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Accessibility and Adoption Patterns of AR/VR Tools in Secondary History Education: A Multiple-Response Analysis

Liang Jie
Kuala Lumpur University of Science and Technology, Malaysia
Email: 232924123@s.klust.edu.my

Mahendran Maniam*
Faculty of Languages and Communication, Universiti Pendidikan Sultan Idris (UPSI), Malaysia
Email: mahendran@fbk.upsi.edu.my

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Abstract
The integration of Augmented Reality (AR) and Virtual Reality (VR) technologies into secondary education has transformed classroom engagement and experiential learning. This study examines the patterns of AR/VR tool usage among secondary school students using a multiple-response framework. The data reveal that AR Mobile Applications (72%) are the most widely used tools, followed by Google Expeditions (65%), VR Educational Platforms (54%), Oculus Devices (49%), and Merge Cube (37%). The findings suggest that accessibility, affordability, and ease of implementation significantly influence adoption rates. Mobile-based AR tools dominate due to their compatibility with existing devices, whereas specialized VR hardware shows comparatively moderate usage. The study contributes to understanding technological accessibility and its pedagogical implications in immersive learning environments. It highlights the need for strategic infrastructure planning and teacher training to maximize the potential of immersive technologies in education.
Keywords: Augmented Reality, Virtual Reality, Immersive Learning, Educational Technology, Accessibility, Secondary Education

Introduction

The rapid advancement of digital technologies in the twenty-first century has profoundly reshaped educational theory, pedagogy, and classroom practice. Traditional teacher-centered instruction is increasingly being supplemented and in some cases replaced by interactive, student-centered learning environments supported by digital tools. Among these innovations, immersive technologies such as Augmented Reality (AR) and Virtual Reality (VR) have emerged as transformative instruments capable of redefining how students experience knowledge construction.

AR overlays digital elements onto real-world environments, while VR creates fully immersive simulated environments that allow learners to interact within three-dimensional spaces. Educational platforms such as Google Expeditions enabled students to participate in guided virtual field trips, exploring historical monuments, museums, underwater ecosystems, and outer space without leaving their classrooms. Similarly, hardware devices like Oculus Devices provide immersive 360-degree experiences that enhance spatial awareness and experiential engagement. Portable AR tools such as Merge Cube further democratize access by transforming ordinary smartphones or tablets into interactive 3D visualization tools.

The integration of AR and VR aligns strongly with constructivist learning theory, which posits that learners construct knowledge actively through experience and interaction (Piaget, 1952). Immersive technologies create experiential contexts in which learners can explore historical events, manipulate scientific models, and visualize abstract concepts in concrete forms. This experiential dimension strengthens cognitive processing and long-term retention.

However, despite their pedagogical promise, disparities in access, infrastructure, and teacher preparedness create unequal implementation patterns across institutions. Schools with strong technological infrastructure can deploy VR headsets and advanced platforms, whereas resource-constrained institutions often rely primarily on mobile-based AR applications. Such inequalities raise critical questions regarding equitable technology integration and digital inclusion.

Understanding which tools are most commonly adopted and why is essential for policymakers, administrators, and curriculum designers. Adoption patterns are influenced by cost, usability, training requirements, hardware availability, and curriculum alignment. This study, therefore, investigates the distribution of AR/VR tool usage among secondary school students and analyzes accessibility-driven adoption trends to inform more inclusive and sustainable integration strategies.

Review of Literature

A growing body of scholarly research confirms that AR and VR technologies significantly enhance student engagement, motivation, and conceptual understanding. According to Wu et al. (2013), AR environments promote interactive learning by integrating virtual content into real-world contexts, thereby increasing learner attention and curiosity. Similarly, Radianti et al. (2020) found that VR-based instruction improves experiential learning outcomes, particularly in disciplines requiring spatial visualization.

One of the most widely studied educational VR platforms is Google Expeditions. Research indicates that guided virtual tours increase student immersion and collaborative discussion. Students report heightened interest and improved retention when lessons are supported by structured virtual exploration (Merchant et al., 2014). The ability to “visit” historical sites or scientific environments fosters what scholars describe as historical empathy and contextual understanding, especially in social science classrooms.

Studies examining Oculus Devices emphasize the cognitive advantages of fully immersive VR systems. Makransky and Lilleholt (2018) demonstrated that immersive VR enhances presence and emotional engagement, leading to improved learning motivation. However, the same

research also acknowledges the potential limitations of high-end VR systems, including cost barriers, technical setup requirements, and the need for teacher training. Mobile-based AR applications present a more accessible alternative. Tools such as Merge Cube allow students to visualize 3D models through smart phones, reducing dependency on expensive hardware. According to Bacca et al. (2014), mobile AR solutions are particularly effective in secondary education because they combine affordability with interactive visualization capabilities.

Exposure to multiple immersive platforms contributes to digital literacy development. Digital competence frameworks emphasize adaptability and multimodal engagement as key 21st-century skills (Redecker, 2017). When students interact with different AR/VR tools, they develop broader technological fluency and cognitive flexibility. Such exposure prepares learners for digitally mediated academic and professional environments. Scholars consistently highlight infrastructure disparity as a critical challenge. Access to VR headsets, high-speed internet, and technical support remains uneven across urban and rural schools. Consequently, adoption patterns often reflect accessibility rather than purely pedagogical preference. This underscores the need for institutional planning that balances innovation with equity.

The literature establishes that AR and VR technologies enhance engagement, experiential learning, and conceptual clarity. However, successful implementation depends on accessibility, affordability, teacher preparedness, and institutional infrastructure.

Methodology

Research Design

The present study adopted a quantitative descriptive research design to examine the patterns of AR and VR tool usage among secondary school students. A descriptive design was considered appropriate because the primary objective of the study was to systematically identify, measure, and interpret the distribution of specific immersive technologies used by students, rather than to manipulate variables or establish causal relationships.

Quantitative descriptive research enables the researcher to collect numerical data that reflect observable trends within a defined population. In the context of this study, the focus was on identifying the frequency and percentage of students who engage with different AR/VR tools. This design allows for objective measurement, statistical representation, and clear comparison of usage patterns across multiple technological platforms.

The structured format ensured uniformity in responses, reduced researcher bias, and enhanced reliability. By quantifying tool adoption rates, the study provides empirical evidence regarding accessibility-driven trends in immersive educational technology usage.

Sample

The sample consisted of 260 secondary school students (N = 260) who reported their usage of AR/VR tools within their academic learning environment. The selection of secondary school students was appropriate, as this group actively engages with digital learning technologies and represents a critical stage for the development of analytical and technological competencies.

A survey-based sampling approach was adopted, and students voluntarily participated in the study. The sample size of 260 ensures adequate representation and allows for reliable percentage-based statistical analysis.

A multiple-response format was used in the questionnaire, allowing students to select more than one AR/VR tool. Since immersive technologies are often used in combination within educational settings, this approach provided a realistic representation of actual exposure patterns. Because of this multiple-response design, total percentages exceed 100%, as each percentage represents the proportion of students who used a specific tool independently.

Data Collection Tool

Data were collected using a structured questionnaire designed specifically to capture usage patterns of immersive technologies. The instrument included a checklist of commonly used AR and VR tools in secondary education:

Google Expeditions	Oculus Devices	AR Mobile Applications	VR Educational Platforms	Merge Cube

Participants were instructed to indicate all tools they had used in their learning experience. The structured format of the questionnaire ensured clarity and simplicity in response selection, enabling participants to understand the questions easily and provide accurate answers without confusion. It also maintained consistency across all participants, as each respondent engaged with the same standardized set of questions and response options. Furthermore, the format facilitated ease of quantitative analysis, allowing the collected data to be systematically coded, tabulated, and statistically interpreted with greater reliability and efficiency.

The questionnaire was designed to focus specifically on tool exposure rather than on the frequency of use or measurable learning outcomes. This deliberate limitation was maintained because the primary objective of this section was to identify patterns in the distribution and adoption of AR and VR technologies. By concentrating on exposure levels, the study was able to map adoption trends clearly without conflating them with performance-related variables, which were examined separately in other sections of the research.

Data Analysis

The collected data were analyzed using percentage analysis**,** which is appropriate for categorical survey data. The percentage method allows for straightforward interpretation of how widely each tool is adopted among the sampled population.

Because the survey followed a multiple-response format**,** total percentages exceed 100%. This is a standard statistical outcome in multiple-response datasets, as each participant may select more than one option. Therefore, percentages represent the proportion of students who reported using each tool independently rather than mutually exclusive categories.

The analysis aimed to identify:

- The most widely adopted AR/VR tools

- Relative adoption differences between mobile-based and hardware-based technologies
- Accessibility-driven usage trends

This approach provides a clear quantitative representation of immersive technology penetration in secondary education.

Analysis

Table 1

Tools Used (Multiple Response)

Tool	% of Users
Google Expeditions	65
Oculus Devices	49
AR Mobile Apps	72
VR Educational Platforms	54
Merge Cube	37

The findings reveal clear variations in the adoption rates of different immersive technologies among secondary school students. AR Mobile Applications emerged as the most widely adopted tools, with 72% of students reporting usage. This high level of adoption can be attributed to their compatibility with smartphones and tablets, minimal infrastructure requirements, lower implementation costs, and ease of classroom integration. Unlike fully immersive VR systems, mobile-based AR tools do not require specialized headsets or high-end computing systems. Since many students and institutions already possess mobile devices, these applications provide a cost-effective, scalable, and easily accessible solution, which significantly contributes to their widespread use.

Google Expeditions follows closely, with 65% of students indicating usage. This suggests strong acceptance of guided virtual exploration platforms within classroom settings. Its structured format, teacher-controlled navigation, and curriculum-aligned content enhance its practicality for instructional purposes. The relatively high adoption rate indicates that semi-immersive VR experiences, which do not require expensive standalone systems, are more feasible and manageable for many schools.

VR Educational Platforms demonstrate moderate adoption at 54%, reflecting a growing interest in immersive pedagogy. These platforms typically offer subject-specific simulations and interactive modules that enrich conceptual understanding. However, their implementation may be constrained by infrastructure limitations, technical support requirements, or institutional readiness, which can restrict universal access.

Oculus Devices are used by 49% of students, indicating moderate engagement with fully immersive VR systems. Although these devices provide highly engaging 360-degree experiences and strong spatial immersion, their usage requires dedicated VR headsets, technical setup and maintenance, and significant institutional investment. The comparatively lower adoption rate, when contrasted with mobile-based tools, suggests that cost and logistical considerations strongly influence implementation decisions.

Merge Cube records the lowest adoption rate at 37%. While it is an innovative AR tool capable of enhancing three-dimensional visualization and interactive learning, its limited usage may

stem from lower awareness levels, restricted subject integration, and dependence on specific AR-compatible applications. Importantly, lower adoption does not necessarily indicate limited pedagogical value; rather, it may reflect reduced institutional exposure or limited availability within schools. Overall, the distribution underscores the central role of accessibility, affordability, and infrastructure readiness in shaping the adoption patterns of immersive technologies in secondary education.

Findings and Discussion

The findings of the study reveal three significant patterns in the adoption and usage of immersive technologies among secondary school students. First, there is a clear dominance of mobile-based AR tools, with AR Mobile Applications recording the highest usage rate at 72%. This pattern highlights the central role of accessibility and affordability in determining technological adoption within educational institutions. Because these applications function on smartphones and tablets—devices that are already widely available among students and schools—they eliminate the need for additional hardware investment. Their ease of installation, user-friendly interfaces, and compatibility with existing digital infrastructure make them highly practical for classroom implementation. This trend strongly aligns with existing research indicating that cost-effectiveness and scalability are major determinants of technology integration in schools. In contexts where budgets are limited and infrastructure varies, mobile-based AR applications provide an inclusive pathway for immersive learning without imposing significant financial or technical burdens.

The second major finding is the strong adoption of guided VR platforms, including Google Expeditions (65%) and other VR Educational Platforms (54%). These platforms demonstrate substantial usage because of their structured educational design and alignment with curriculum objectives. Teacher-controlled navigation, guided exploration features, and pre-designed content modules make them pedagogically manageable and adaptable to classroom needs. Unlike fully immersive VR systems that require complex setup procedures, these platforms often operate through smart phones paired with basic viewers or web-based systems, thereby reducing implementation barriers. Their relatively high adoption indicates that schools prefer solutions that balance immersive engagement with instructional control and logistical feasibility. Moreover, such guided platforms enhance collaborative learning, classroom discussion, and contextual understanding, particularly in subjects like history and geography where experiential visualization enriches conceptual comprehension.

The third notable pattern is the comparatively limited use of specialized hardware such as Oculus Devices (49%) and Merge Cube (37%). Although these tools offer advanced immersive capabilities, their adoption rates are lower due to specific hardware requirements, technical maintenance demands, and institutional investment costs. Fully immersive VR headsets require dedicated equipment, technical setup, and teacher training, which may not be feasible for all schools, particularly those in resource-constrained settings. Similarly, while Merge Cube provides innovative 3D visualization experiences, its integration often depends on specific AR-compatible applications and subject alignment, which may limit widespread use. Importantly, the lower adoption rates do not indicate lower educational value; rather, they reflect structural and logistical constraints that influence institutional decision-making.
Another important aspect of the findings is the multiple-response format of the data. Since students were allowed to select more than one tool, the results demonstrate that many

learners engage with multiple immersive technologies rather than relying on a single platform. This diversified exposure suggests a blended technological ecosystem within schools, where different tools are used for different pedagogical purposes. Such exposure can enhance digital competence, adaptability, and multimodal learning skills. Engaging with multiple platforms encourages students to navigate diverse interfaces, interact with various forms of digital content, and develop flexible technological literacy—skills that are essential in contemporary education.

The findings indicate that accessibility, affordability, and institutional infrastructure are the primary determinants shaping adoption patterns. Schools appear to prioritize scalable and manageable solutions over technologically advanced but resource-intensive systems. Thus, technology adoption in education is influenced as much by practical feasibility as by pedagogical innovation.

Conclusion

The study concludes that accessibility plays a decisive role in determining the adoption of AR and VR technologies in secondary education. Mobile-based AR tools dominate usage patterns because of their compatibility with existing devices, minimal infrastructure requirements, and lower implementation costs. These characteristics make them inclusive and scalable solutions for a wide range of educational settings. In contrast, while fully immersive VR hardware offers deeper experiential and spatial learning opportunities, its adoption remains moderate due to financial constraints, technical setup requirements, and the need for ongoing maintenance and teacher training.

The findings emphasize the importance of strategic planning at the institutional and policy levels. To ensure equitable access to immersive learning technologies, schools must invest not only in hardware but also in infrastructure readiness, teacher professional development, and curriculum integration strategies. A balanced approach that combines accessible mobile-based tools with gradually expanded immersive systems may provide a sustainable pathway for innovation.

Future research should move beyond adoption patterns and investigate the direct relationship between frequency of tool usage and measurable learning outcomes, such as academic performance, critical thinking development, and student engagement levels. Longitudinal studies could also examine how sustained exposure to multiple immersive technologies influences digital literacy and cognitive growth over time. Through such research, a clearer understanding of the educational impact of AR and VR can be established, guiding more effective and equitable technology integration in schools.

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