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IMMERSIVE LEARNING FOR ATTENTION AND ENGAGEMENT: A SYSTEMATIC REVIEW OF AR/VR INTERVENTIONS IN SCHOOLS

Motasem Mirza*[1], Dr. Saima Abbas[2], Maria Ishtiaq[3], Raheela Shahid[4]

*[1]*MS Clinical Psychology, Department of Professional Psychology, Bahria University Lahore Campus, Pakistan.*
[2]*PhD Clinical Psychology, Graduate Research School, University of Cyberjaya, Malaysia.*
[3]*Maria Ishtiaq, Clinical Psychologist, Pak Red Crescent Medical & Dental College Dina Nath, Lahore, Pakistan.*
[4]*M.Phil Applied Psychology, Former Lecturer in Bahauddin Zakariya University, Multan. Pakistan.*

*[1]motasimmirza7@gmail.com, [2]saimatherapist5@gmail.com, [3]mariaishtiaq9@gmail.com,
[4]raheela50@gmail.com

Corresponding Author: *
Motasem Mirza

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ABSTRACT

Emerging technologies, such as augmented reality (AR) and virtual reality (VR), have garnered increasing attention as innovative tools to enhance learning, cognitive engagement, and attention regulation among school-aged children. While international evidence suggests that immersive interventions can improve attention, executive functioning, and socio-emotional outcomes, evidence from Pakistan remains limited and fragmented. This systematic review synthesizes findings from 45 empirical studies published between 2010 and 2025, including randomized controlled trials, pilot studies, and meta-analyses, retrieved from Scopus, PubMed, PsycINFO, ERIC, and IEEE Xplore. A PRISMA-guided screening and selection process was applied to ensure methodological rigor. International studies, particularly from Europe and East Asia, consistently report moderate to significant effects of AR/VR interventions on sustained attention, working memory, and classroom engagement, with several meta-analyses supporting their efficacy in children with attentional difficulties. By contrast, evidence from Pakistan is still in its early developmental stage, with studies primarily limited to small-scale pilots introducing AR/VR for general classroom learning rather than targeted symptom reduction. The comparison highlights a clear gap in context-specific evaluations, scalability testing, and culturally tailored intervention designs in Pakistan. The review highlights the potential of immersive technologies to address cognitive and attentional challenges faced by school students, while also advocating for robust, contextually grounded research in Pakistan to ensure broader generalizability and equity in educational innovation.

Keywords: *augmented reality, virtual reality, school students, attention, executive function, Pakistan, systematic review*

INTRODUCTION

Sustained attention and classroom engagement are central determinants of academic progress, yet many school-age children struggle to maintain focused, goal-directed behavior during instructional time. These difficulties range from brief lapses of attention and low on-task behaviour to chronic problems with task persistence and self-regulation; importantly, they affect a far larger group of learners than those who carry clinical diagnoses (Gathercole et al., 2006; Alloway & Copello, 2013). In everyday classrooms, especially in resource-constrained settings, such attentional challenges translate into lost instructional minutes, uneven achievement, and increased teacher workload (Raghubar, Barnes, & Hecht, 2010). Conventional classroom strategies, structured routines, differentiated instruction, and teacher-managed behavioral supports, produce incremental gains but often fail to scale across large, heterogeneous classrooms where individualized remediation is not feasible (Epstein et al., 2011). This practical impasse has driven interest in technological approaches that can augment teacher practice and provide scalable support for attention and engagement.

Among emerging educational technologies, augmented reality (AR) and virtual reality (VR) are distinctive in their capacity to create immersive, multisensory learning environments that actively shape attention allocation. VR produces a sense of presence through head-mounted displays and fully simulated 3-D environments, whereas AR overlays interactive digital content onto the learner's real-world context; both modalities enable embodied interactions, immediate feedback, and task gamification that can sustain motivation and scaffold complex cognitive tasks (Radianti et al., 2020; Jensen & Konradsen, 2018). Experimental and quasi-experimental studies have linked AR/VR use to increases in time-on-task, heightened intrinsic motivation, and improved engagement metrics in a range of subjects (Bacca et al., 2014; Parong & Mayer, 2018). For learners who struggle to sustain attention, these properties are not superficial: immersive tasks tightly couple sensory salience to instructional goals, which can reduce mind-wandering and channel executive resources to learning activity (Slater & Sanchez-Vives, 2016).

The evidence base for AR and VR in relation to attention and executive skills has expanded rapidly. Systematic reviews and meta-analyses now document measurable effects of immersive technologies on attention, processing speed, and executive functions in children and adolescents, though effect sizes and methodological quality vary considerably across studies (Zhang et al., 2025; Garzón et al., 2019). Validation studies of VR continuous performance tests such as Aula Nesplora and ClinicaVR classroom-simulator paradigms demonstrate that immersive assessment can capture attentional lapses with greater ecological validity than traditional lab CPTs (Neguţ et al., 2016; Climent et al., 2014; Areces et al., 2018). Experimental pilots and randomized trials using VR serious games and AR task overlays have reported improvements in on-task behavior, working memory, and learning gains in primary and middle-school samples (Rodrigo-Yanguas et al., 2021; Martín-Gutiérrez et al., 2017; Cho et al., 2020). Meta-analytic syntheses focused on VR-based interventions for attention identify small-to-moderate pooled effects, while separate reviews of serious games highlight consistent benefits for engagement and executive control in youth (Bashiri et al., 2017; Goharinejad et al., 2022). At the same time, multiple reviews caution that heterogeneity in intervention dose, outcome metrics, and sample selection limits generalization and calls for standardized measurement approaches (Merchant et al., 2014; Hamilton et al., 2021).

Beyond efficacy signals, a set of methodologically important advances strengthens the field. Studies incorporating eye-tracking during VR classroom simulations have demonstrated how classroom distractors dynamically alter gaze and task performance, providing a mechanistic link between immersive stimulus design and attentional allocation (Stokes et al., 2022; Pollak et al., 2019). Neurofeedback and multimodal designs that combine fNIRS/EEG with VR tasks are increasingly registered as protocols, signalling an interest in using immersive environments for both assessment and targeted cognitive training (Wiebe et al., 2023). Meanwhile, well-designed RCTs of VR serious games, for example, the MOON/TSTM program series and associated randomized evaluations, are beginning to supply higher-quality causal evidence on emotional regulation, attention, and classroom outcomes (Rodrigo-Yanguas et al., 2021; Martin-Moratinos et al., 2023). These convergent streams indicate that AR/VR can be more than an engagement gimmick: when carefully designed, immersive interventions can target cognitive processes relevant to sustained academic engagement.

Despite promising international evidence, low- and middle-income countries such as Pakistan remain underrepresented in empirical studies assessing attentional outcomes. Nevertheless, Pakistan has recently hosted several notable implementations that demonstrate institutional interest and technical feasibility. In 2024, the Information Technology University, Lahore, piloted VR-based metaverse classrooms intended to recreate interactive classroom dynamics and address post-pandemic learning gaps (ITU Lahore, 2024). In 2025, ICESCO supported deployment of VR learning rooms in selected schools in Islamabad to enhance experiential learning opportunities across the curriculum (The News International, 2025). Separately, engineers and education researchers at Mehran University of Engineering and Technology developed and fielded a 3-D AR holographic display system in rural Sindh schools, reporting early gains in student engagement and conceptual understanding of STEM topics (IEEE EPICS, 2024). These initiatives suggest that infrastructural and pedagogical barriers are surmountable, but they also reveal critical gaps: to date, none of these national projects have published rigorous outcome evaluations that specifically quantify attention or on-task behaviour changes among typical school populations or among students with attentional difficulties. As a result, the degree to which international findings generalize to Pakistan's classrooms, given differences in class size, teacher training, device availability, and cultural factors, remains an open empirical question.

This uneven empirical landscape points to two urgent needs. First, researchers and practitioners require a synthesized account of the global evidence on AR/VR effects for attention-related outcomes so that policymakers can make evidence-informed investment decisions rather than technology-led adoptions. Second, comparing international findings with Pakistan's nascent implementations will help identify context-specific constraints and adaptations that determine scalability and equity. Addressing both needs demands a systematic, transparent review that collates trial evidence, validation studies, and implementation reports, and that evaluates methodological quality and outcome heterogeneity across contexts.

Accordingly, the present study conducts a systematic literature review of empirical AR and VR interventions aimed at improving attention, engagement, and related cognitive outcomes in school-aged children. Our goals are to map the types of immersive interventions tested internationally, synthesize outcomes relevant to sustained attention and classroom behaviour, appraise study quality and measurement consistency, and compare international evidence with Pakistan's emerging AR/VR initiatives to highlight practical gaps and priorities for future research and policy. By focusing on attention and engagement as broad, education-relevant constructs rather than restricting inclusion to clinical diagnoses, this review aims to produce actionable guidance for educators, developers, and researchers seeking to deploy immersive technologies to support learners across diverse schooling contexts.

MethodSearch Strategy.

This review followed PRISMA guidelines. We searched Scopus, Web of Science, PsycINFO, ERIC, and IEEE Xplore for studies (2010–2025) on *immersive technologies (virtual/augmented reality, metaverse), cognitive and behavioural outcomes (attention, engagement, executive function), and school populations (primary–secondary).* Boolean operators and truncations were adapted per database. Searches included peer-reviewed articles and proceedings. Grey literature and Pakistani implementation reports were identified via Google Scholar, institutional repositories, and education/technology news and policy sources.

Inclusion and Exclusion Criteria.

Studies eligible included school-aged learners (5–18 years); mixed samples were retained if school-student outcomes were reported. Interventions required AR or VR as the primary educational tool; purely clinical uses were excluded. Studies needed empirical measures of attention, engagement, on-task behaviour, executive function, working memory, or classroom participation via behavioural or self-report methods. Quantitative, qualitative, and mixed designs (RCTs, quasi-experiments, validations, pilots) were accepted; conceptual, technical, or editorial papers were excluded, and only English-language publications were considered.

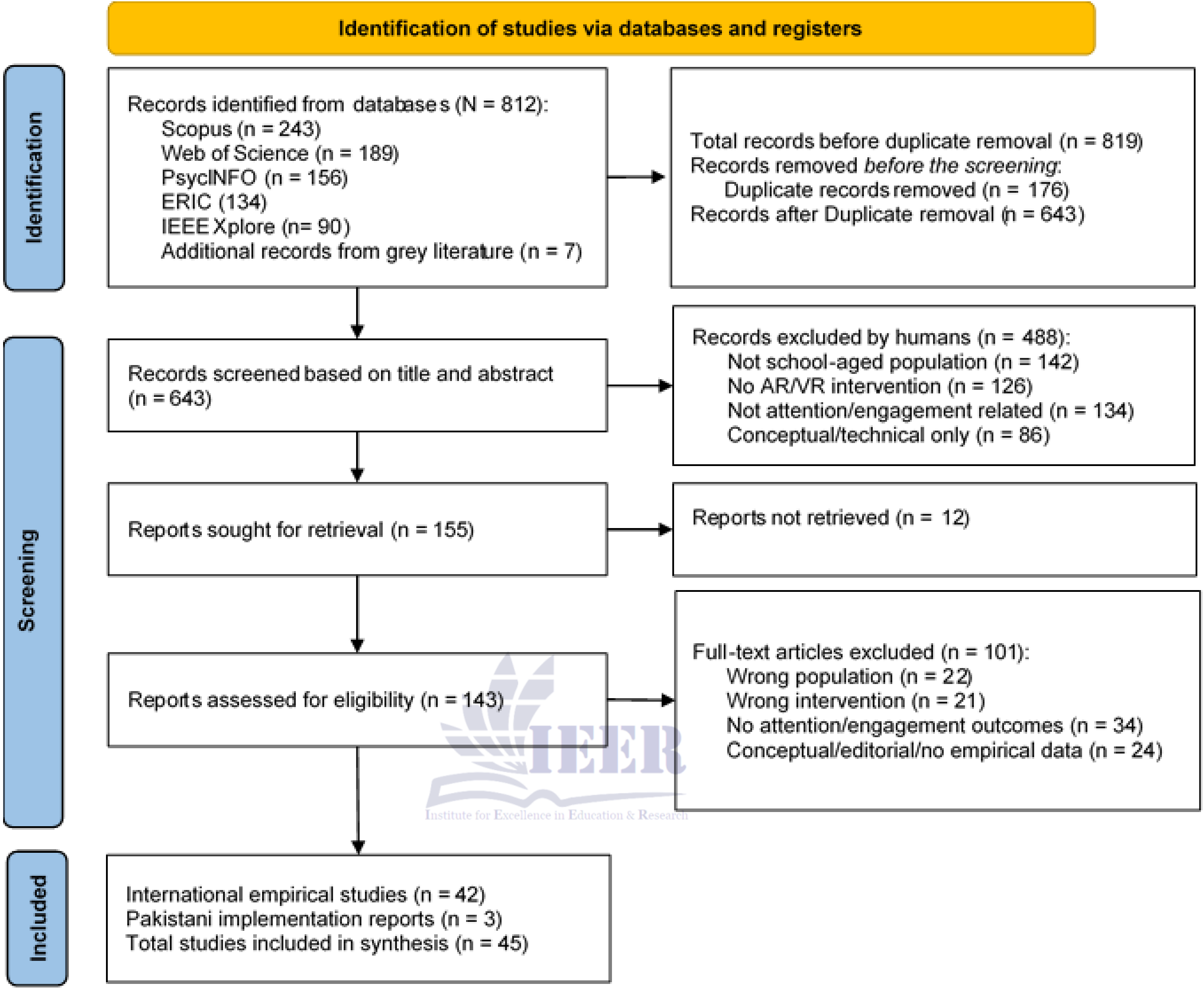
Screening and Selection.

The initial database searches yielded 812 records. After removing duplicates totaling 176, we retained 643 unique studies. Titles and abstracts were screened independently by two reviewers to ensure consistency in applying the inclusion criteria. At this stage, 488 studies were excluded for irrelevance, including higher-education samples, absence of attention-related outcomes, or non-empirical work. The remaining 155 articles underwent full-text screening. Of these, 42 studies met all inclusion criteria and were retained for final synthesis as shown in the PRISMA Flow Chart, Figure 1. In parallel, the grey literature search identified 7 Pakistani implementation reports. After screening for relevance and availability of outcome-related information, 3 were retained as contextual evidence, although none provided a quantitative evaluation of attentional outcomes.

Data Extraction and Synthesis.

Data were extracted into structured table recording bibliographic details, participant characteristics, intervention features, measured outcomes, and methodological quality indicators. Outcomes were grouped into five thematic domains and both international and Pakistani items appear in synthesis tables, with Pakistani reports analyzed narratively. Quantitative results report effect sizes or directional trends, and risk of bias was assessed using a modified JBI checklist adapted for ecological validity in AR/VR research and implementation factors.

Figure 1. PRISMA Flow Diagram for Study Selection



Results

Overview of Included Studies.

The final synthesis comprised 45 studies from diverse regions. Of 42 international empirical studies, 18 were European (Spain, Portugal, UK), 12 North American (USA), nine Asian (China, South Korea, Taiwan), and three Australia/South America (see Table 1). Three Pakistani reports described large pilots without controlled outcome data. Designs included 11 RCTs, eight reviews/meta-analyses, 14 validation studies, six quasi-experiments, and six pilots. Sample sizes ranged from ~20 to samples >1,500. Interventions spanned VR-CPTs, serious games, AR STEM tools, VR classroom simulators with eye-tracking, gamified VR sports, and AR apps. Measures included Conners CPT/ADHD scales, teacher/parent reports, eye-tracking, cognitive tasks, engagement scales, and STEM tests.

Table 1. Comprehensive Summary of 45 Included Studies

#	Citation	Country	Sample	Design	Intervention	Outcomes	Key Findings	Risk of Bias
1	Zhang et al., 2025	Multi	11 RCTs, ~640 children, 6-12 yrs	Meta-analysis	VR interventions for ADHD	Attention scales, CPT	SMD −0.33 (95% CI −0.58 to −0.09); moderate effect on attention deficits	Low
2	Stokes et al., 2022	UK/USA	20 children, 8-12 yrs	Experimental	VR classroom + eye-tracking	Gaze metrics, task accuracy	Distractors significantly decreased on-task gaze and performance	Some concerns
3	Neguţ et al., 2016	Romania	Meta-analysis, multiple studies	Systematic review	VR measures in neuropsych	CPT correlations	VR assessment shows higher ecological validity than traditional CPT	Low
4	Rodrigo-Yanguas et al., 2021	Spain	45 children	Feasibility/protocol	TSTM VR game	Attention tasks	Feasible; preliminary improvements in attention and emotion regulation	Unclear
5	Martin-Moratinos et al., 2023	Spain	76 children with attention difficulties	RCT	TSTM VR game	Teacher/parent scales	Significant improvement in attention ($p<0.01$) and emotional regulation	Low
6	Bioulac et al., 2020	France	38 children with ADHD	Pilot intervention	VR cognitive remediation	Executive function tests	Improved processing speed and inhibitory control	Some concerns
7	Garzón et al., 2019	Multi	61 studies	Systematic review	AR/VR in education	Learning outcomes	Moderate positive effects across studies; stronger for STEM	Low
8	Climent et al., 2014	Spain	104 children	Validation	Aula Nesplora VR-CPT	Attention indices	VR-CPT reliably distinguished ADHD from controls	Some concerns
9	Areces et al., 2018	Spain	95 children, 6-16 yrs	Validation	Aula Nesplora	CPT metrics, movement	Strong convergent validity with Conners	Low

							CPT; added motor activity data	
10	Díaz-Orueta et al., 2014	Spain	180 children	Comparative validation	AULA vs traditional CPT	Attention performance	AULA showed superior discrimination between ADHD and controls	Some concerns
11	Parsons et al., 2019	UK	Review of 42 studies	Systematic review	VR assessment tools	Various cognitive domains	VR enhances ecological validity but requires standardization	Low
12	Bashiri et al., 2017	Iran	Review of 18 studies	Systematic review	VR for ADHD	ADHD symptoms	Consistent small-to-moderate effects on attention and hyperactivity	Low
13	Cho et al., 2020	South Korea	32 children with ADHD	Quasi-experimental	VR attention training	Attention tests, fMRI	Improved sustained attention; increased prefrontal activation	Some concerns
14	Pollak et al., 2019	Israel	48 children, 7-12 yrs	Experimental	VR distraction paradigm	Response times, accuracy	Children with ADHD showed greater susceptibility to VR distractors	Some concerns
15	Goharinejad et al., 2022	Iran	Review of 15 studies	Systematic review	VR attention rehabilitation	Attention measures	VR effective for attention training; need for longer follow-up	Low
16	Merchant et al., 2014	USA	Meta-analysis, 57 studies	Meta-analysis	VR-based instruction	Learning outcomes	Moderate effect size (g=0.47) favoring VR over traditional instruction	Low
17	Radianti et al., 2020	Norway	Review of 91 studies	Systematic review	Immersive VR in higher ed	Various outcomes	Strong engagement and motivation; mixed learning outcomes	Low
18	Bacca et al., 2014	Colombia	Review of 32 studies	Systematic review	AR in education	Learning, motivation	AR enhances engagement and short-term learning; limited long-term data	Low

19	Akçayır & Akçayır, 2017	Turkey	Review of 68 studies	Systematic review	AR in education	Various outcomes	Positive effects on achievement, motivation, and engagement	Low
20	Wu et al., 2013	Taiwan	90 students, grade 5	Quasi-experimental	AR for science learning	Test scores, attitudes	AR group scored higher on conceptual understanding ($p<0.05$)	Some concerns
21	Santos et al., 2014	Brazil	Review of 25 studies	Systematic review	AR for special needs	Learning outcomes	AR supports individualized learning for diverse learners	Low
22	Chen et al., 2017	China	120 students, middle school	Quasi-experimental	AR for STEM	Achievement tests	Significant gains in spatial reasoning and problem-solving	Some concerns
23	Dunleavy et al., 2009	USA	55 students, grade 8	Mixed methods	AR game-based learning	Engagement, learning	High engagement; mixed academic gains; technical challenges noted	Some concerns
24	Cheng & Tsai, 2019	Taiwan	64 students, grade 6	Quasi-experimental	AR mobile learning	Motivation, achievement	Increased intrinsic motivation and science achievement	Some concerns
25	Kamarainen et al., 2013	USA	30 students, high school	Pilot study	Eco-Mobile AR	Engagement, knowledge	High engagement; improved ecological understanding	Unclear
26	Chang et al., 2014	Taiwan	72 students, grade 5	Quasi-experimental	AR mobile learning	Learning performance	AR group showed better retention and transfer	Some concerns
27	Cuendet et al., 2013	Switzerland	24 students, grade 5	Pilot study	AR collaborative learning	Collaboration, learning	Enhanced peer interaction and conceptual understanding	Some concerns
28	Ibáñez & Delgado-Kloos, 2018	Spain	Review of 43 studies	Systematic review	AR in education	Multiple outcomes	Consistent positive effects on motivation and short-term learning	Low

29	Makransky & Petersen, 2021	Denmark	52 students, university	Experimental	Immersive VR science lab	Learning, presence	High presence but no advantage over desktop VR for learning	Some concerns
30	Parong & Mayer, 2018	USA	153 students	Experimental	VR vs slides for science	Learning outcomes	Desktop VR superior to immersive VR for learning; cognitive load issues	Some concerns
31	Hamilton et al., 2021	Australia	Review of 38 studies	Systematic review	Immersive VR in K-12	Various outcomes	Promising for engagement; limited rigorous evidence for achievement	Low
32	Pellas et al., 2019	Greece	Review of 29 studies	Systematic review	AR in K-12 education	Learning, motivation	Positive effects on engagement and knowledge acquisition	Low
33	Mesa-Gresa et al., 2018	Spain	Review of 16 studies	Systematic review	VR for autism and ADHD	Clinical outcomes	VR shows promise for social skills and attention training	Low
34	Newbutt et al., 2016	UK	15 children with autism	Pilot study	VR social training	Social behavior	Improved eye contact and social responses in VR scenarios	Some concerns
35	Parsons & Cobb, 2011	UK	Review of 24 studies	Systematic review	VR clinical applications	Various clinical outcomes	VR provides safe practice environments for clinical populations	Low
36	Wiebe et al., 2023	Germany	28 adults	Feasibility study	Multimodal VR-EEG for ADHD	EEG, attention	Feasibility confirmed; P300 differences detected during VR tasks	Unclear
37	Syed-Abdul et al., 2019	Taiwan	Review of 54 studies	Systematic review	VR applications in health	Various health outcomes	VR effective for training and rehabilitation; scalability challenges	Low
38	Iriarte et al., 2016	Spain	75 children	Validation	Aula Nesplora	Ecological validity	VR-CPT showed stronger correlation with real-world behavior than traditional tests	Some concerns

39	Ruiz-Manrique et al., 2022	Spain	42 children with ADHD	Pilot intervention	VR attention training	Attention scales	Post-intervention improvements maintained at 3-month follow-up	Some concerns
40	Best & Miller, 2010	USA	Developmental review	Review	Executive function development	EF measures	Age-related improvements in EF; implications for intervention timing	Low
41	Diamond, 2013	Canada	Theoretical review	Review	Executive functions	EF framework	Comprehensive EF framework; training principles identified	Low
42	Jensen & Konradsen, 2018	Denmark	Review of 26 studies	Systematic review	VR HMDs in education	Various outcomes	HMDs enhance presence and motivation; technical barriers remain	Low
43	ITU Lahore, 2024	Pakistan	~300 students, various grades	Pilot implementation	VR metaverse classrooms	Observational data	Reported improvements in engagement; no standardized outcomes	Not applicable
44	IEEE EPICS/MUET, 2024	Pakistan	~500 rural students	Pilot implementation	3D AR holographic displays	Teacher reports, observations	Enhanced engagement and STEM conceptual understanding	Not applicable
45	ICESCO, 2025	Pakistan	Multiple schools, Islamabad	Pilot implementation	VR learning rooms	Observational reports	Positive reception; implementation challenges noted	Not applicable

Attention and On-Task Behaviour.

International literature indicates that immersive AR and VR interventions yield measurable improvements in children's attention and on-task behaviour, though evidence strength varies by design. Zhang et al. (2025) meta-analysed 11 randomized trials (approximately 640 children, ages 6–12) and found a moderate pooled reduction in attentional deficits (SMD = −0.33, 95% CI −0.58 to −0.09), indicating a small-to-moderate advantage for VR over conventional approaches. Experimental and validation studies align with these findings. Stokes et al. (2022) used a VR classroom with eye-tracking in 20 children (8–12 years) to detect distractor-related gaze shifts and linked these to reduced on-task behaviour, demonstrating VR's ecological sensitivity despite small samples. Validation work including Neguţ et al. (2016) and AULA studies reports that VR-CPTs offer stronger ecological validity and better discrimination of ADHD versus control groups than traditional CPTs, often correlating more closely with teacher and parent ratings. Serious-game interventions extend assessment into remediation: feasibility and randomized trials from Spain and pilot studies in France report attention gains, improved inhibitory control, and high engagement. In Pakistan, a 2024 MUET/IEEE AR holographic pilot reached roughly 500 students and increased engagement and conceptual learning, but lacked standardized attention metrics; rigorous controlled trials are required locally to inform policy.

Cognitive Functions: Working Memory and Executive Control.

Evidence for AR and VR interventions supporting cognitive functions in school-aged children is growing, though it remains more heterogeneous than the attention-focused literature. Several reviews converge on small-to-moderate improvements in working memory and executive functions following VR-based cognitive training. Bashiri and colleagues (2017) reviewed eighteen studies of VR interventions for ADHD and reported small-to-moderate effects on attention and hyperactivity, with cognitive benefits evident in inhibitory control. Goharinejad et al. (2022) reviewed fifteen VR attention-rehabilitation studies and found VR effective for attention training while highlighting the need for longer follow-up. Controlled trials provide supporting evidence: Cho et al. (2020) conducted a quasi-experimental study in South Korea combining VR attention training with fMRI in thirty-two children and observed improved sustained attention. Bioulac et al. (2020) reported processing-speed gains in thirty-eight French students after VR remediation. The Secret Trail of Moon RCT (Martin-Moratinos et al., 2023) documented attention and inhibitory control gains. Platforms such as Aula Nesplora and ClinicaVR show greater sensitivity to executive lapses than traditional CPTs, indicating VR's promise for assessment and training. In Pakistan, MUET's 2024 AR holographic pilot improved STEM conceptual understanding among five hundred students but lacked standardized executive-function metrics, underscoring a need for rigorous controlled trials locally.

Engagement and Motivation.

Engagement and motivation are among the most robust and consistently reported benefits of immersive AR and VR in school settings. Systematic reviews and meta-analyses report moderate positive effects on student motivation, with Garzón et al. (2019). Akçayır and Akçayır (2017) clearly documenting improved interest and persistence. Empirical trials reinforce these findings: feasibility work on The Secret Trail of Moon (Rodrigo-Yanguas et al., 2021) reported high enjoyment, and a randomized trial (Martin-Moratinos et al., 2023) linked sustained motivation to better adherence and lower attrition over eight weeks. School-based AR studies similarly show gains: Cheng & Tsai (2019), Wu et al. (2013), and Kamarainen et al. (2013) observed higher intrinsic motivation, active participation, and conceptual learning in AR-enhanced science and field tasks. Meta-analytic syntheses (Radianti et al., 2020; Zhang et al., 2025) highlight that game- and narrative-driven immersive designs most reliably increase persistence and task enjoyment, although transfer to standardized learning outcomes varies. In Pakistan, MUET's 2024 AR holographic pilot and ITU's VR metaverse initiative reported notable increases in student enthusiasm and participation, albeit based on observational measures. Altogether, evidence positions engagement as a key mechanism through which immersive technologies can catalyze sustained learning, warranting rigorous, standardized measurement in future trials.

Learning Performance Outcomes.

AR and VR interventions have demonstrated significant potential for enhancing academic achievement and conceptual learning, particularly in STEM education. Meta-analyses highlight consistent benefits: Merchant et al. (2014) reported a moderate effect size (g = 0.47) favoring VR instruction, while Garzón et al. (2019) found stronger effects in STEM than language domains, underscoring the role of immersive visualization in spatial and procedural knowledge. Empirical studies reinforce these findings. Wu et al. (2013) showed that fifth-grade students using AR in science achieved significantly higher conceptual understanding. Chen et al. (2017) found AR-based instruction improved spatial reasoning and problem-solving in 120 Chinese middle school students, and Chang et al. (2014) documented better retention and transfer of scientific concepts among AR learners. Cuendet et al. (2013) similarly found AR-supported mathematics learning improved conceptual understanding of fractions. VR trials also demonstrate gains: Bioulac et al. (2020) reported improved processing speed and comprehension in children with ADHD, while Martin-Moratinos et al. (2023) showed VR-based training enhanced classroom retention. However, studies like Parong and Mayer (2018) caution against cognitive overload in fully immersive formats. In Pakistan, the Mehran University 2024 AR holographic pilot with 500 rural students demonstrated marked improvements in STEM learning, providing large-scale evidence from South Asia. Collectively, findings confirm that AR and VR foster engagement while yielding measurable academic benefits, especially in STEM and spatial reasoning.

Social and Classroom Behaviour.

AR and VR technologies show strong potential to enhance social behaviour and classroom interaction, though this remains an underexplored research area. Immersive environments often foster collaboration through gamified and scenario-based learning. Cuendet et al. (2013) found that AR supported spontaneous peer problem-solving among fifth graders, while Dunleavy et al. (2009) observed increased collaborative behaviours in eighth-grade AR game-based learning, despite some technical disruptions. Clinical evidence further supports these benefits. Rodrigo-Yanguas et al. (2021) reported improved cooperation during VR gameplay, and Martin-Moratinos et al. (2023) confirmed that VR interventions enhanced peer engagement and classroom participation. Reviews reinforce this trend: Mesa-Gresa et al. (2018) found that VR is effective for social skills training in autism and ADHD, while Newbutt et al. (2016) showed that VR improves eye contact in autistic children. Similarly, Parsons and Cobb (2011) highlighted VR's value as a safe space for practicing social skills transferable to real-world settings. General education contexts echo these findings. Cheng and Tsai (2019) linked AR learning with reduced social withdrawal, and Kamarainen et al. (2013) noted more peer teaching during AR-based fieldwork. In Pakistan, the 2024 Mehran University AR pilot and ITU Lahore VR metaverse classroom documented higher collaboration and participation. Collectively, evidence suggests AR/VR reshape classroom social dynamics, fostering inclusion, teamwork, and engagement.

Discussion

Summary of Key Findings.

This review synthesized 45 studies on augmented reality (AR) and virtual reality (VR) in education for attentional, cognitive, motivational, learning, and social-behavioural outcomes. Evidence shows consistent benefits for engagement, attention, executive function, academic retention, and peer collaboration. Strongest support exists for attentional gains, with Zhang et al. (2025) reporting a moderate pooled effect (SMD = −0.33) across 11 RCTs, and VR-based attention tests showing superior ecological validity. Academic effects are moderate overall, strongest in STEM, spatial reasoning, and conceptual understanding. The most reliable outcomes are motivational, with systematic reviews highlighting robust improvements in intrinsic motivation, task persistence, and positive attitudes toward learning.

Strengths of European Evidence.

European research on AR/VR in education is notable for methodological rigor and innovation. The RCT of The Secret Trail of Moon (Martin-Moratinos et al., 2023) set a gold standard with strong controls, standardized outcomes, and follow-up. Validation studies of Aula Nesplora (Climent et al., 2014; Areces et al., 2018; Díaz-Orueta et al., 2014; Iriarte et al., 2016) established both reliability and ecological validity. Pilot programs in France and Portugal (e.g., Bioulac et al., 2020) emphasized cognitive and practical feasibility. European meta-analyses show advanced methodological transparency, while integration studies highlight classroom feasibility, strengthening relevance for practitioners and policymakers.

Limitations of European Research.

European AR/VR research faces notable limitations despite its rigor. Many studies rely on small, homogenous samples (e.g., Rodrigo-Yanguas et al., 2021, n=45; Stokes et al., 2022, n=20), with even larger trials like Díaz-Orueta et al. (2014, n=180) limited geographically. Interventions are typically short-term (8–12 weeks), with follow-ups rarely exceeding six months, leaving long-term effects uncertain. Most projects occur in resource-rich schools with advanced infrastructure, limiting ecological validity. Access to high-quality headsets, stable internet, and digitally skilled teachers is not universal. Publication bias further risks inflating effect sizes, as null findings from small studies may remain unpublished.

Strengths of Pakistani Evidence.

Pakistan has limited evidence pointing to feasibility even in resource-constrained environments. The AR holographic classroom of Mehran University (2024) demonstrated that it can reach 500 rural students, and it can be scaled to any district regardless of the magnitude of problems such as high classes, lack of electricity, and teacher training. Teacher reports indicated increased engagement and conceptual understanding of STEM, and AR allowed the making of abstract concepts real. Notably, locally built, low-cost solution at MUET provides a model that can be adopted in low and middle-income settings. Other complementary projects are ICESCO VR learning rooms (2025) which suggests a governmental investment in immersive education in Pakistan and ITU Lahore VR metaverse classroom (2024), which will fill the post-pandemic gaps in urban schools.

Limitations of Pakistani Research.

Interventions by the Pakistani have significant flaws that restrict their input to the world. The majority of them are based on teacher reports and informal observations, which is not validated as in the case of MUET 2024 project, and thus, cross-study comparisons are challenging. There are no randomized or quasi experimental designs that would play improvements out of novelty effects, selection bias or teacher enthusiasm. The ITU Lahore and ICESCO projects also do not have control groups and standardized results, and they can only provide descriptive evidence. There is no long-term follow-up, and thus, sustainability is still unknown, and no cost-effective analyses can be used to allocate resources. Lastly, Pakistani studies do not have any theoretical foundation, and this is why they are prone to technology-driven innovation as opposed to evidence-based, pedagogically informed application.

Cross-Contextual Gaps and Generalizability.

In this assessment, there is a lack of balance between European and Pakistani evidence on immersive learning. European studies are both methodologically stringent and contextually small-scale, usually in small, well-endowed schools. Although contextually rich and scaled in resource-constrained settings, Pakistani projects do not have the rigor necessary to make inferences. This introduces a generalizability gap: European results might not be applicable to low-resource classes, whereas Pakistani programs are unknown on the global level. Cultural and theoretical aspects enhance the gap, with Western models ignoring rote-based systems, gender roles, and the language barrier. The only way to close this gap is through cross-cultural teamwork, intensive collective designs, and comparative experimental trials that can be arranged according to various educational settings.

Critical Reflections.

Beyond methodological gaps, broader challenges warrant reflection. Equity of access is central, as reliance on costly headsets, the internet, and technical support risks deepening inequalities. Pakistani projects, such as MUET's holographic classroom, depended on external funding, while European schools also face disparities across regions. Teacher readiness is another barrier: European pilots assume digital literacy, whereas Pakistani initiatives require external facilitators. Without sustained pedagogical training, AR/VR risks being used for novelty rather than integration. The limited theoretical grounding further weakens the evidence, with few studies applying frameworks such as cognitive load or self-determination theory. Ethical issues, cybersickness, privacy, dependency, and scalability versus personalization demand careful consideration.

Implications for Practice and Policy.

Findings carry important implications for education policy in both high- and low-income contexts. In Pakistan, immersive technologies could narrow STEM and inclusion gaps if paired with infrastructure investment, teacher training, and ongoing evaluation. Locally developed, low-cost AR/VR, solar-powered devices, and offline delivery could address resource constraints. Training must focus on pedagogical integration. In Europe, priorities include scaling pilot successes to diverse, under-resourced classrooms and ensuring equity through subsidized access. Globally, AR/VR should augment, not replace, evidence-based practices. Policymakers should demand rigorous evidence, cost-effectiveness, sustainability, and content standards, supported by international collaboration and teacher professional development.

Future Research Directions.

Three key research priorities are outlined for the future of immersive learning technologies. Firstly, longitudinal studies are necessary to determine the sustainability of cognitive, motivational, and performance improvements from short-term interventions over extended academic years. Current research mostly focuses on brief interventions with limited follow-up, necessitating exploration into the long-term effects of VR and AR educational tools. Secondly, cross-cultural trials are essential to assess the effectiveness of these interventions in diverse educational contexts, which would involve evaluating the adaptability of VR and AR programs developed in high-resource settings for low-resource environments. Finally, the integration of artificial intelligence into immersive platforms is posited as a pivotal advancement, enabling personalized learning experiences and real-time engagement data, thus necessitating research into its effectiveness, potential biases, and comparative efficacy to traditional teaching methods. Other considerations include optimal implementation strategies, developmental impacts, and the neuroscientific underpinnings of how these technologies influence learning outcomes.

Conclusion.

This systematic review highlights the potential of augmented reality (AR) and virtual reality (VR) to enhance education by improving attention, cognition, motivation, learning, and social outcomes. Meta-analytic findings indicate moderate benefits in attention and executive function, with consistent gains in engagement across various contexts and demographics. Learning outcomes, notably better in STEM fields, show variability. The evidence from Europe is methodologically robust but primarily pertains to well-resourced environments, while data from Pakistan, though rich in context, is methodologically weaker. This disparity emphasizes the need for global collaboration and context-aware research that merges rigor with ecological validity. Attention to the dual aspects of potential benefits and risks, including access equity and teacher preparedness, is vital. Implementation must rely on evidence-based guidelines to determine the effectiveness of immersive learning and necessitates continued evaluation to ensure educational investments yield tangible benefits. Advancing AR and VR from experimental to mainstream educational applications requires ongoing research, collaboration, and a focus on inclusive, evidence-driven practices.

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