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Embracing Augmented Reality and Virtual Reality in South African Basic Education: A Systematic Literature Review

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Abstract. This study reviews the integration of augmented reality (AR) and virtual reality (VR) in South African basic education. To investigate how immersive technologies are applied in teaching and learning, focusing on learner outcomes, teacher preparedness and systemic enabling conditions. The systematic literature review (SLR) was guided by Preferred Reporting Items for Systematic Reviews and Meta-analyses (PRISMA) and Systematic Procedures and Rationales for Systematic Literature Reviews (SPAR-4-SLR) frameworks and analysed 22 studies from journal articles, conference papers and theses published between 2018 and 30 September 2025. AR and VR adoption remains uneven and largely experimental, with implementation concentrated in urban and better-resourced facilities, particularly within STEM-related subjects. Browser-based simulations, low-cost virtual laboratories and mobile applications were the most frequently reported technologies, while fully immersive VR deployments were limited due to the financial and infrastructural constraints. Also, immersive technologies can improve experiential learning, conceptual understanding and learner engagement. Adoption is constrained by policy limitations, inadequate infrastructure, unequal access between rural and urban schools and insufficient teacher training. Synthesising fragments evidence and interpreting adoption patterns through the Technology Acceptance Model (TAM), Unified Theory of Acceptance and Use of Technology (UTAUT) and Theory of Planned Behavior (TPB). There is a need for context-sensitive implementation strategies, infrastructural investment and improved teacher development to support AR/VR integration.

Keywords: systematic literature review, augmented reality, virtual reality, South African basic education, teacher preparedness

1. INTRODUCTION

The educational practices in the whole world have faced a paradigm shift due to the fourth industrial revolution (4IR) technologies; schools have been made to reimagine the pedagogical approaches by the integration of technologies such as augmented reality (AR) and virtual reality (VR). In South Africa, where educational disparities are still persistent due to historic, socio-economic, and infrastructural inequality, 4IR has democratized access to quality education; in addition, it has advocated for a turnaround period informed by the integration of social, digital and economic divergence driven by technological advancements [1], [2]. This has informed a paradigm shift in education, encouraging the introduction of AR and VR applications in teaching and learning activities with the aim of equipping learners with creative and collaborative skills, problem-solving skills and critical thinking skills [3].

According to extant reviews, AR and VR can enhance spatial understanding, immersive simulations and student participation across various subjects, which may stem from STEAM, History and even language subjects [4], [5], [6], [7], [8]. Therefore, aligning education with 4IR technologies highlights the importance of teaching students to navigate volatile, ambiguous complex and resource-constrained environments using AR/AV [9], [10]. This is however determined by teaching and learning activities involved, student acceptance, teacher preparation and reliable infrastructure [11], [12].

Immersive technologies such as AR and VR in education in South Africa's basic education are still in its formative stages [8]. Various pilot application development and testing initiatives are being done in teaching and learning activities. Examples include Merge Cube, Google Expeditions, phone-based 360 degrees and other mobile AR applications [12]. Studies show that VR has been successfully integrated into higher and tertiary education, training colleges, but implementation in basic education is still very low due to the deficits in infrastructure, teacher development and lack of supporting policies [13], [14]. Their study [13] states that only a fraction of the reviewed literature addressed primary school teachers' perspectives of VR, revealing an empirical gap in discussing how AR/VR are perceived and utilised in basic education. South African schools are faced with the underutilisation of robust context to explain how AR/VR influences educational outcomes in diverse contexts. Studies like [13] discuss constructivist and experimental learning applications, but still, there is limited theorisation that accounts for the socio-technical dynamics of technological implantation in under-resourced schools. In addition, most empirical investigations we came across are isolated studies or pilot implementations with limited discussion on comparative analyses that could inform scalable policy and practice [2], [17].

The purpose of the study is to investigate the application of AR/VR in South African basic education and to uncover the impact they have on teaching and learning activities. Factors such as learner achievement, teacher engagement, curriculum alignment and inclusivity are expected to be improved. AR superimposes digital content from sound and visuals onto the real world, enhancing interactive and engaging experiences [13], [16]. VR uses multisensory inputs such as images and computer graphics to immerse students in simulated environments, allowing them to experience imaginary learning in an environment where all explorations and simulations are replacing physical engagements such as laboratory and surgical experiments [17]. The two technologies have improved cognitive development goals, especially in subject areas such as natural science, arts, history, language instruction and geography [9], [13].

The study aims to study the patterns, gaps, and theoretical foundations that can inform future research, teacher development and policy formulation by answering these research questions:

1) Which AR/VR platforms and applications are mostly used in basic education in SA?
2) What are the reasons for or for not applying for the AR/VR application in basic education in SA?
3) Which subjects are most taught in conjunction with AR/VR applications?

The study addresses the gap in the literature by systematically synthesizing evidence on immersive technology adoption specifically within South African basic education, where implementation remains fragmented and undertheorised. While extant studies [8], [12]. demonstrate the pedagogical potential of immersive technologies, there is limited evidence on how contextual factors such as policy environments, infrastructure inequality and teacher preparedness shape adoption in South Africa (S.A.). Therefore, this study aims to provide a structured synthesis of empirical evidence on AR/VR adoption using PRISMA and SPAR-4-SLR protocols. The study contributes by revealing contextual barriers, dominant applications and adoption patterns through the lenses of TAM, UTAUT and TPB while acknowledging that the evidence base is limited and largely piloted. The following sections are presented as theoretical development follows the introduction; methodology then follows. Results, discussions, and recommendations will be the subsequent sections; limitations, future studies and conclusions will be presented in their order.

2. METHODS

2.1. Theory development

This SLR adopts three theories to underpin a thorough investigation of AR/VR applications in SA basic education. The frameworks guide the inquiry to understand how teachers and students perceive, adopt and utilised these 4IR technologies in teaching and learning activities. The Technological Acceptance Model (TAM) postulates that perceived usefulness and perceived ease of use are the key factors for technology adoption [18]. In AR/VR these constructs have shown that teachers' attitudes towards these emerging technologies are informed by their perceived pedagogical value and usability [13], [16]. For example, teachers in rural schools expressed interest in VR's potential to improve science instruction, although they were skeptical due to costs, instructor training and infrastructure.

The Unified Theory of Acceptance and Use of Technology (UTAUT) adds other constructs such as social influence and facilitation conditions where technology uptake is influenced by policy frameworks, institutional support, peer collaboration and the push to equal access to technology [15], [19]. The issues of poor infrastructure, diverse linguistics, unequal access, cultural background and policy frameworks keep popping up as the major barriers to the full implementation of major technological advancements in South African schools [2], [16]. These findings underscore the need for systemic support in promoting sustainable implantation of immersive technologies.

The Theory of Planned Behaviour (TPB) adds the role of behavioral intentions, subjective norms, perceived behavioral control and attitudes as factors that affect the application of technologies [20]. [21] posits that preservice teachers' intention to apply VR as their teaching tools was significantly influenced by perceived behavioral control and their attitude, implying that on top of their confidence, if they get adequate training, their future engagement with immersive tools will be shaped. [13] stressed that teachers need professional development and collaborative teaching plans to effectively adopt VR into their pedagogical activities.

Combining the three theories informs the proposal of an integrated framework that can be employed to examine AR/VR adoption and consequently, application in South African schools. The resulting framework is expected to account for contextual, institutional and individual factors that affect the integration of technology and provides a comprehensive template for analysing thematical findings as well as guiding future research. The TAM, UTAUT and TPB underpin our SLR, aiming to move beyond mere descriptive accounts of AR/VR applications towards a deeper understanding of the practices, perceptions and conditions that shape their pedagogical impact. Theoretical inquiry helps the study to identify gaps in literature as well as offer a strategic lens for developing interventions and policies and initiating training programs that can harness the potential of emerging technologies in SA education.

2.2. Systematic Literature Review Approach

The study employed the SLR approach to explore the applications of AR/VR in basic education in SA. The review was guided by PRISMA to ensure transparency and reproducibility and SPAR-4-SLR was used to structure the review process and ensure rigor and clarity in reporting. The search strategy employed a keyword search with Boolean operators to guide the outcome of articles. Keywords and phrases that were searched are "augmented reality" AND "South Africa education"; "virtual reality" AND "South Africa education"; "virtual reality" AND "South Africa teaching and learning"; "augmented reality" AND "South Africa teaching and learning"; "virtual reality" OR "augmented reality" AND "primary schools"; and "virtual reality" OR "augmented reality" AND "secondary schools." Databases that were searched include Scopus, ERIC, IEEE Xplore and the Google Scholar search engine was also used to complement the limited literature on the application of AR/VR in basic education in South Africa [13]. In addition to supporting limited literature, Google Scholar produces grey literature such as theses and conference papers that usually capture emerging insights. Manual backward and forward citation tracking was also applied to identify additional studies from the reference lists of included articles [22]. Table 1 presents the inclusion and exclusion criteria applied to select the articles to be analysed.

Table 1. Inclusion and exclusion criteria

Criteria	Inclusion	Exclusion
Population	South African primary and secondary schools, learners, teachers and preservice teachers	South African higher and tertiary education or non-South African basic education
Intervention	AR/ VR technologies in teaching and learning	Immersive technologies in non-teaching areas, other ICT technologies in teaching and learning
Results	Empirical studies from pedagogical impact, preparedness, perception and integration, content analysis, literature review/ synthesis	SLR articles
Publication type	Peer-reviewed journal articles, conference papers, book chapters and theses	Blog posts, editorials and non-academic reports
Time period	2018-September 2025	Published before 2018 or after September 2025

The study included conference papers, book chapters, theses and preservice teacher studies as presented in T able 1 because AR/VR in South African basic education remains an emerging area. Much of the evidence is pilot-oriented and exploratory, with many important studies reported in postgraduate research and scholarly book chapters. In addition, preservice-teacher literature provide valuable insights into technology readiness, future implementation capacity and behavioural intention which are directly relevant to understanding AR/VR adoption in basic education setting [21], [22], [23], [32], [33]. The PRISMA protocol in Figure 1 shows the selection flow of the combined studies.

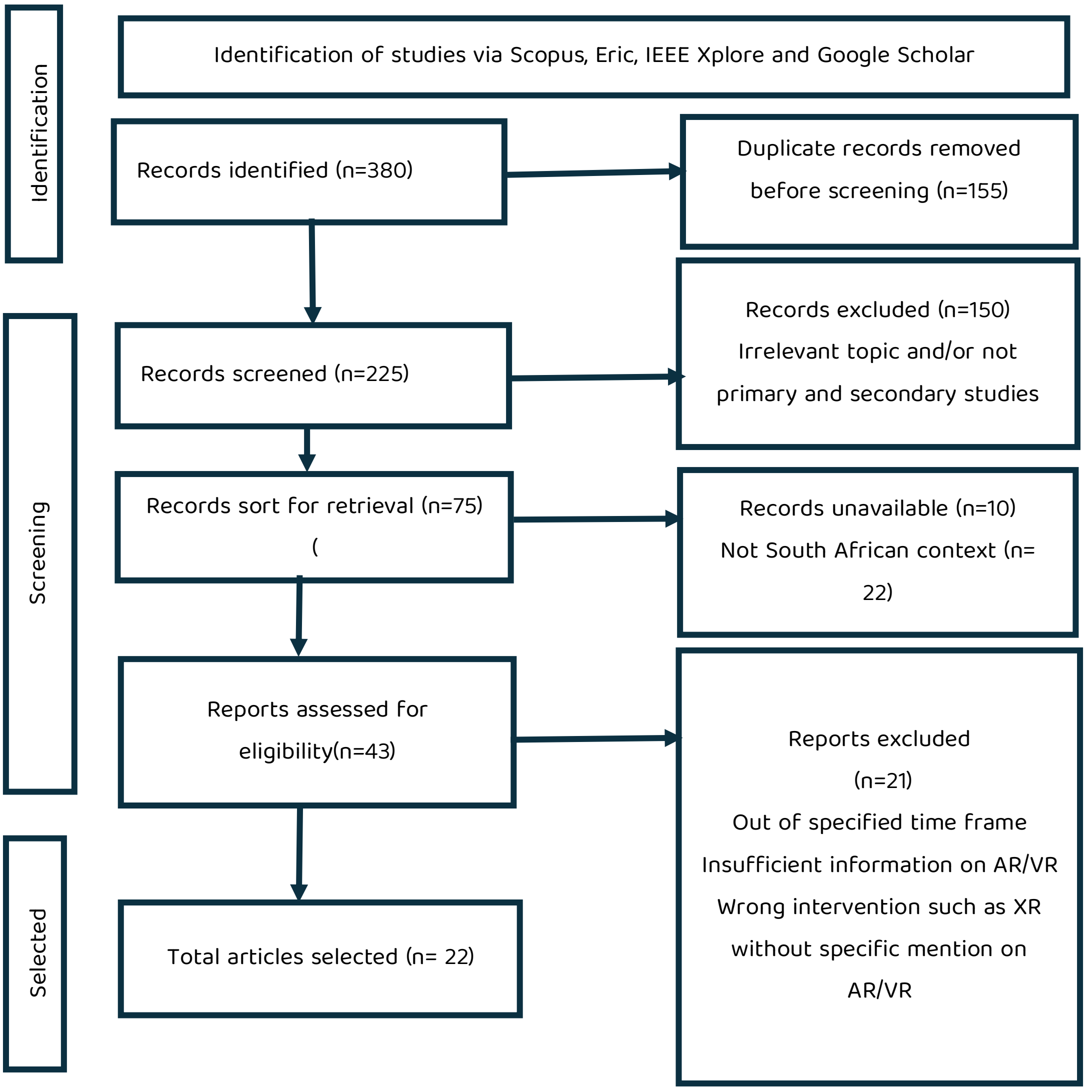


Figure 1. PRISMA flow chart

The PRISMA flow diagram in Figure 1 shows the systematic and transparent selection of studies included in this SLR. 380 records were identified across Scopus, IEEE Xplore, ERIC and Google Scholar, reflecting a broad search strategy designed to capture both peer-reviewed and emerging literature. 155 studies were removed because of duplication and 225 remained for screening. This indicates a substantial overlap across databases due to the inclusion of Google Scholar. After the screening, 150 studies were excluded due to irrelevance to the research scope; most studies focused on a higher education, non-South African context, or unrelated technological interventions. Of 75 studies sorts for retrieval 32 were not found, leaving 43 studies to be assessed to check for eligibility through full-text review and 21 were discarded, leading to the inclusion of 22 studies for review. The database search string and summary illustrating the above PRISMA screening summary is presented in Table 2.

Table 2. Database Search and screening summary

Database	**Search string (example)**	**Records retrieved**	**Duplicates removed**	**Screened records**	**Excluded records**	**Final included**
Scopus	"Virtual reality" OR “augmented reality” AND "primary schools"; "augmented reality" AND “South Africa education”; “virtual reality” AND “South Africa education”	95	38	57	49	8
IEE Xplore	"Virtual reality" OR “augmented reality” AND “secondary schools"; "virtual reality" OR “augmented reality” AND "primary schools"	50	29	21	21	0
ERIC	"Augmented reality” AND “South Africa education”; "virtual reality” OR “augmented reality” AND “secondary schools"; "virtual reality" OR “augmented reality” AND "primary schools"; "virtual reality" AND “South Africa teaching and learning”	57	21	36	34	2
Google Scholar	"Augmented reality” AND “South Africa education”; “virtual reality” AND “South Africa education”; "virtual reality” AND “South Africa teaching and learning”; “augmented reality” AND “South Africa teaching and learning”	176	67	106	99	10

Database	Search string (example)	Records retrieved	Duplicates removed	Screened records	Excluded records	Final included
Citation tracking		2	0	2	0	5
Total		380	155	225	203	22

Table 2 presents a database-level retrieval and screening outcomes. As presented in the table the Google scholar contributed a substantial number from the search but could not beat the Scopus to the final selection. The total number of the selected pool of studies shows that there is limited and fragmented research on AR/VR in South African basic education. This is one of the reasons why the theses and conference papers were included. This demonstrates that there is still need for rigorous peer-reviewed journals with empirical research on AR/VR in primary and secondary schools in S.A. However, the theses were selected after checking that they were published after examined by reputable institutional committees and the grey literature included had empirical data. The AACODS (Authority, Accuracy, Coverage, objectivity, Date, Significance) criteria were used to evaluate Theses and conference papers for credibility [23]. Table 3 shows the criteria for assessing the credibility of the theses and conference papers.

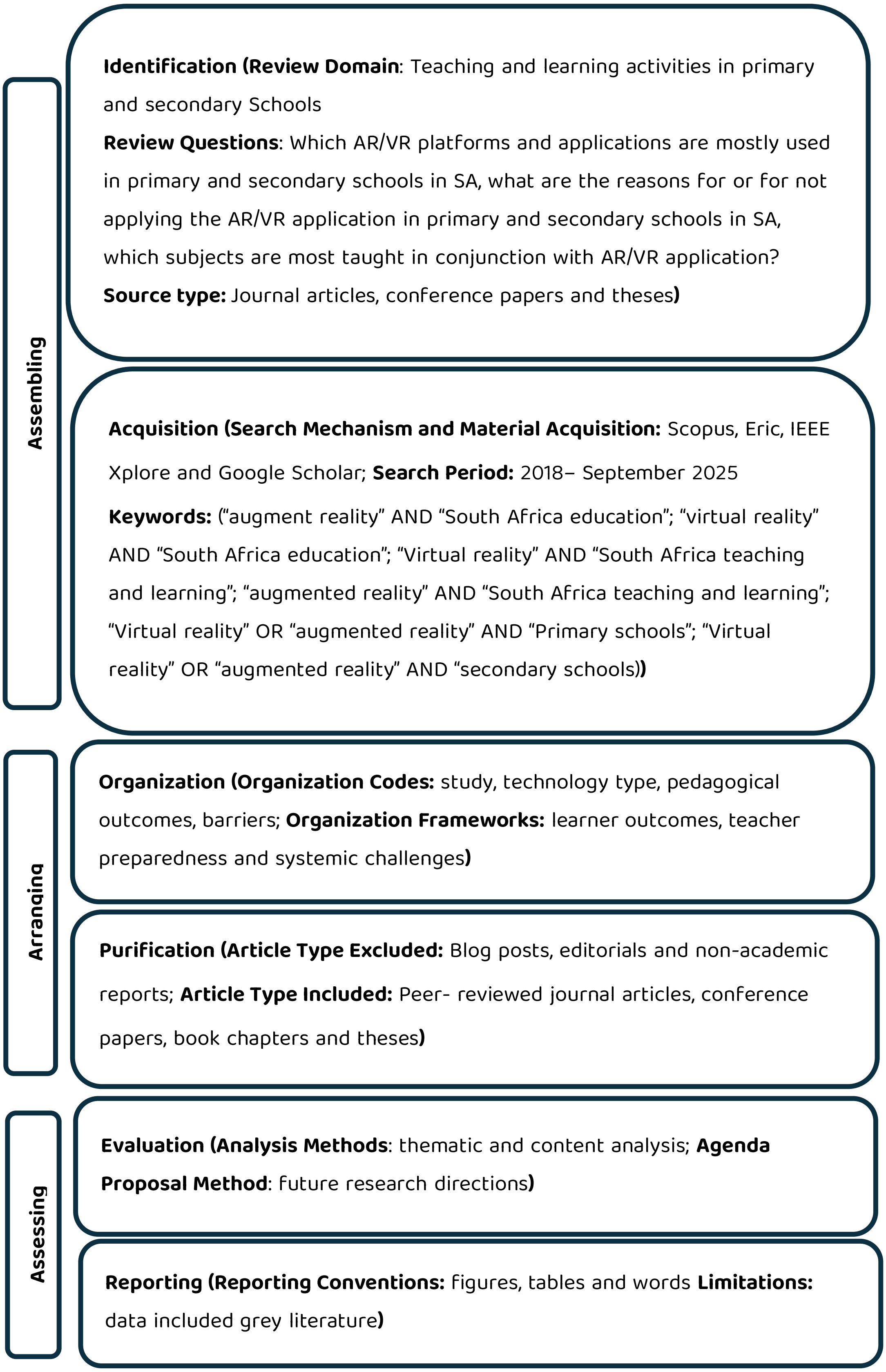
Table 3. Quality assessment summary using AACODS

Criterion	Assessment focus	Application in this study
Authority	Author credibility and affiliation	Studies from accredited universities and peer reviewed sources were included.
Accuracy	Methodological quality and evidence quality	Studies with clear empirical procedures and findings were prioritised.
Coverage	South African basic education related	Only studies addressing AR/VR in South African basic education contexts were included.

Criterion	Assessment focus	Application in this study
Objectivity	Neutrality and academic rigour	Opinion-based and promotional articles were excluded.
Date	Publication period	From 2018 to September 2025
Significance	Contribution to AR/VR basic educational research	Studies needed to contribute meaningful evidence of integration, pedagogy or implementation.

The SPAR-4-SLR framework in figure 2 was used to structure the review process, complementing the procedural transparency of PRISMA with a more analytical and organisational lens. The SPAR-4-SLR has six key stages that contribute to the rigour and reproducibility of the review. The first two stages (identification and acquisition) ensured a comprehensive search strategy across multiple databases using structured Boolean queries. The third stage (organisation) enabled the categorisation of studies based on key analytical dimensions, including technology used, study type, barriers to adoption and pedagogical outcomes. The structure coding applied in this study facilitated cross-study comparison and thematic synthesis. The evaluation and reporting (stages 4 and 5) were particularly critical in aligning the findings with the theoretical demands of TAM, UTAUT, and TPB. These models were integrated to point the review from descriptive to synthesis towards explanatory analysis of technology adoption patterns. The last stage of purification ensured that only studies meeting the inclusion criteria were retained.

Data coding was done in accordance with the SPAR-4-SLR. This protocol was used in conjunction with PRISMA because it complements the limitations of PRISMA by providing a model specifically for SLRs. It provides a structured framework with clear guidelines for decision-making when coding that improve transparency and rigor in data analysis [24]. Codes deduced included *contextual* elements, which we catergorised into (i) study: where we are analysing whether the school is primary, secondary, or from pre-service teachers; (ii) technology type: are they applying AR/VR or both; (iii) pedagogical outcomes: area of study, concept mastery, skills gained and engagement; (iv) barriers: infrastructure, professional development, costs and access. This helped in answering the research questions declared in the introduction section. Thereafter, thematic analysis was done across studies to synthesise findings in terms of learner outcomes, teacher preparedness and systemic issues and these were interpreted using the TAM, UTAUT and TPB lenses.



Identification (Review Domain: Teaching and learning activities in primary and secondary Schools
Review Questions: Which AR/VR platforms and applications are mostly used in primary and secondary schools in SA, what are the reasons for or for not applying the AR/VR application in primary and secondary schools in SA, which subjects are most taught in conjunction with AR/VR application?
Source type: Journal articles, conference papers and theses**)**

Acquisition (Search Mechanism and Material Acquisition: Scopus, Eric, IEEE Xplore and Google Scholar; **Search Period:** 2018– September 2025
Keywords: ("augment reality" AND "South Africa education"; "virtual reality" AND "South Africa education"; "Virtual reality" AND "South Africa teaching and learning"; "augmented reality" AND "South Africa teaching and learning"; "Virtual reality" OR "augmented reality" AND "Primary schools"; "Virtual reality" OR "augmented reality" AND "secondary schools)**)**

Organization (Organization Codes: study, technology type, pedagogical outcomes, barriers; **Organization Frameworks:** learner outcomes, teacher preparedness and systemic challenges**)**

Purification (Article Type Excluded: Blog posts, editorials and non-academic reports; **Article Type Included:** Peer- reviewed journal articles, conference papers, book chapters and theses**)**

Evaluation (Analysis Methods: thematic and content analysis; **Agenda Proposal Method**: future research directions**)**

Reporting (Reporting Conventions: figures, tables and words **Limitations:** data included grey literature**)**

Figure 2. SPAR-4-SLR protocol framework

3. RESULTS AND DISCUSSION

The literature search was conducted in September 2025; initially we got 380 studies. The rigorous inclusion and exclusion were applied; as a result, 22 publications were available for in-depth analysis. The study looked at basic education contexts, including several focusing on preservice teachers and system readiness, reflecting the early-stage nature of AR/VR adoption in South African basic education. This distribution reveals that the evidence base is still emerging, with a strong emphasis on preparatory and exploratory research rather than large-scale classroom implementation.

3.1. AR/VR Applications and Subject Distribution

The analysis of included studies in Table 4 shows that VR is more commonly used in the classroom than AR; this is shown as many studies are focusing exclusively on VR or combining the two. Dominance of VR can be attributed to its strong alignment with simulation-based learning environments, especially in science education, where abstract concepts benefit from immersive illustration [9], [14], [25]. Table 4 illustrates the key elements that were used to critically analyse the information source of the search results relating to author credentials, research focus, and methodology used in the study. In addition, it attempts to answer some of the research questions declared: *Which AR/VR platforms and applications are mostly used in basic education in SA? And which subjects are most taught in conjunction with AR/VR applications?* At the same time, it is guided by the codes that were declared the codes deduced *contextual* elements, which we catergorised into *(ii) technology type: are they applying AR/VR or both?* From the analysis, science subjects are the most dominating for AR/VR applications, with VR being the dominating application and mobile apps being the dominating platforms used.

Table 4. Information source of search results

Authors	**Research focus**	**Methodology**	**AR/VR**	**Platforms**	**Subject covered**
[26]	VR in Open Schooling	Literature review and content analysis	VR	ODL platforms, VR glasses	general

Authors	Research focus	Methodology	AR/VR	Platforms	Subject covered
[27]	Preservice teachers' views on AR	Surveys and interviews	AR	Mobile AR applications	SBE, General Sciences
[28]	Readiness for 4IR technologies in schools	Qualitative interviews	AR and VR	Gamification, VR, and IoT	STEM
[29]	AR in Life Science teaching	Qualitative case study	AR	AR anatomy app	Life support systems
[30]	VR for mathematics learning	Prototype development	VR	Unity, C#, Java Script	Mathematics
[31]	VR vs. traditional chemistry labs	Quasi-experimental	VR	Phet simulations	Chemistry
[32]	Preservice teacher adoption of VR	Survey	VR	Institutional VR classroom app	Sciences
[33]	Teacher preparedness for 4IR	Case study and focus group	AR and VR	ICT tools and TPACK framework	General ICT integration
[34]	Factors Influencing VR/AR Use	Qualitative interviews	AR and VR	Mobile AR and VR headsets	Science and Technology
[9]	Virtual labs in rural schools	Quasi-experimental	VR	Desktop VR labs	Life sciences

Authors	Research focus	Methodology	AR/VR	Platforms	Subject covered
[35]	Pre-Service Teachers' AR/VR Engagement	Mixed methods	AR and VR	Jigspace, ARloopa, SharecareVR, and PhysicsLab	Natural sciences
[36]	Readiness for AR/VR adoption	Quantitative (questionnaires)	AR and VR	AR mobile apps, VR headsets, eLearning platforms	General application
[37]	AR/VR in music education	Qualitative content analysis	AR/VR	Gamification, VR/AR immersive practice space apps, VR instruments	Music
[38]	Adoption of Virtual Labs	Quantitative survey	AR and VR	Virtual lab software	Life sciences
[39]	Teacher perceptions of VR	phenomenological approach (questionnaire)	VR	Conceptual VR tools	General
[40]	Digital technology integration in science	Quantitative survey	AR/VR	AR/VR science apps.	Natural sciences
[41]	VR and pedagogy	Qualitative	VR	VR classroom Simulations, VR goggles	Various subjects
[42]	VR chemistry and learning	Mixed methods	VR	videos, simulations, Phet simulations	Chemistry

Authors	**Research focus**	**Methodology**	**AR/VR**	**Platforms**	**Subject covered**
[11]	AT/VR Inquiry Learning	Mixed methods	VR and AR	high-end gaming laptops, head-mounted displays, smart AR glasses	Natural Sciences
[25]	VR in Life Science Education	Qualitative methods	VR	Human anatomy VR, Meta Quest 3 VR headsets, Sight Lab VR	Life Sciences
[12]	VR in Social Sciences (Geography)	Case study, qualitative	VR	VR goggles, 360-degree videos, AR overlays, smartphone-based VR views, virtual map manipulation, geospatial modelling activities	Geography

The synthesis in Table 4 reveals three major patterns. First, the reviewed studies are based in urban and better resourced schools, this means that infrastructure availability significantly shapes AR/VR adoption. Second, the implementations in the study rely on low-cost and accessible technologies such as desktop VR labs, mobile AR applications and browser-based simulations [14], [27], [28]. Fully immersive VR technologies, such as head-mounted displays, appear less frequently due to technical complexity, infrastructure requirements and high cost [11], [25]. Unfortunately, this indicates that adoption is shaped more by affordability and accessibility than by technological sophistication. Third, the subject distribution indicates a strong concentration in STEM-related subjects, particularly chemistry, life sciences, and natural sciences [9], [14], [25], [29]. This trend reflects the pedagogical suitability of AR/VR for abstract, visualising complex and spatially intensive concepts. On the other side, subjects such as languages and humanities remain underrepresented, meaning limited curriculum integration and fewer established use cases. These findings answers research questions 1 and 3 by revealing that immersive technologies are primarily used within STEM-related subjects are positively skewed to affordability, institutional readiness and accessibility.

3.2. Drivers and barriers to AR/VR adoption

Table 5 highlights a consistent pattern of drivers and barriers across the reviewed studies. While AR/VR technologies have strong educational benefits, their implementation is constrained by systemic and infrastructural challenges. The section answers the research question number 2: *What are the reasons for or for not applying for the AR/VR application in basic education in SA?* At the same time aligned with the declared themes of learner outcomes, teacher preparedness and systemic issues. Table 5 analyses the drivers and the barriers for AR/VR adoption according to the sentiments of each author under SLR and guided by the codes declared in section 3 of this study: *(iii) pedagogical outcomes: area of study, concept mastery, skills gained and engagement; (iv) barriers: infrastructure, professional development, costs and access.*

Table 5. Drivers and Barriers for Adoption

Author	Drivers for adoption	Barriers from adoption
[43]	Enhances engagement and satisfaction, enables safe experimentation, and supports authentic assessment	High costs, learner isolation, limited subject applicability, potential health effects
[36]	Enhance interactivity, improve engagement and performance, promote digital transformation, support modern teaching	Large class sizes, lack of teacher readiness, limited infrastructure, limited awareness, resource constraints
[31]	Improves conceptual understanding, supports repeated experimentation, is a cost-effective alternative to labs, enhances engagement.	Large class sizes, infrastructure costs, limited access in rural areas, reduced hands-on experience

Author	Drivers for adoption	Barriers from adoption
[37]	Enhances creativity and collaboration, enables remote learning, supports diverse learning styles, promotes inclusivity	Digital divide, resistance to change, low digital literacy, technical support limitations
[39]	Supports active and experiential learning, enables remote access, enhances imagination.	Infrastructure limitations, unequal access, inconsistent implementation, limited teacher development
[38]	Cost-effective lab alternatives, supports rural education, improves conceptual understanding	Underfunding, usability challenges, lack of infrastructure, limited technical support
[35]	Enhances engagement and motivation, simplifies complex concepts, improves critical thinking,	High costs, limited institutional support, lack of technical skills, connectivity issues
[40]	Supports inquiry-based learning, aligns with policy goals, improves academic achievement	Resource limitations, inconsistent implementation, teacher resistance, lack of support,
[27]	Enables immersive learning, bridges digital gaps, supports innovation	Low teacher confidence, unclear policies, lack of infrastructure, high costs
[26]	Enhances engagement, expands access to education, supports open learning	Lack of infrastructure, inadequate policy support, high implementation costs
[32]	Improves motivation and interest in science, has strong social influence, supports simulations	Limited access to resources, teacher anxiety, lack of exposure, cultural barriers
[11]	Enhances engagement and creativity, enables virtual field trips, supports inclusivity	High costs, curriculum misalignment, lack of training, inequality between schools
[28]	Supports personalised learning, promotes innovation, enhances problem-solving.	Poor infrastructure, unreliable connectivity, lack of funding, policy rigidity

Author	Drivers for adoption	Barriers from adoption
[29]	Improves motivation, enhances collaboration, simplifies abstract concepts	High costs, lack of teacher training, limited access, content reliability issues
[34]	Enhances participation, promotes collaboration and confidence, improves retention.	Unequal access, high maintenance costs, technical issues, negative teacher attitudes
[33]	Supports learner-centered learning, aligns with 4IR, enhances higher-order thinking	Digital divide, insufficient infrastructure, lack of training, resistance to change
[42]	enhances engagement and collaboration, improves conceptual understanding	High costs, lack of technical expertise, limited internet access
[9]	Enhances understanding of complex concepts, promotes engagement and cost-effective labs.	Lack of resources, limited time, overcrowded classrooms, sustainability issues
[41]	Supports constructivist learning, enhances collaboration, improves problem-solving	High costs, lack of infrastructure, resistance to change, sustainability concerns
[25]	Supports experiential learning, enhances engagement, improves critical thinking	Limited accessibility, technical challenges, health concerns
[12]	Improves visualisation and engagement, promotes creativity, supports experiential learning.	High costs, lack of training, limited equipment, digital inequality

In Table 3, educational benefits of AR/VR are consistently appearing across the reviewed studies, especially, regarding collaboration, learner engagement, conceptual understanding , experiential and inquiry-based learning [35], [40], [41]. In science subjects, virtual laboratories provide a safe, cost-effective alternative to physical labs, particularly in low-resource schools [9], [14], [38]. These findings support TAM, where perceived usefulness strongly influences adoption (18).

However, the findings shows that, despite high perceived usefulness, substantial barriers persist; the most dominant challenges include high costs, lack of teacher training, unequal access between rural and urban schools and limited infrastructure [28], [33], [36]. These limitations reflect broader systemic imbalance in South African education, where infrastructure determines the extent of technological integration from a UTAUT perspective, facilitating conditions such that policy frameworks, infrastructure and institutional support are sufficiently developed, reducing widespread adoption [15], [40]. Similarly, TPB posits that although teachers may have positive attitudes towards AR/VR, their perceived behavioural control remains low because of a lack of resources and technical competence [21]. These findings directly address research question 2 by demonstrating that adoption is shaped by perceived usefulness, institutional support, facilitating conditions

3.3. Studies with the level of education mentioned in the study

Figure 3 presents the levels of education that were studied in the literature reviewed, guided by the code declared in section 2 of this study *(i), where we are analysing whether the school is primary, secondary, or from pre-service teachers.* This shows that studies are more concentrated on the upper levels of education, while the lower levels are left aside, but in actual sense, if concepts are introduced from a tender age, understanding and concept abstraction will be easier even in higher levels.

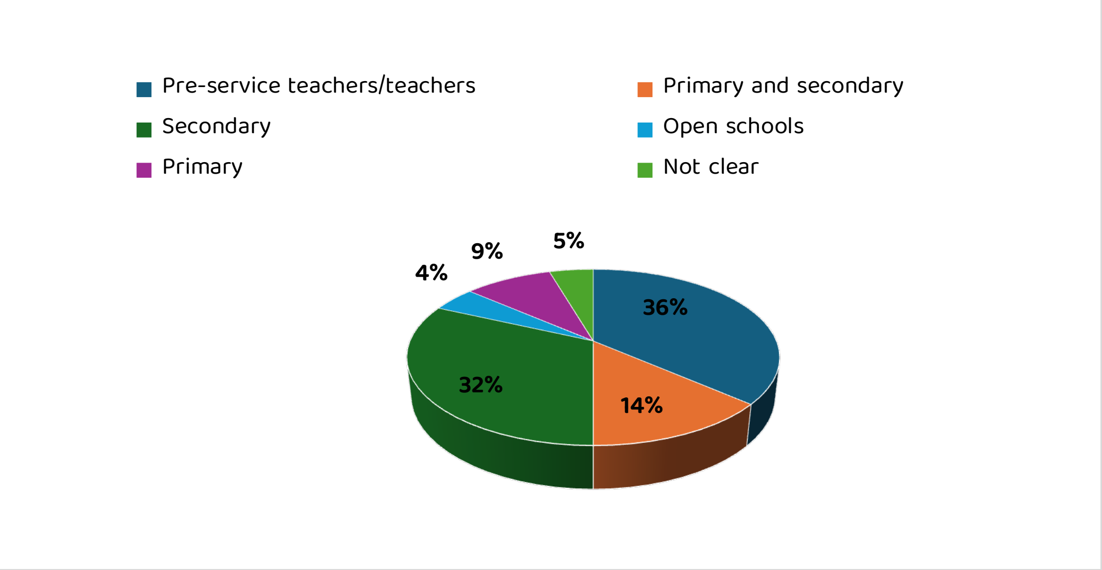


Figure 3. Level studied in SLR

As shown in figure 3, the distribution of studies presented across different levels of education reveals a notable imbalance in the current review. Most of the studies focus on secondary education and preservice teachers, while very few studies explicitly examine the primary school context. This shows that research on AR/VR in South African basic education is positively skewed towards higher levels of education and in preparatory teacher environments. The prominence of tertiary studies, in particular pre-service teacher studies, indicates that much of the existing research is concerned with perceptions, readiness and future adoption rather than actual classroom implementation. Although this evidence provides valuable insights into potential adoption pathways, it also reveals a gap in empirical evidence on actual AR/VR use in primary classrooms.

This anomaly has important implications for both research and practice. Early exposure to immersive technologies could enhance foundational understanding and digital literacy. However, the limited focus on this level suggests missed opportunities for early integration. The other notable point is the concentration of studies in secondary education, which shows the dominance of STEM subjects in AR/VR applications at this level; that's where abstract concepts are more prevalent and immersive tools are more easily justified pedagogically. This also agrees with section 2 of this study, where AR/VR adoption is still emerging, with uneven research attention across educational levels and a requirement for more empirical studies on primary school contexts.

3.4. Discussion

The discussion section was done in conjunction with the declared themes, *learner outcomes, teacher preparedness and systemic issues and* the theories TAM*, UTAUT, and TPB,* which underpinned this study.

Learner outcomes: Basic education in South Africa is gradually using the AR/VR applications in teaching and learning activities. Answering research question 1: *Which AR/VR platforms and applications are mostly used in basic education in SA?* The most frequently used applications are desktop VR labs and mobile applications like AR anatomy and 360-degree virtual trips, which include Google Expeditions and PHE simulations [10]. STEM subjects such as life sciences, general science, mathematics and chemistry are the most hosts for AR/VR integration [5], [25] and this statement answered *Question 3: Which subjects are most taught in conjunction with AR/VR applications?* AR/VR proved to have a high perceived usefulness and VR labs have unequivocally improved science cognitive skills in resource-constrained schools such as rural schools [9]. In addition, VR anatomy apps helped in simplifying difficult life sciences concepts [29]. In the same vein, when comparing the two on the perceived ease of use, mobile AR and browser-based VR are found at a higher level than headset-based immersive VR because the latter is costly and complex [21].

The UTAUT model's performance expectancy is measured with the improved achievement. The natural subjects like biology and chemistry, enjoyment and novelty are regarded as the factors in hedonic motivation for drive adoption. However, device availability and connectivity are some of the facilitating conditions that remained limited, causing uneven and unequal influence on learner outcomes [2]. Basically, students' attitudes towards AR/VR looked positive, although subject norms in which peer and teacher influence and perceived behavioural control and ease of access to resources are the major determinants of whether engagement corresponds to sustained learning. For instance, rural teachers are optimistic and their learners are enthusiastic but unfortunately cannot control issues like poor infrastructure and lack of resources.

A further distinction emerges between actual classroom implementation studies, readiness studies and pilot studies. Actual classroom implementation studies remain few and largely concentrated in urban and better-resourced schools where technological resources and connectivity are more readily available [9], [29], [34]. In contrast, readiness studies primarily examine pre-service teachers and teacher's intentions, perceptions and preparedness to adopt immersive technologies, often reporting favourable attitudes but concerns regarding institutional support, infrastructure and training [27], [32], [36]. Pilot studies generally report positive outcomes such as conceptual understanding, motivation and learner engagement when AR/VR tools are introduced in actual learning environment [9], [11], [31].

Teacher preparedness: This section attempts to answer research question number 2: *What are the reasons for or for not applying for the AR/VR application in basic education in SA?* Teacher preparedness emerges as a critical bottleneck; schools' uptake and teacher preparedness depend on the status of the school. Teachers in fee-paying schools are more prepared to experiment with AR/VR [28] than teachers in rural schools, since they face barriers like lack of teacher development that result in lack of confidence and under-resourced infrastructure [41].

A clear gap also surfaces between classroom implementation studies and teacher readiness studies. Most implementation work was conducted in urban or relatively well-resourced schools where access to connectivity, devices and institutional support is readily available. In contrast, studies conducted in rural and non-paying schools focused mostly on readiness challenges, teacher confidence and infrastructure limitations rather than sustained classroom integration. This imbalance demonstrates that AR/VR adoption in South African basic education remains heavily shaped by infrastructural and socio-economic inequalities.

The contrast between readiness and adoption studies further reinforces this observation. Literature on fee paying and urban schools tend to record actual experimentation with AR/VR applications in classroom settings, whereas literature on rural and non-paying schools are more likely to focus on perceived usefulness, anticipated barriers and actual preparedness rather than active implementation [28], [34], [36]. This pattern suggests that professional development opportunities, institutional support and infrastructure plays a determining role in whether schools progress from technological readiness to meaningful classroom integration. Therefore, the evidence base remain skewed towards schools that have the necessary resources to support pilot implementation projects. In addition, this unequal access to resources among schools has forced rural schools to employ underqualified teachers, as the qualified would be opting for better-resourced schools [38]. This has resulted in the low perceived ease of use for the AR/VR. Yes, teachers' perceived usefulness of AR/VR is high, but the limitations remain high because workshops with once-off exposure do not sustain professional development [25].

From the UTAUT framework, social influence, which can be viewed as peer collaboration, encouragement from institutions, and facilitation conditions that include OCT support and institutional policies, is regarded as the decisive factors in teacher preparedness. Better-resourced schools provide teachers with a better platform to integrate AR/VR more readily as they perceive total support from their institution [27], [36]. This is different with rural schools and less-resourced teachers who suffer from a lack of these better facilitating conditions, explaining the uneven adoption of these immersive technologies [2]. TPB explains teachers' behavioural intentions as being informed by attitude, in our case, positive attitudes toward the integration of AR/VR technologies; subjective norms, which can be regarded as colleagues' and leadership expectations; and perceived behavioural control which in our case is the confidence teachers have with using AR/VR devices. Studies show that pre-service teacher's preparedness significantly predicts intention to use VR, although perceived behavioural control remains weak when infrastructure is poor [21], [43].

Systemic issues: Research question 1 and part of research question 2 are answered in this section, when making a comparison on the different categories of studies included in this review, a clear implementation continuum becomes evident. Readiness studies demonstrate positive behavioural intentions and strong interest towards AR/VR among teachers and preservice teachers [27], [32], [36], while pilot studies comes in with encouraging evidence regarding learner engagement and conceptual learning benefits [9], [11], [31]. However, comparatively few studies document long-term classroom implementation across educational districts or multiple schools [29], [34]. This shows that South African AR/VR research is currently positioned in the middle of exploration and adoption, with a lot of schools demonstrating readiness and isolated pilot success but limited evidence of large-scale institutionalisation. The transition from pilot integration to sustainable classroom practice appears to be limited primarily by infrastructure limitations, teacher development needs and funding challenges.

South African basic education is heavily affected by systemic barriers that range from policy gaps, resistance to change, the digital divide and the cost of software, hardware and integration of those applications in the system [2]. The absence of facilitating conditions such as government intervention and ICT infrastructure explains why AR/VR remains marginal. Policy frameworks in South Africa emphasise ICT broadly, but when it comes to those immersive technologies, their capture is still very low [8]. TPB denotes that even when attitudes and subjective norms are positive, perceived behavioural control is low at a systemic level; teachers and learners cannot act on intentions when resources are lacking. This is the major reason why AR/VR adoption is concentrated in urban, fee-paying schools and university-led pilot projects [5].

Having discussed the above, this study poses its limitations, which span from heterogeneous studies from grey literature, which may be underrepresented [22] because AR/VR interventions in South African basic education are pilot projects that prevent us from getting longitudinal evidence and AR/VR adoption is still emerging, with uneven research attention across educational levels and a requirement for more empirical studies on primary school contexts. From the results analysis, the distribution of the studies reveals that the evidence base is still emerging, with a strong emphasis on preparatory and exploratory research rather than large-scale classroom implementation.

Therefore, there is a CTA for teacher training programs to build confidence, reduce resistance to change and impart pedagogical competence in immersive teaching activities. In the same vein, teacher retention programs are recommended for rural teachers so that rural schools can retain professional teachers and combat the problem of having less qualified teachers. These can be in the form of incentives or special rural allowances that are significant enough that any teacher would want to teach in rural settings. In addition, there is a need for intense support from the government and private sector in subsidising AR/VR hardware and software, facilitating the infrastructural renovations, particularly in resource-constrained contexts like rural schools and non-fee-paying schools. This will reduce the digital gap between the well-resourced and less resourced schools, thereby giving them equal educational opportunities considering that the curriculum is the same across those different educational contexts.

4. CONCLUSION

The integration of AR/VR into South African basic education demonstrates significant potential to promote basic education change teaching and learning through improved learner engagement, experiential learning and conceptual understanding. However, the evidence base remains, uneven, limited and pilot-oriented, with implementation concentrated in STEM subjects and better-resourced urban schools. Most reported applications in the study rely on low-cost mobile AR tools, desktop virtual laboratories, browser-based simulations, while fully immersive VR adoption remains low due to infrastructural, technical and financial barriers. Unequal access between rural and urban school, teacher preparedness, insufficient policy integration and limited institutional support continue to constrain large-scale implementation. Therefore, without systemic investment in infrastructure, curriculum policy and teacher development and collaboration support from government, the private sector and educational institutions, AR/VR may remain a niche innovation. In addition, from the TAM, UTAUT and TPB lenses, adoption is grounded on perceived usefulness, facilitating conditions and behavioural control. Even though the reviewed studies indicate positive educational outcomes, stronger empirical and longitudinal research is still needed to evaluate sustainable classroom implementation and broader educational impact across diverse South African school context.

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