR with cognitive constructivist principles, clarify the challenges associated with its implementation, and propose evidence-based practices for its effective integration After a systematic analysis of Scopus and Web of Science databases using the PRISMA methodology, 14 relevant publications that satisfied the predefined inclusion and exclusion criteria were found. According to research findings, AR improves experiential learning and conceptual understanding, especially in STEM and vocational education. However, there is a lack of longitudinal studies evaluating AR long-term impact on cognitive development, skill retention, and motivation. The gap shows the necessity for further research and refined pedagogical frameworks. The review suggests that future research should focus on personalized AR experiences and investigate its application across diverse educational domains. Furthermore, increased investment in infrastructure, educator training, and collaboration between researchers and practitioners is deemed essential to fully harness AR potential in education.

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INTRODUCTION

Augmented Reality (AR) has become a powerful tool in several domains, most notably education, where it bridges the gap between digital and physical interactions to improve students' comprehension and engagement. The effective pedagogical outcomes of education in the digital age depend on the integration of learning theories with technology. The convergence of AR and cognitive constructivist theory which is a theory that highlights learning as an active, creative process is the subject of this study (Hof, 2021). Based on Piaget's research, cognitive constructivism asserts that knowledge is actively constructed by students via experiences and reflection (Y. F.Richard, 2022). This theoretical framework and AR's immersive characteristics offer a chance to investigate how technology can facilitate deeper cognitive development. Even though AR holds great potential for education, there remains a gap in how to successfully combine technology with cognitive constructivist theory to improve learning results. Due to budgetary limitations, technological impediments, and the requirement for pedagogical adaptation, many educators find it difficult to implement AR. Furthermore, whereas the short-term advantages of AR in enhancing engagement and comprehension are widely known, its long-term effects on cognitive growth and skill retention are still poorly understood. More research is required to determine how AR and cognitive constructivism might work together to produce learning experiences that are more meaningful and long-lasting.

LITERATURE REVIEW

The current research extensively emphasizes the effectiveness of Augmented Reality (AR) in education, specifically for increasing involvement and enhancing conceptual comprehension. AR has shown great effectiveness in closing the distance between theoretical knowledge and its real-world use by offering engaging and interactive experiences. This is particularly noticeable in fields like vocational education and STEM, where practical learning is essential for building skills. Research by (Daniel Araya & Peter Marber, 2023)and (Hassan, 2023) show that AR enhances student involvement through interactive, practical simulations that encourage greater understanding and interest. Although there have been positive results, various obstacles are preventing the widespread integration of AR in educational environments. Significant hurdles persist in the form of technological challenges, such as the requirement for advanced hardware and dependable internet connectivity. Furthermore, financial limitations frequently restrict the capacity of institutions to incorporate AR technologies, especially in educational systems that lack adequate funding. Additionally, the absence of clearly outlined educational frameworks tailored for AR creates challenges for educators looking to integrate this technology into their teaching methods(Nikolaeva et al., 2023). Another important area that needs further research is the lack of long-term studies evaluating the effects of augmented reality on students. Although short-term advantages such as higher motivation and quick skill improvement have been observed, there is limited understanding of AR impact on cognitive advancement, persistent motivation, and skill retention in the long term (Bermejo et al., 2023). It is crucial to address these gaps to fully comprehend the potential of AR in shaping future educational environments.

OBJECTIVE

This study aims to:

1. Explore the incorporation of AR within the framework of cognitive constructivist theory to enhance educational practices.
2. Identify the challenges and barriers that educators encounter in implementing AR in alignment with constructivist learning principles
3. Examine the long-term cognitive advantages of AR in the classroom, with particular attention to skill transfer, memory, and comprehension.

METHODOLOGY

The execution of the systematic literature review process is conducted utilizing the PRISMA Framework, which entails a meticulous examination through three primary phases delineated in the subsections Identification, Screening, and Eligibility. Upon the conclusion of the data formulation, the processes of data abstraction and analysis describe the review grounded in the PRISMA framework.

IDENTIFICATION

In the undertaking of assembling a collection of relevant scholarly research for this investigation, the systematic review methodology comprises three essential stages. The first stage involves identifying key terms and examining related, analogous language by consulting thesaurus, glossaries, encyclopedias, and previous academic studies. After the identification of all relevant keywords, search strings were developed to query the Scopus and Web of Science databases, as delineated in Table 1. Throughout the preliminary phase of the systematic review endeavor, this research successfully accumulated a total of 123 scholarly articles from the databases mentioned earlier

Table 1**:** Search String

Database	Search String
Scopus	TITLE-ABS-KEY ((("augmented reality" OR "AR" OR "mixed reality" OR "extended reality" OR "virtual environment") AND ("cognitive constructivism theory" OR "constructivist learning theory" OR "cognitive constructivism" OR "constructivist theory" OR "constructivist learning")))
WoS	(("augmented reality" OR "AR" OR "mixed reality" OR "extended reality" OR "virtual environment") AND ("cognitive constructivism theory" OR "constructivist learning theory" OR "cognitive constructivism" OR "constructivist theory" OR "constructivist learning"))

Source: September 2024(Scopus and Web Of Science)

SCREENING

During the preliminary screening phase, extraneous articles were eliminated, leading to the exclusion of 7 papers in the initial stage. Consequently, the subsequent screening phase entailed the assessment of 123 articles predicated on a defined set of inclusion and exclusion criteria formulated by researchers. The predominant criterion utilized was the type of literature, which favored empirical research articles as the principal source of practical knowledge. Furthermore, this criterion included the exclusion of reviews, systematic reviews, meta-analyses, meta-syntheses, book series, standalone books, and book chapters that did not correspond with the most current research findings. It is significant to emphasize that this selection process was confined to publications in the English language and concentrated on the five years preceding the year 2020, extending to 2024. Ultimately, a total of 98 publications were excluded based on these specific criteria.

ELIGIBILITY

In the third phase, designated as the eligibility assessment, a total of 18 articles were assembled. The titles and fundamental content of these articles underwent a rigorous evaluation to ascertain that they satisfied the inclusion criteria and were congruent with the prevailing research objectives. Consequently, 4 articles were excluded from the assessment due to their failure to meet certain criteria, including insignificant titles, abstracts that did not pertain to the review objective, and reports that were outside the relevant field. Ultimately, 14 articles remain available for analysis, as delineated in table 2:

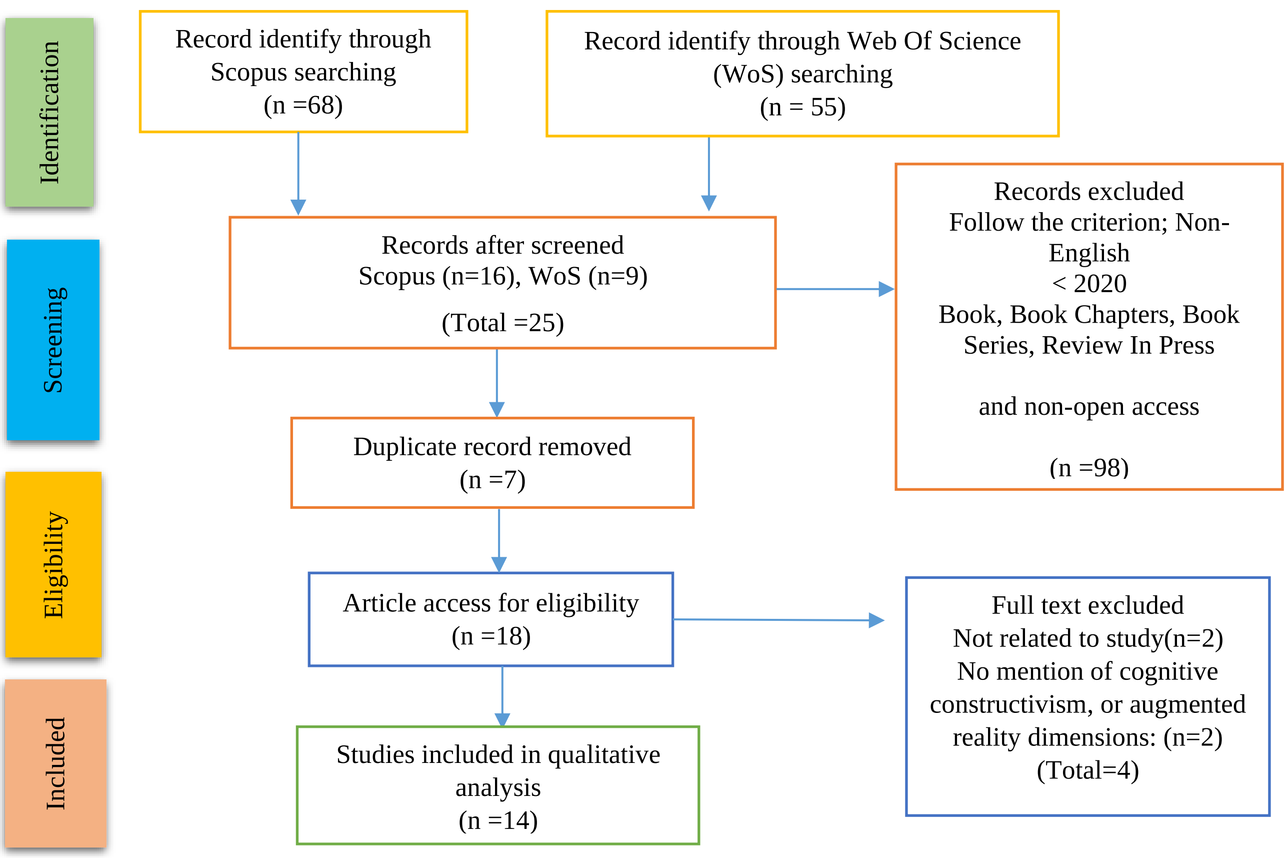
Table 2: The selection criterion of searching

Criterion	Inclusion	Exclusion
Language	English	Non-English
Timeline	2020-2024	< 2020
Literature type	Journal (Article), Conference Proceedings	Book chapters, Book Series, Review
Publication Stage	Final	In Press

DATA ABSTRACTION AND ANALYSIS

This study utilized a comprehensive integrative analytical framework to synthesize various research paradigms encompassing qualitative, quantitative, and mixed methodologies. The principal aim was to delineate pertinent themes and subthemes about augmented reality and cognitive constructivist principles within the context of vocational education pedagogy and learning settings. The data acquisition phase entailed a rigorous examination of 15 scholarly publications, from which relevant information was meticulously extracted to address the focal topics of the study. Three predominant themes surfaced: "Effectiveness of AR as a Pedagogical Tool," "Challenges in Implementing AR," and "Gap in AR," which were subsequently elaborated upon alongside associated themes and concepts through collaborative discourse among the authors. A detailed enumeration of the articles categorized by theme is presented in Table 3. A comprehensive and meticulous record was consistently preserved during the data analysis phase to chronicle methodologies, outcomes, inquiries, and any pertinent details. The researchers additionally participated in extensive deliberative dialogues to address any inconsistencies identified during the thematic development process, consequently guaranteeing the internal consistency of the formulated themes. The analysis was scrutinized by experts in the domains of Educational Technology (EdTech) and Curriculum Development to ascertain domain validity, thereby ensuring each sub-theme's relevance, clarity, and appropriateness. The expert review segment encompassed the integration of feedback and professional insights into the analysis, culminating in modifications aimed at augmenting the study's validity and reliability. The PRISMA Framework's methodology is explained in Figure 1:

Figure 1: Adapted from Moher et al., (2009)



RESEARCH FINDINGS AND DISCUSSION

Based on all the articles that have been discussed, 3 themes have been identified which are:

i. Effectiveness of AR as a Pedagogical Tool

ii. Challenges in Implementing AR

iii. Gap In AR

Effectiveness of AR as a Pedagogical Tool

AR has been demonstrated to substantially augment student engagement, cognitive comprehension, and academic achievement across diverse educational frameworks, particularly within technical and scientific disciplines. AR facilitates immersive and interactive learning experiences, enabling students to interact with content in a dynamic and significant way. It reconciles the divide between theoretical knowledge and practical application, permitting students to witness theoretical concepts in action. AR applications empower learners to explore scenarios that would be difficult to replicate within conventional classroom environments. Nevertheless, for AR to realize its full efficacy, it must be assimilated within a meticulously designed pedagogical structure. Absent deliberate planning and explicit instructional design, AR risks being regarded as a mere novelty rather than a transformative educational instrument. Educators must ascertain that AR is not only engaging but also substantially contributes to the intended cognitive outcomes. This necessitates ongoing refinement of pedagogical methodologies to align AR technology with the curriculum, ensuring it enriches the educational experience without undermining academic objectives. The summarized findings can be seen in table 3

Table 3: Overview Findings of Effectiveness of AR as a Pedagogical Tool

Theme	Authors	Title	Findings
Effectiveness of AR as a Pedagogical Tool	Cavanaugh et al., 2023	Immersive Learning and Participatory Engagement : Connecting in the Online Classroom Through Virtual Reality	The research indicated that augmented reality (AR) significantly improves student involvement and comprehension within the realm of chemistry education, especially in the synthesis of theoretical concepts with practical applications.
	Jain et al., 2023.	Real-Time Interactive AR for Cognitive Learning	The findings showed that student satisfaction with AR is influenced by interactive content, ease of use, and perceived relevance in entrepreneurship education.
	Lawlor et al., 2021	Virtual reality considerations for curriculum development and online instruction	The study emphasized AR's potential to promote sustainable learning practices by improving learning outcomes while reducing the environmental footprint of traditional education methods.
	Badilla-Quintana et al., 2020	Augmented Reality as a Sustainable Technology to Improve Academic Achievement in Students with and without Special Educational Needs	Results indicated that AR in constructivist environments supports better conceptual understanding and higher engagement levels compared to traditional methods.
	Ercag & Yasakci, 2022	The Perception Scale for the 7E Model-Based Augmented Reality Enriched Computer Course (7EMAGBAo): Validity and Reliability Study	The study revealed that while teachers found AR useful in aligning assessments with learning objectives, implementation challenges such as technological barriers persisted.
	Jain et al., 2020	Virtual reality: an aid as cognitive learning environment-a case study of Hindi language	The findings demonstrated that immersive AR increased student participation and deepened learning in distance education contexts, making it a valuable tool for remote learning.

Challenges in Implementing AR

The integration of AR within educational contexts encounters a multitude of challenges, as elucidated in scholarly discussions. A foremost obstacle pertains to the considerable financial expenditure necessitated for the adoption of AR technology. The financial implications associated with procuring the requisite hardware, software, and continuous maintenance can be prohibitive for numerous educational establishments, particularly those functioning with constrained financial resources. Furthermore, technological barriers, including insufficient infrastructure and antiquated systems, further impede the seamless integration of AR into existing curricula. A significant number of institutions are devoid of the comprehensive technical support essential for the effective implementation and sustainability of AR-based educational tools. Another pivotal challenge is the imperative for pedagogical training.Teachers must develop new competencies and expertise to proficiently incorporate AR into their instructional strategies, a process that demands substantial time, effort, and resources. In the absence of adequate training, educators may encounter difficulties in fully harnessing the potential of AR, resulting in its underutilization or improper application. Additionally, the disparate levels of preparedness among both students and educators, combined with a reluctance to embrace novel technologies, further intensify these challenges. Some individuals may exhibit hesitance or lack the requisite digital literacy to engage with AR, thereby complicating its integration. Collectively, these challenges establish significant impediments to the extensive adoption of AR within educational settings. Table 4 shows the summary of it.

Table 4: Overview Findings of Challenges in Implementing AR

Theme	Authors	Title	Findings
Challenges in Implementing AR	Castaneda et al., 2023	Don't forget to assess: How teachers check for new and deeper learning when integrating virtual reality in the classroom	The 7E model-based AR application significantly improved students' perceptions of the learning process, showing enhanced engagement and comprehension in scientific subjects.
	Vassigh et al., 2024	Performance-Driven VR Learning for Robotics	The real-time interactive AR system led to improved cognitive learning, particularly in problem-solving tasks, demonstrating AR's potential for real-time student engagement.
	Arzapalo & Giraldo, 2021	Factors Influencing Student Satisfaction With The Virtual Entrepreneurship Modality At A Private University In Lima	The study found that both AR and VR positively impacted cognitive learning processes, with AR proving more effective for real-time educational experiences.

Gap In AR Integration

The analysis indicates a significant deficiency in the longitudinal assessment of AR impact on vocational education, particularly in relation to skill retention and transferability. Although the immediate advantages of AR, including heightened engagement and improved comprehension, are extensively documented, there exists a conspicuous lack of empirical studies investigating its long-term effects. Inquiries regarding how AR influences learners' capacity to retain and apply skills over protracted durations remain predominantly unresolved. This research shortfall constitutes a considerable obstacle, as comprehending the enduring implications of AR is vital for determining its genuine educational merit, especially within vocational domains where the practical application of skills is paramount. Furthermore, the existing literature underscores the necessity for more individualized AR experiences that address the distinct learning environments of individual students. Present AR applications frequently adopt a generalized framework, however for AR to realize its full potential, it must be customized to accommodate the varied needs, learning modalities, and contexts of learners. Personalizing AR experiences has the potential to enhance learner outcomes, as students are more inclined to engage profoundly with material that aligns with their specific educational requirements. Table 5 shows the overview of the findings.

Table 5: Overview Findings of Gaps in AR Integration

Theme	Authors	Title	Findings
Gaps in AR Integration	Arroba et al., 2023	Innovating Chemistry Education: Integrating Cultural Knowledge through a Practical Guide and Augmented Reality	The findings indicated that AR-enhanced curriculum development provided better student engagement and understanding of complex skills, though it required careful integration into existing educational frameworks.
	Boedding et al., 2023	Augmented reality for constructivist learning at work: current perspectives and future applications	Preliminary findings showed that plane-detection AR improved spatial learning and interaction, suggesting potential for applications in fields requiring spatial awareness.
	Hsu & Liu, 2023	The construction of a theory-based augmented reality-featured context-aware ubiquitous learning facilitation framework for oral communication development	The study found that well-designed AR pedagogical tools improve student outcomes, particularly in mobile learning environments where flexibility and interaction are key.
	Na, 2021	Work-in-Progress-the use of plane-detection augmented reality in learning geometry	AR and VR were shown to significantly improve performance in robotics education by offering interactive, real-time simulations that enhanced student learning.
	Wongchiranuwat et al., 2020	The Study of Learner Context for the Development of Constructivist Learning Environment Model Combined with Mixed Reality Flipped Classroom to Enhance Creative Thinking in Product Design for High School Students	The findings highlighted the need for longitudinal studies to assess AR's long-term impact on motivation and skills transfer, particularly in vocational training contexts.

CONCLUSION AND RECOMMENDATION

This systematic literature review highlights the potential of AR in augmenting student engagement, comprehension, and the pragmatic application of theoretical knowledge, particularly when congruent with cognitive constructivist theory. AR effectively act as a bridge between abstract concepts and tangible experiences, rendering it particularly advantageous in experiential fields such as vocational education and STEM. Nonetheless, obstacles such as financial constraints, technological impediments, and the absence of well-defined pedagogical frameworks persistently impede its wider adoption in educational environments. Although the immediate advantages of AR are explicit, encompassing enhanced participation and enriched conceptual understanding, there remains a pressing necessity for further investigation into AR longitudinal influence on cognitive development and educational outcomes.

The present investigation predominantly focuses on vocational and STEM education, thereby providing an opportunity for subsequent inquiries into the prospective applications of AR within alternative academic disciplines, including the humanities and social sciences. Future scholarly endeavors should aspire to execute longitudinal studies that examine the effects of AR on skill retention, motivation, and learning transferability, in addition to investigating more customized AR experiences that are specifically designed to accommodate the unique needs of individual learners.

Creating structured pedagogical frameworks that connect AR technology with cognitive constructivist learning principles is crucial to achieving AR full educational potential. The financial and technological obstacles to AR integration must be overcome with increased investment in infrastructure and educator training. Furthermore, to maximize AR potential in the classroom and guarantee that it fosters engaging, active learning, cooperation between researchers, practitioners, and educational technologists is required.

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