Journal of Information Technology Education: Research

An Official Publication of the Informing Science Institute
InformingScience.org

JITEResearch.org

Volume 24, 2025

ENHANCING ENGLISH LANGUAGE PROFICIENCY AND DIGITAL LITERACY THROUGH METAVERSE-BASED LEARNING: A MIXED-METHODS STUDY IN HIGHER EDUCATION

Nepoleon Prabakaran	CMS Business School, Jain (Deemed-to-be University), Bengaluru, India	nepoleonbonoparte@gmail.com
Harold Andrew Patrick*	CMS Business School, Jain (Deemed-to-be University), Bengaluru, India	harold.patrick@jainuniversity.ac.in
Jacqueline Kareem	CHRIST (Deemed to be University), Bengaluru, India	jacqueline.loleta@christuniversity.in

* Corresponding author

ABSTRACT

Aim/Purpose	This paper investigates three key aspects of metaverse-based platforms in English language teaching: (1) their effectiveness in enhancing language learning outcomes, (2) their impact on digital literacy development in higher education, and (3) their accessibility and inclusivity implications for diverse student populations.
Background	Despite growing interest in digital language learning, research gaps exist in understanding the long-term effectiveness of immersive technologies, particularly in resource-constrained settings. The metaverse – an integrated platform combining augmented reality (AR) for real-world digital overlays and virtual reality (VR) for immersive experiences – remains little studied in language education. While existing research examines AR or VR separately, this study investigates their combined impact through metaverse technology, addressing the unexplored intersection of language proficiency, digital literacy, and learning sustainability in higher education.

Accepting Editor Janice Whatley | Received: October 29, 2024 | Revised: January 11, February 12, February 28, March 12, March 28, 2025 | Accepted: March 30, 2025.
Cite as: Prabakaran, N., Patrick, H. A., & Kareem, J. (2025). Enhancing English language proficiency and digital literacy through metaverse-based learning: A mixed-methods study in higher education. *Journal of Information Technology Education: Research, 24,* Article 10. https://doi.org/10.28945/5484

Methodology	A mixed-methods study was conducted with 60 undergraduate students divided equally between experimental (metaverse-based) and control (traditional online) groups for an 8-week English course. The experimental group used an integrated metaverse platform combining AR and VR technologies for one hour daily. Quantitative assessment included pre-test, post-test, and six-month retention measurements of language proficiency (reading, writing, speaking; 10-point scale each) and digital literacy (36-item standardized scale). Semi-structured interviews with 15 participants from resource-limited environments explored accessibility and inclusivity challenges.
Contribution	This research contributes to understanding technology-enhanced language learning in immersive environments, challenging assumptions about digital literacy's impact on academic performance and providing insights into the long-term effects of metaverse-based learning on language skills.
Findings	The results revealed significant improvements in reading, writing, and speaking skills among the experimental group, with reading and writing gains maintained over six months. While participants showed substantial improvement in digital literacy, no significant relationship was found between digital literacy and academic performance. Qualitative analysis uncovered two key themes: inclusive social interaction opportunities and technical barriers in the learning process.
Recommendations for Practitioners	To maximize the effectiveness of metaverse-based language learning, three key recommendations emerge: institutions should prioritize robust technological infrastructure alongside comprehensive training for both educators and students, educational platforms should be developed with greater inclusivity and customization options, and regular practice sessions or hybrid learning models should be implemented to maintain speaking skills over time.
Recommendations for Researchers	Future research directions should focus on three critical areas: conducting longer-term studies to better understand how metaverse-based learning affects academic performance and language proficiency, exploring the complex relationship between digital literacy and academic achievement through alternative success measures, and investigating how adaptive learning systems within metaverse environments can effectively address diverse learner needs.
Impact on Society	The findings suggest that metaverse technology has the potential to revolutionize language education, making it more engaging and effective. However, they also highlight the need to address technical challenges and ensure inclusivity to prevent new forms of educational inequality.
Future Research	Future investigation should address three key areas: examining how digital skills gained in metaverse environments transfer to real-world contexts and other academic disciplines, developing standardized assessment tools for evaluating language proficiency and digital literacy in immersive virtual settings, and studying the long-term impact of metaverse-based learning across different age groups and educational levels.

Keywords	metaverse, English language teaching, digital literacy, immersive learning environments, educational technology

INTRODUCTION

In recent years, the integration of metaverse technology into education has sparked excitement, particularly in the field of English language teaching. With its immersive, interactive environments, the metaverse offers unique opportunities for students to engage with language learning in ways that traditional methods cannot. For instance, studies have shown how metaverse platforms can enhance student interaction, promote deeper learning, and foster greater motivation among learners (del Carmen Avendaño Porras et al., 2024; Li & Yu, 2023). By providing real-world simulations and collaborative virtual spaces, the metaverse brings a fresh dimension to language acquisition, making abstract concepts more tangible and learning experiences more dynamic (İbïli et al., 2024). However, despite its promising potential, the widespread adoption of metaverse-powered education faces several significant hurdles that need to be addressed (İbïli et al., 2024).

Various obstacles prevent the full advantages of metaverse technology, such as Teachers and students dealing with technical issues, inadequate digital knowledge, and trouble accessing required infrastructure. These restrictions mean that many pupils do not have the same experience. Evidence of how these virtual environments contribute to enhancing long-term learning results is lacking. Therefore, it is unclear if adopting the metaverse is really superior to conventional approaches or merely a new fancy tool with lots of issues (H. Chen, 2023; Guo & Gao, 2022; Lu et al., 2023).

The integration of immersive technologies in education has created new possibilities for language learning, particularly through metaverse platforms that offer interactive, three-dimensional virtual environments. While these platforms show promise for enhancing language acquisition, three critical gaps exist in current research. First, there is limited understanding of long-term effectiveness. Although studies have demonstrated the immediate benefits of virtual environments in language learning, there is insufficient evidence regarding the sustained impact on language proficiency over time, particularly in tracking how students maintain their language skills beyond the immediate learning period (Oliwa, 2020; Tracy-Ventura et al., 2025). Second, the relationship between digital literacy and language learning outcomes remains unexplored. While digital competency is presumed important for virtual learning environments, its specific role in metaverse-based language acquisition and its impact on academic performance has not been systematically studied (G. Chen et al., 2024; Hwang & Chien, 2022; Tlili et al., 2022). Third, there is a significant lack of comprehensive accessibility research (Othman et al., 2024). Despite the growing adoption of virtual learning platforms, limited research exists on how to ensure inclusive access, particularly in resource-limited settings where technological infrastructure may be constrained.

This study addresses these gaps by examining how metaverse-based platforms can enhance language proficiency and digital literacy in higher education. Through a mixed-methods approach combining quantitative assessments and qualitative insights, we investigate three key research questions:

1. How does metaverse-based language learning affect immediate and long-term language proficiency across reading, writing, and speaking skills?
2. What is the relationship between students' digital literacy development and academic performance in metaverse-based learning environments?
3. How can metaverse platforms be made more accessible and inclusive for language learners in resource-limited settings?

The study employs an 8-week experimental intervention with undergraduate students to evaluate immediate and sustained learning outcomes while exploring solutions for improving accessibility in metaverse-powered education. By addressing these questions, this research aims to provide practical insights for implementing effective and inclusive metaverse-based language learning environments.

LITERATURE REVIEW

This literature review examines five key areas relevant to metaverse-based language learning in higher education. First, the review establishes the theoretical foundation for language learning in virtual environments by exploring Vygotsky's sociocultural theory. Next, it defines the metaverse concept and its technological components. The review then investigates metaverse adoption patterns in higher education, followed by an examination of how metaverse technologies impact academic outcomes and language skill retention. Finally, it explores the role of digital literacy in metaverse learning environments and addresses inclusivity considerations. Through this structured approach, the review identifies research gaps regarding long-term effectiveness, digital literacy impact, and accessibility that form the basis for the research hypotheses.

THEORETICAL FOUNDATION

According to Vygotsky's sociocultural theory, social interaction and cultural skills help to essentially filter language learning as a social process (Vygotsky, 1978). This theoretical paradigm is especially important in the framework of metaverse-based language learning since it clarifies how virtual environments might support language acquisition through social interaction and collaborative learning (Perry, 2021; Tavares & Somby, 2023). While it offers an avenue for social contact that Vygotsky judged essential for cognitive growth, the metaverse platform functions as a cultural tool mediating learning events. Particularly relevant to metaverse-based learning environments is the idea of the Zone of Proximal Development (ZPD), the difference between what a learner can do without assistance and what they can do with direction from experienced peers (Ponmani & Geetha, 2022; Roth & Jornet, 2016). These systems allow for various forms of scaffolding to be implemented, such as peer-to-peer interaction in virtual spaces, immediate feedback mechanisms, graduated difficulty levels in language tasks, and virtual mentoring opportunities (Roth & Jornet, 2016). By leveraging these tools effectively, learners can receive tailored support and guidance to enhance their learning experience in the metaverse.

WHAT IS METAVERSE?

The metaverse is a dynamic concept that combines physical and digital realities to create a 3D virtual environment that is both immersive and seamless. User avatars enable them to interact with digital objects and other users in real-time, thereby eliminating physical barriers (Cali et al., 2022; Kozlov, 2024; Mandala et al., 2023). Fundamentally, the metaverse combines augmented reality (AR) and virtual reality (VR) to produce a hybrid environment in which virtual and real-world components live peacefully (Cali et al., 2022; Mandala et al., 2023; Sathyamoorthy et al., 2024). By providing a comprehensive platform for social interactions, this technology helps users to participate in many activities such as gaming, education, and virtual meetings, thus promoting a sense of presence and community in digital environments (Mandala et al., 2023; Selvarajan et al., 2024; Yaqob & Hafez, 2023). The metaverse is distinguished in part by its use of digital twin technology, in which changes in the physical world are reflected in the virtual environment and vice versa, therefore producing a dynamic and responsive virtual ecosystem (Sathyamoorthy et al., 2024). The metaverse uses cutting-edge technologies such as 3D holographic avatars, cloud computing, and the Internet of Things (IoT), all working in concert to improve user experience and enable seamless interaction inside the virtual world (Cali et al., 2022). The metaverse stands apart from conventional virtual environments and is positioned as a transforming platform for many uses, including education, because of its thorough integration of advanced technologies and social aspects.

METAVERSE ADOPTION IN HIGHER EDUCATION

The adoption of metaverse in higher education is shaped by a complicated interaction of social, personal, and technological aspects. While perceived cyber risk functions as a major obstacle, studies have revealed that students' intention to adopt metaverse technology is mostly driven by perceived

usefulness, personal innovativeness in IT, and perceived enjoyment (Al-Adwan et al., 2023; Prabakaran & Patrick, 2024). According to the Unified Theory of Acceptance and Use of Technology (UTAUT) model, stakeholders' attitudes toward metaverse adoption depend critically on social influence and self-efficacy, performance and effort expectation, and also on performance and effort expectation (Dang et al., 2023; Galindo-Manrique et al., 2024). The metaverse presents many advantages in educational environments, including better student involvement, expanded learning chances, and cooperative possibilities over geographic distances (Puneet et al., 2024; Tyagi et al., 2023). Immersive and interactive virtual worlds allow creative thinking, critical thinking, and novel educational approaches (Ak et al., 2024; Akbar et al., 2024). Technical and infrastructure constraints, device compatibility problems, privacy issues, and major financial consequences are among the various difficulties the integration encounters (Ak et al., 2024; Akbar et al., 2024). Institutions should concentrate on encouraging active learning, careful integration of extended reality (XR) technologies, increased customizing choices, and strong technical support systems (Ak et al., 2024) to guarantee effective deployment. Effective metaverse implementation in higher education environments depends on this awareness of advantages and difficulties.

Impact of Metaverse Technology on Academic Outcomes and Retention of Language Skills

The integration of metaverse technologies, particularly virtual reality (VR) and augmented reality (AR), into English language learning environments, has garnered significant attention in recent years due to its potential to enhance academic performance and promote long-term retention of language skills. Several studies have demonstrated the efficacy of VR in improving specific language skills. For instance, research on using Google Earth VR to enhance expository writing among English language learners revealed statistically significant improvements in writing skills (Y. Chen et al., 2019). This finding suggests that VR can play a crucial role in developing critical language competencies, including comprehension and retention. The immersive nature of the metaverse allows for the simulation of real-world scenarios, providing language learners with authentic contexts to practice their skills, which is essential for long-term language retention (Jia et al., 2023).

AR has also shown promise in enhancing student motivation and achievement in language learning. A study focusing on AR-based platforms for English vocabulary instruction found that the use of 3D graphics and immersive gameplay significantly increased students' vocabulary retention compared to traditional methods (Hao & Lee, 2019). The interactive and engaging elements within the metaverse appear to reinforce language skills by offering varied and repeated practice opportunities in a virtual environment. The retention of language skills in metaverse environments is not solely attributed to initial engagement but also long-term exposure and application. Research indicates that students are more likely to retain information when actively involved in the learning process, a feature facilitated by metaverse technologies. The interactive nature of the metaverse, which enables students to engage with both peers and content in a virtual space, supports the development of critical thinking and problem-solving skills, both crucial for language retention (Teo et al., 2021).

Moreover, it has been demonstrated that including peer assessment in virtual environments helps students' critical thinking, reflection capacity, and speaking skills. Peer assessment procedures raised learning motivation and lowered anxiety, thus boosting long-term retention of language skills, according to a study on the use of spherical video-based virtual reality (SVVR) for English as a Foreign Language (EFL) students (Chien et al., 2019). These results highlight in metaverse-based learning environments the need for cooperation and feedback for both long-term retention and immediate academic performance. Measurable results show that students using metaverse platforms showed more consistent performance over time, with less variation in their academic results, compared to standard and metaverse-enhanced classrooms. This implies that the metaverse provides a more consistent and dependable framework for language acquisition, therefore fostering consistent academic development and skill retention (Yuan et al., 2023). The dynamic and interesting learning environment the metaverse offers helps students to review and strengthen important ideas, hence enhancing retention.

While existing studies demonstrate promising potential for metaverse technology in language learning, several critical limitations persist. Most research has focused on immediate learning outcomes without examining long-term retention and skill transfer. For instance, while Y. Chen et al. (2019) and Hao and Lee (2019) show positive immediate results for writing and vocabulary acquisition, but they don't explore whether these gains persist over time. Furthermore, studies have typically examined individual language skills in isolation rather than investigating comprehensive language proficiency development. This fragmented approach limits our understanding of how metaverse technologies impact overall language competency. Thus, investigating this could offer a more complete knowledge of how metaverse technologies affect the whole range of language abilities and their pragmatic use over a long period. This body of studies results in the following hypotheses:

H1: Metaverse technology causes significant differences in English language proficiency

H2: Metaverse technology causes a significant increase in long-term retention of English language skills

Role of Digital Literacy in Metaverse-Based Learning Environments

Digital literacy evolved from media and information literacy in the 1990s to encompass essential computer competencies, including word processing, spreadsheet management, and digital tool usage (Leaning, 2019; Nichols & Stornaiuolo, 2019). It expanded in the 2000s to include digital material creation, information curation, and critical analysis (Samaniego, 2024). The importance of digital literacy for citizenship and lifelong learning was emphasized in the college curriculum (Marín & Castañeda, 2023). In the 2010s, immersive learning technologies like augmented and virtual reality revolutionized education by introducing innovative methods to engage students (Szűts & Vaughan, 2024). By the 2020s, the convergence of digital literacy and immersive learning was evident. To improve educational outcomes, scholars and educational institutions established frameworks to integrate XR with digital literacy (Chang et al., 2023). The COVID-19 pandemic accelerated the integration of digital and immersive learning approaches, emphasizing the need for digital literacy in distant and hybrid educational settings (Taggart et al., 2023).

The integration of metaverse technologies in education, particularly in English language learning, has highlighted the critical role of digital literacy in determining academic outcomes. As these virtual environments become increasingly prevalent in educational settings, research has begun to explore the relationship between students' digital competencies and their ability to engage with and benefit from these innovative learning platforms effectively. A study focusing on university interns using mobile-assisted language learning (MALL), gamification, and VR technologies during the COVID-19 pandemic revealed a strong correlation between digital literacy levels and students' ability to adapt to and benefit from these technologies (Azar & Tan, 2020). The findings suggest that digital literacy is not merely advantageous but a prerequisite for students to fully leverage the potential of metaverse-based learning environments. Students with higher digital literacy levels demonstrated superior engagement with the platforms, leading to enhanced learning experiences and improved academic performance. This trend is further corroborated by research on augmented reality (AR)-based mobile learning, which found a significant impact of digital literacy on learning outcomes. The study showed that students proficient in navigating AR tools achieved higher learning gains compared to their peers with lower digital literacy levels (Syarifudi & Suharjito, 2020). This indicates that digital literacy not only facilitates access to metaverse platforms but also enhances the effectiveness of the learning process itself.

The complexity of metaverse-based learning environments often demands a high level of digital competence from learners. A study on the application of VR in an English for Specific Purposes (ESP) course demonstrated that students with higher digital literacy navigated the virtual environment more efficiently, resulting in better performance in speaking and vocabulary acquisition (Hsu et al., 2023). This finding underscores the importance of digital literacy in maximizing the benefits of VR-based

language learning, as students with lower digital competence may struggle to engage with the platform, potentially limiting their learning outcomes. Beyond technical proficiency, digital literacy has been shown to play a crucial role in reducing anxiety and increasing motivation in language learning contexts. Research involving metaverse platforms for English-speaking practice found that students with higher digital literacy experienced lower levels of anxiety and higher levels of motivation (M. A. Chen & Hwang, 2020). This suggests that digital literacy not only enhances technical abilities but also positively influences students' emotional responses to the learning process, which can significantly impact overall academic performance.

Furthermore, digital literacy has been found to foster collaboration and peer learning in metaverse environments. A study on peer assessment in VR settings indicated that digitally literate students were better able to provide constructive feedback to their peers, enhancing the learning experience for all participants (Chien et al., 2019). This highlights the role of digital literacy in promoting a collaborative and interactive learning environment, which is essential for the success of metaverse-based education.

Current literature reveals significant gaps in understanding digital literacy's role in metaverse-based learning. While studies like Azar and Tan (2020) suggest correlations between digital competency and learning outcomes, they fail to examine how varying levels of digital literacy might create educational inequalities. The assumption that digital literacy uniformly enhances academic outcomes needs more critical examination, particularly in contexts where access to technology varies significantly. As these platforms become more widespread in English language education, the importance of ensuring students have the necessary digital skills to navigate and engage with virtual learning environments becomes increasingly apparent. This body of research leads to the following hypothesis:

H3: There is a significant increase in digital literacy when exposed to metaverse environments

H4: There is a significant influence of digital literacy on academic outcomes after being exposed to the Metaverse environment.

Inclusivity and Metaverse

The integration of the metaverse in education offers significant potential for enhancing inclusivity and accessibility. The metaverse can bridge the gap between digital and physical worlds, providing a safe, controlled, and diverse interactive learning environment that promotes student engagement and satisfaction (Jindal et al., 2024; Ueno et al., 2024). It transcends geographical boundaries, enabling inclusive education by offering equal learning opportunities to students from various backgrounds and with different abilities (Verma et al., 2024). However, challenges such as ensuring accessibility features for students with disabilities and addressing privacy concerns remain critical (Damasceno et al., 2024). The previous studies done by Ueno et al. (2024) and Jindal et al. (2024) have demonstrated that inclusive metaverse environments can enhance student engagement and satisfaction, but there is a lack of understanding of which or how factors contribute to or hinder inclusivity in the virtual spaces. To address this gap, our study employs a qualitative approach through semi-structured interviews with students from resource-limited environments, specifically exploring their experiences with metaverse-based language learning.

Ethical Considerations in Metaverse-Based Education

It is important to consider ethical questions raised by the use of metaverse technologies in the classroom. Since metaverse platforms gather vast user behavioral data and learning analytics (Ak et al., 2024), primary issues include data privacy and security. While metaverse technology promises enhanced learning experiences, the high costs of VR equipment and requirements for stable internet connectivity risk aggravating existing educational inequalities, especially in resource-limited settings (Akbar et al., 2024; Tyagi et al., 2023). The digital divide presents another important ethical challenge: exposure to virtual worlds (İbİli et al., 2024) raises psychological well-being and digital addiction con-

cerns; accessibility challenges for students with impairments call for careful thought in platform design (Galindo-Manrique et al., 2024). These ethical consequences highlight the need for creating thorough policies that strike a balance between fair access and student welfare protection with regard to technical innovation.

This literature review has examined metaverse-based language learning through multiple lenses. The review of immersive technologies' impact on language outcomes supports hypotheses H1 and H2, suggesting that metaverse technology significantly improves both immediate language proficiency and long-term retention. Research on digital literacy development in virtual environments provides the foundation for H3, proposing significant increases in digital literacy through metaverse exposure, while studies connecting digital competency to learning outcomes inform H4, suggesting digital literacy influences academic performance. The inclusivity section, along with ethical considerations regarding data privacy, digital inequality, and accessibility challenges, underscores the importance of developing metaverse platforms that enhance learning without widening educational disparities.

METHODOLOGY

Focusing on academic achievement, digital literacy, and inclusiveness in resource-limited environments, this mixed-methods research study investigates the long-term influence of metaverse-based platforms on English language acquisition.

RESEARCH DESIGN

The research is divided into two phases: quantitative and qualitative. In the quantitative phase, a pre-test/post-test experimental design was used to assess language performance and retention. A sample of 60 English language learners (undergraduate students) from an educational institution were selected. Students engaged in an 8-week English language course conducted via a metaverse platform. Language proficiency (reading, writing, speaking) was measured at three stages: before the intervention (pre-test), immediately after the course (post-test), and six months later (retention test). Standardized test models of IELTS were used for assessment. Additionally, digital literacy was measured using a Digital Literacy Questionnaire both before and after the course to assess the role of digital competency in metaverse-based learning.

Semi-structured interviews with a subgroup of 30 students from resource-limited environments were carried out in the qualitative phase to investigate obstacles to accessing the metaverse platform and issues of inclusiveness and adaptability. Students' opinions on how to make the digital world more accessible and their experiences with it were the main subjects of the interviews.

The study used a metaverse platform with an education focus that satisfied strict language learning selection requirements. The chosen platform has specialized language learning features like interactive conversation spaces and pronunciation feedback systems; multi-device accessibility that supports both VR headsets and regular computer interaction for inclusive participation; and dedicated educational tools like language-specific learning modules, synchronous collaboration spaces, and customizable virtual classrooms. Through the demo version of the platform, users could access the virtual environment's designated areas for particular language activities, such as speaking practice areas, collaborative writing spaces, and reading comprehension zones.

SAMPLING

In the quantitative phase, the sample consisted of 60 undergraduate students who were interested in learning the English language. To ensure balanced representation, stratified random sampling was employed. The students were divided into two strata. One group was introduced to metaverse (VR learning approach), and the other group was introduced to a traditional online approach. From each stratum, a random selection of students was made, ensuring a diverse mix of learners in terms of both socio-economic background and digital resource availability. This technique ensures that the

study captures a broad spectrum of experiences with metaverse-based learning, reflecting differences in accessibility to digital technologies. The stratified sampling method allowed for comparative analysis between students in different environments, helping to assess the impact of resource availability on language learning outcomes and digital literacy in a metaverse environment.

In the qualitative phase, a subset of 15 students was selected from the participants in the quantitative phase, focusing primarily on students from the experimental group. The sampling was conducted using purposive sampling, as the goal was to gain in-depth insights into the barriers these students faced in accessing the metaverse platform, as well as their adaptive strategies and experiences regarding inclusivity.

PROCEDURE

Phase 1

In Phase 1, a quantitative approach was employed to assess the impact of a metaverse-based English language course on students' language proficiency and digital literacy. The experimental group spent one hour every day continuously for eight weeks. The course structure included reading activities in virtual environments (20 minutes), writing tasks using virtual tools (20 minutes), and speaking practice through role-play and discussions (20 minutes). Specific activities included engaging with virtual texts for reading comprehension, collaborative writing projects on virtual whiteboards, descriptive essays about virtual locations, group discussions in virtual meeting rooms, and presentations based on metaverse experiences. The control group underwent the same course through online mode training without metaverse exposure.

Using tasks modeled on the IELTS form, participants in both the control and experimental groups first completed a pre-test to gauge their baseline competency in reading, writing, and speaking. Students in the experimental group engaged in an 8-week English language course run under a metaverse-based learning platform following the pre-test. The training included immersive learning opportunities meant to improve language competency and interactive virtual settings. Students from both groups completed a post-test to gauge their language competency and computer literacy after finishing the course. A 6-month follow-up test was also given to evaluate long-term language skill retention.

Phase 2

For members of the experimental groups, Phase 2 used a qualitative approach to investigate the accessibility and inclusivity of metaverse-based learning environments. A selection of fifteen Phase 1 students were chosen for semi-structured interviews using purposive sampling. The semi-structured interviews centered on two specific questions designed to explore participants' experiences and gather recommendations for improvement. The open-ended questions allowed participants to share detailed insights about their experiences whilst providing concrete suggestions for future development of metaverse-based language learning platforms.

INSTRUMENTS

We conducted the English language proficiency tests for the participants in this study both before and after the experiment, based on the IELTS exam model checking proficiency based on reading, writing, and speaking. The language proficiency test had 30 marks (10 for each component) in both the pre-experiment and post-experiment phases. The experiment uses reading comprehension to measure reading proficiency, allocating 10 marks for it. We tested writing proficiency by assigning five marks to each short essay and letter writing component. We introduced three parts to assess speaking proficiency. The first part has an introduction (3 marks), the second part has spontaneous speech (4 marks), and the third part has a general discussion (3 marks). The assessment of this speaking proficiency yielded 10 marks. The same pattern of questions was used to measure the long-term retention of language proficiency.

We used a standardized scale by Amin et al. (2022) to test the digital literacy of students. The scale has nine components, which are communication (7 items), collaboration (3 items), critical thinking (3 items), creativity (4 items), citizenship (4 items), character (3 items), curation (3 items), copyright (4 items), and connectedness (5 items). In total, the digital literacy scale has 36 items. We measured each item using a 5-point Likert scale, ranging from strongly disagree to strongly agree, and we assessed the participants' academic outcomes using their regular GPA (grade point average). We measured the academic outcomes for subsequent semesters after the experiment. This approach allowed us to test H4 by examining whether increased digital literacy from metaverse exposure positively influenced students' academic performance in subsequent coursework.

For the qualitative phase of the study, we asked two questions to the participants to explore their views towards accessibility and inclusivity, posing questions as follows:

> In what ways did you feel included/excluded in the learning process?
>
> What improvements would you suggest for making this technology more accessible?

ANALYSIS

The effectiveness of metaverse-based learning was investigated using several statistical techniques applied to quantitative data analysis. With a significance level set at $p < .05$, paired t-tests were used to evaluate variations in both experimental and control groups for comparison of pre-test and post-test scores. Cohen's d was used to estimate effect sizes; small, medium, and large effects respectively were denoted by values of 0.2, 0.5, and 0.8. The study concentrated on digital literacy scores and three main elements of linguistic competency: reading, writing, and speaking. While long-term impacts were evaluated by means of comparisons between pre-test and retention test scores after six months, mean variations between pre-test and post-test scores were computed for instantaneous effects. Multiple regression analysis was used to investigate the association between digital literacy and academic performance, using R^2 values to ascertain the variance explained by the model, together with Beta coefficients and their significance levels for every digital literacy variable. Every statistical test was run on SPSS version 26.

CONTROL GROUP

On average, participants showed improvement in all skill areas (reading, writing, speaking) from the pre-test to the post-test (Table 1). Digital literacy scores also improved from the pre-test to the post-test. The average GPA outcome is 6.06, with a relatively small standard deviation of 0.25. The age range of participants is from 19 to 23, with a mean of 20.87 years.

From Table 2, it is observed that the gender distribution is perfectly balanced with 15 males and 15 females. Most participants are in their 3rd year of study (36.67%), followed closely by 2nd year (33.33%) and 4th year (30%). A majority of participants (56.67%) have previous experience with online learning. Most participants (73.33%) have access to high-speed internet. Laptops are the most common device used for learning (56.67%), followed by smartphones (20%).

On average, participants showed improvement in all areas (Table 3), with reading and writing showing the most improvement (0.84 points each) and speaking showing a smaller improvement (0.30 points). For all three skills, the improvement from pre-test to post-test is statistically significant ($p < 0.05$). Reading and writing show identical improvements, both highly significant ($p < 0.001$). Speaking shows a smaller but still significant improvement ($p = 0.010$). The intervention had a large effect on reading and writing skills. The effect on speaking skills was medium-sized.

Table 1. Descriptive scores of English proficiency of control group

Variable	Mean	Median	Min.	Max.	Standard deviation
Reading score (pre-test)	5.33	5.5	3	7	1.32
Writing score (pre-test)	4.33	4.5	2	6	1.32
Speaking score (pre-test)	5.33	5.5	3	7	1.32
Reading score (pre-test)	6.17	6	4	8	1.23
Writing score (pre-test)	5.17	5	3	7	1.23
Speaking score (pre-test)	5.63	6	3	7	1.25
GPA outcome	6.06	3.1	2.6	3.4	0.25
Age	20.87	21	19	23	1.25

Table 2. Sample distribution of control group

Variable	Category	Frequency	Percentage
Gender	Female	15	50%
	Male	15	50%
Age	19	5	16%
	20	6	20%
	21	8	26.7%
	22	7	23.3%
	23	4	13.3%
Year of study	2nd year	10	33.33%
	3rd year	11	36.67%
	4th Year	9	30%
Previous experience with online learning	Yes	17	56.67%
	No	13	43.33%
Access to high-speed internet	Yes	22	73.33%
	No	8	26.67%
Device used for learning	Laptop	17	56.67%
	Smartphone	6	20%
	Desktop computer	4	13.33%
	Tablet	3	10%

Table 3. Pre-test and post-test scores of English proficiency of control group

Skill	Mean difference	T-statistic	Cohen's d	Interpretation	p-value
Reading	0.84	7.94	1.45	Large effect	<0.001
Writing	0.84	7.94	1.45	Large effect	<0.001
Speaking	0.30	2.77	0.51	Medium effect	0.010
Degrees of freedom (df) = 29 for all tests					

Experimental Group

From Table 4, it is identified that the experimental group has an equal distribution of males and females, providing a balanced representation. The majority of participants (76.66%) are between 20 and 22 years old. The mean age is approximately 21 years, with a relatively narrow range of 4 years.

There's a fairly even distribution across the 2nd, 3rd, and 4th years, with a slight majority in the 3rd year. This distribution allows for insights across different stages of university education. The group represents a diverse range of academic disciplines. Business-related fields (Business Administration, Marketing, Finance, Economics) make up 36.67% of the participants. STEM fields (Computer Science, Engineering, Biology) account for 30% of the group. Humanities and Social Sciences (English Literature, Psychology, Political Science, Sociology, Media, and Communication) represent 33.33% of the participants.

Table 4. Demographic information of the experimental group

Characteristic	Category	Count	Percentage
Gender	Male	15	50%
	Female	15	50%
Age	19	4	13.33%
	20	7	23.33%
	21	9	30%
	22	7	23.33%
	23	3	10%
Year of study	2nd year	10	33.33%
	3rd year	11	36.67%
	4th year	9	30%

All three skills show improvement from the pre-test to the post-test (Table 5), with means increasing by 2 points each. Standard deviations remain constant from the pre-test to the post-test (1.31), indicating consistent variability. Retention test scores show some decay but remain higher than pre-test scores. Variability decreases in the retention test (lower SD), suggesting more consistent performance across participants. Substantial improvement from the pre-test (mean 50.00) to the post-test (mean 62.80). Increased standard deviation in the post-test (2.58 vs. 1.91) suggests more varied improvement across participants. Retention test scores (mean 61.00) show slight decay but remain significantly higher than pre-test scores. A mean GPA of 6.78 with a median of 7.00 indicates generally high academic performance. Relatively low standard deviation (0.46) suggests consistent performance across the group. The range from 6.00 to 7.40 shows some variability, but all are within a good performance bracket.

Table 5. Descriptive scores of the experimental group

Variable	Mean	Median	Min	Max	Standard deviation
Reading score (pre-test)	5.27	5.50	3.00	7.00	1.31
Writing score (pre-test)	4.27	4.50	2.00	6.00	1.31
Speaking score (pre-test)	5.27	5.50	3.00	7.00	1.31
Reading score (post-test)	7.27	7.50	5.00	9.00	1.31
Writing score (post-test)	6.27	6.50	4.00	8.00	1.31
Speaking score (post-test)	7.27	7.50	5.00	9.00	1.31
Reading score (retention)	6.47	6.00	5.00	8.00	0.86
Writing score (retention)	5.70	6.00	5.00	7.00	0.65
Speaking score (retention)	5.63	5.50	5.00	7.00	0.61
Digital literacy (pre-test)	50.00	50.00	46.00	54.00	1.91
Digital literacy (post-test)	62.80	63.00	58.00	68.00	2.58
Digital literacy (retention)	61.00	61.00	57.00	66.00	2.49
GPA	6.78	7.00	-	-	0.46

All skills show statistically significant improvements ($p < 0.001$), as shown in Table 6. The mean differences are consistent across reading, writing, and speaking (2.00 points each). Digital literacy shows the largest mean improvement (12.80 points). Effect sizes are large for all skills, with digital literacy showing the largest effect ($d = 3.10$).

Table 6. Pre-test vs. post-test scores of English proficiency of the control group (to test the immediate effect)

Skill	Mean difference	T-statistic	Cohen's d	p-value
Reading	2.00	30.00	2.36	<0.001
Writing	2.00	30.00	2.36	<0.001
Speaking	2.00	30.00	2.36	<0.001
Digital literacy	12.80	24.76	3.10	<0.001

From Table 7, it is observed that reading, writing, and digital literacy maintain statistically significant improvements ($p < 0.001$). Speaking skills show a marginally significant improvement ($p = 0.059$). Mean differences are smaller compared to immediate effects, indicating some skill decay. Effect sizes remain large for writing and digital literacy, medium for reading, and small for speaking. Digital literacy shows the best retention, maintaining a large effect size. Writing skills also demonstrate good retention with a large effect size. Reading skills show some decay but still maintain a medium to large effect. Speaking skills show the most decay, with only a small long-term effect.

Table 7. Pre-test vs. retention test scores of English proficiency of the control group (to test the long-term effect)

Skill	Mean difference	T-statistic	Cohen's d	p-value
Reading	1.20	6.40	0.94	<0.001
Writing	1.43	9.55	1.69	<0.001
Speaking	0.36	1.96	0.35	0.059
Digital literacy	11.00	20.39	2.56	<0.001

Comparative Analysis

The immediate improvement in reading skills for the experimental group is much larger compared to the control group (mean difference of 2.00 compared to 0.84, Cohen's $d = 2.36$ vs. 1.45). Over the long term, the experimental group still retains a medium to large effect size (Cohen's $d = 0.94$), indicating a substantial difference between the experimental and control groups. Cohen's d measures the standardized mean difference, with values around 0.2 considered small, 0.5 medium, and 0.8 or higher large. A d measure of 0.94 suggests that the effect of the intervention remains strong over time. The immediate impact of the intervention in the experimental group is significantly larger compared to the control group (mean difference of 2.00 vs. 0.84). In the long term, the large effect size is maintained for the experimental group (Cohen's $d = 1.69$), suggesting strong retention of writing skills, much better than we would expect based on the control group's results. The immediate improvement in speaking for the experimental group (mean difference of 2.00) is far superior compared to the control group (0.30). The large effect size in the experimental group (Cohen's $d = 2.36$) suggests the intervention had a substantial effect on speaking skills in the short term. However, long-term retention is weak in the experimental group for speaking, as the effect size drops to small (Cohen's $d = 0.35$). This suggests that speaking skills are harder to maintain over time despite the strong initial improvement. Digital literacy saw the largest improvement in the experimental group, with an extremely large immediate effect (Cohen's $d = 3.10$). The long-term effect size remains very large (Cohen's $d = 2.56$), indicating that digital literacy improvements were well-retained, making it the best-retained skill in the experimental group.

The experimental group provided the best results compared to the control group. The intervention produced much larger immediate improvements, and skills like digital literacy and writing showed excellent long-term retention. Even though speaking skills decayed over time, the initial improvement was much stronger than in the control group. Therefore, the hypotheses – (H1) that Metaverse technology causes significant differences in English language proficiency and (H2) that Metaverse technology significantly enhances long-term retention of English language skills – are supported.

All digital literacy variables shown in Table 8 seem to have a statistically significant increase from the pre-test to the post-test (all p-values < .001). This suggests that there was a substantial improvement in all measured aspects of digital literacy between the two time points. The largest increase was in curation (F = 31.87), followed by creativity (F = 29.81) and connectedness (F = 27.54). The smallest increase, though still significant, was in communication (F = 15.42). Every digital literacy variable showed improvement, indicating a broad-based enhancement of digital skills and knowledge. The improvements across all digital literacy variables suggest that the intervention or time period between the pre-test and post-test was effective in enhancing these skills. Our hypothesis (H3) – that there is a significant increase in digital literacy when exposed to Metaverse environments – is supported.

Table 8. Pre-test vs. post-test comparison of digital literacy variables

Variable	Pre-test mean	Post-test mean	F-value	P-value	Change
Communication	3.33	3.90	15.42	<.001	↑
Copyright	2.88	3.73	24.18	<.001	↑
Critical thinking	3.14	3.78	18.76	<.001	↑
Character	3.71	4.38	22.95	<.001	↑
Citizenship	3.58	4.28	24.63	<.001	↑
Curation	2.66	3.64	31.87	<.001	↑
Connectedness	2.17	3.05	27.54	<.001	↑
Creativity	2.28	3.18	29.81	<.001	↑
Collaboration	3.54	4.23	19.37	<.001	↑

Note: ↑ indicates an increase, ↓ indicates a decrease, − indicates no change, Degrees of freedom for all F-tests: (1, 58)

From Table 9, it is noted that $R^2 = 0.301$, indicating that the model explains 30.1% of the variance in GPA outcomes. The model's p-value is 0.498, which is not statistically significant at the conventional 0.05 level. None of the digital literacy variables show statistically significant relationships with academic outcomes (all p-values > 0.05). Based on the regression results, we failed to support hypothesis H4. Most digital literacy variables continue to show negative relationships with GPA, which is counterintuitive and warrants further investigation.

Table 9. Influence of variables on academic outcomes

Variable	B	SE B	β	t	p
Constant	7.2014	0.7104		10.137	.000
Communication	-0.0223	0.1132	-0.0516	-0.197	.846
Copyright	0.0452	0.1073	0.1043	0.421	.678
Critical thinking	0.0315	0.1341	0.0727	0.235	.817
Character	-0.0574	0.1515	-0.1326	-0.379	.709
Citizenship	-0.0387	0.1391	-0.0894	-0.278	.784
Curation	-0.0156	0.1277	-0.0360	-0.122	.904
Connectedness	-0.1436	0.1182	-0.3315	-1.215	.239
Creativity	-0.0762	0.1312	-0.1759	-0.581	.568
Collaboration	0.0328	0.1255	0.0757	0.261	.797

Note: $R^2 = .301$ (N = 30, p = .498)

QUALITATIVE ANALYSIS

Starting with a careful familiarization with the responses from the open-ended questions, the theme analysis process involved several readings of the participants' answers. Then, by spotting repeating trends and important data points, the first codes were produced, which were methodically used throughout the whole data collection process. Finding themes by organizing similar codes and seeing general trends came next. After that, these possible topics were examined to guarantee they fairly reflected the facts and tackled the study issues. Every theme established clear definitions and titles to best express its core. Finally, the study was written using supporting and interesting extract examples to highlight every subject. Constant comparison and iterative reflection were used throughout this approach to guarantee the analysis stayed anchored in the data and offered significant insights into the participants' experiences with metaverse technology in language acquisition.

The thematic analysis shown in Table 10 indicates important consequences for the design of metaverse learning. Although interactive engagement themes and inclusive social interaction show the platform's capacity for collaborative learning, the appearance of technological impediments and digital skill discrepancies points to particular design needs. These results show that effective implementation in the metaverse virtual learning environments calls for careful attention to both social affordances and accessibility aspects.

Table 10. In what ways did you feel included/excluded in the learning process?

Participant ID	Response summary	Codes	Theme
P01	Felt included due to interaction with diverse students	- Diverse interaction - Engaging environment	Inclusive social interaction
P10	Included through interactive experiences in shared virtual space	- Interactive experiences - Shared virtual environment	
P06	Included through real-time communication and collaboration	- Real-time communication - Collaborative activities	Interactive engagement
P08	Included through collaborative projects	- Collaborative projects - Community feeling	
P12	Involved through collaborative real-time language practice	- Collaborative tasks - Real-time practice	
P15 (partial)	Included in group activities	- Group activities inclusion	
P02	Felt excluded during technical issues	- Technical problems - Missed discussions	Technical barriers
P09	Excluded due to technical issues causing missed lessons	- Technical problems - Missed content	
P15 (partial)	Excluded due to internet issues	- Internet connection problems	
P05	Excluded during quick-response activities due to navigation difficulties	- Navigation challenges - Speed of response issues	Digital skill disparities
P07	Felt excluded due to a slower grasp of VR tools	- Learning curve - Skill gap	
P14	Excluded during fast-paced activities due to slower adaptation	- Adaptation speed - Fast-paced activities	

Participant ID	Response summary	Codes	Theme
P04	Included due to equal access to technology	- Equal technology access - No technological gap	Equitable access
P13	Included due to equal access to resources and the environment	- Equal resource access - Level playing field	
P03	Connected through VR but missed external discussions	- Immersive learning - Missed external interactions	Immersion vs. isolation
P11	Excluded during challenging activities like spontaneous speaking	- Activity difficulty - Speaking task challenges	Task-specific challenges

Thematic analysis in Table 11 has indicated important design implications for systems in the metaverse. The themes of supporting training, improving infrastructure, and adding features to the platform draw attention to specific areas that need improvement. It is important to note that participants' suggestions stress the need for a three-tiered implementation approach: improving technology infrastructure, offering full user support, and making learning interfaces more flexible to meet the needs of all students.

Table 11. What improvements would you suggest for making this technology more accessible?

Participant ID	Response summary	Codes	Theme
P01	Better training sessions on using VR headsets and navigation	- Pre-course training - Navigation guidance	Training and support
P04	Quick tutorial within VR for first-time users	- In-VR tutorial - Basic control instruction	
P10	Tech support is readily available during lessons	- Real-time tech support - Minimizing class disruptions	
P02	Improving internet infrastructure in the college	- Internet infrastructure - Smooth experience	Infrastructure and equipment
P05	More ergonomic headsets for comfort in longer sessions	- Ergonomic design - Extended use comfort	
P11	Less resource-intensive platform for smoother running	- Resource optimization - Device compatibility	
P03	Allow use of VR headsets outside the classroom	- Extended access - Extra practice	Increased access and practice
P06	Provide space for VR practice in free time	- Practice space - Self-paced learning	
P07	Better integration with real-world tasks	- Real-world integration - Physical material interaction	Platform features and customization
P08	Adjustable settings to reduce motion sickness	- Motion sickness reduction - Comfort settings	
P12	More personalized feedback during VR sessions	- Personalized feedback - Inclusive learning	
P13	Improved avatar interaction features	- Enhanced avatars - Realistic group work	

Participant ID	Response summary	Codes	Theme
P14	Option to switch between immersive and non-immersive modes	- Mode flexibility - Comfort options	
P15	Better audio and communication tools	- Improved audio - Enhanced communication	
P09	Offer a hybrid model combining VR and traditional methods	- Hybrid learning - Method flexibility	Hybrid learning models

DISCUSSION

With great effect sizes (Cohen's d = 2.36 for all skills), the experimental group demonstrated notable increases in reading, writing, and speaking abilities immediately following the intervention. This implies that for language acquisition, metaverse-based learning environments can be successful. These results are consistent with earlier studies showing the effectiveness of virtual reality in strengthening language proficiency, such as the one on the improvement of expository writing through Google Earth VR (Y. Chen et al., 2019). The immersive character of metaverse worlds probably provides real settings for language learning, which enhances performance. The novelty effect of adopting new technology could help to explain the significant effect sizes noted; this could have raised student enthusiasm and involvement in the short term.

The experimental group maintained significant improvements in reading and writing skills after six months, with medium to large effect sizes (Cohen's d = 0.94 for reading, 1.69 for writing). However, speaking skills showed less retention (Cohen's d = 0.35). It is worth mentioning that this decreased ability to retain speaking abilities goes against the norm described by Hennig-Thurau et al. (2022), as Metaverse environments are specifically designed to foster real-time verbal engagement and communication. The sustained improvements in reading and writing align with research on the benefits of immersive learning environments for long-term retention (Jia et al., 2023). The interactive nature of metaverse platforms may reinforce these skills through varied practice opportunities. The weaker retention of speaking skills suggests that some language competencies may require more ongoing practice or different types of interventions to maintain improvements. This highlights the need for balanced language learning approaches that address all skill areas effectively.

With the biggest effect size among all evaluated outcomes (Cohen's d = 3.10 immediate, 2.56 long-term), the experimental group demonstrated notable increases in digital literacy. This result aligns with studies showing that using sophisticated technology improves general digital competency (Jamrus & Razali, 2021). The metaverse setting most certainly gave pupils chances to acquire a variety of digital abilities outside of language acquisition. Contrary to what conventional ideas of educational technology would have us believe, these significant improvements in digital literacy did not result in better academic performance. Against predictions, the study revealed no appreciable correlation between digital literacy characteristics and GPA. This outcome questions presumptions regarding how directly digital skills affect academic performance (Pagani et al., 2016). It implies that, although navigating metaverse-based learning settings requires computer literacy, other elements can be more crucial for general academic performance. The rather small sample size (N=30) of the trial or the short-term character of the intervention could be the causes of the lack of significance. Furthermore, GPA might not be the best indicator of academic performance in this regard since it might not entirely reflect the particular linguistic and digital competencies acquired during the metaverse intervention.

The qualitative analysis revealed themes such as inclusive social interaction, interactive engagement, and technical barriers. Students reported feeling included through diverse interactions and collaborative activities but also experienced exclusion due to technical issues and digital skill disparities. These

findings align with research on the benefits of collaborative virtual environments for language learning (Chien et al., 2019). The reported technical barriers are consistent with challenges identified in implementing VR technologies in educational settings (H. Chen, 2023). The experiences of inclusion and exclusion varied among participants, highlighting the need for personalized support and adaptable learning environments. The technical barriers reported suggest that metaverse-based learning may inadvertently create new forms of educational inequality if not implemented with careful consideration of all students' needs and resources.

Participants suggested improvements in areas such as training and support, infrastructure and equipment, increased access and practice opportunities, and platform features and customization. These suggestions align with research on the importance of teacher training and digital infrastructure in successfully implementing AR and VR technologies in education (Jamrus & Razali, 2021). The focus on increased access and practice opportunities supports the need for flexible, hybrid learning models. Implementing all suggested improvements may be resource-intensive and challenging for many educational institutions. Prioritizing which improvements to focus on and finding cost-effective solutions will be crucial for the wider adoption of metaverse-based language learning.

The integration of qualitative and quantitative findings offers insights into the relationship between digital literacy and academic performance. While quantitative results showed negative correlations between some digital literacy variables and GPA, these relationships were not statistically significant. The qualitative data suggests that the link between digital literacy and academic success is more complicated than initially hypothesized, therefore helping to contextualize this result. Participants' experiences show that, although crucial for platform navigation, digital literacy might be only one of several elements affecting learning results. The qualitative data showed that students used the tool in a variety of ways, regardless of how technical they were. While some very technologically advanced students said they concentrated on technical inquiry, others said they gave language study top priority. This implies that individual learning strategies and involvement patterns can be more important than digital literacy by itself. Qualitative results also point out additional crucial elements such as platform accessibility, training support, and infrastructure quality. This more general view implies that rather than depending just on digital literacy, effective learning results in metaverse contexts depend upon multiple interconnected factors.

Theoretical Implications

In some respects, this work greatly advances the theoretical knowledge of technology-enhanced language acquisition. Most importantly, it shows how metaverse platforms provide new kinds of social mediation in language acquisition, hence extending Vygotsky's sociocultural theory in virtual contexts. In contrast to Ma and Yuen (2010), who emphasized the significance of social connection in online learning, our research reveals how virtual scaffolding and peer-to-peer interactions in fully immersive 3D settings promote the Zone of Proximal Development. Social mediation in virtual environments may operate differentially across language competencies according to the varied retention patterns across reading, writing, and speaking skills. This extends the work of Diep et al. (2018) on virtual learning environments. Moreover, our results contradict accepted wisdom on the link between digital literacy and academic achievement in virtual environments. Our findings point to a more nuanced link, especially in immersive settings, as opposed to G. Chen et al. (2024), who claim that digital literacy directly affects learning outcomes. This emphasizes the requirement of separating technical proficiency from pedagogical efficacy independently, therefore supporting developing theories regarding technology integration in language learning. Building on Kulal et al.'s (2024) research on digital equity in education, our qualitative results about inclusivity and technical constraints enhance present theoretical frameworks about accessibility in virtual learning settings. According to these findings, the metaverse adds new perspectives to discussions of educational involvement and access, necessitating that theoretical frameworks take into account the social as well as the technological components of virtual learning environments.

PRACTICAL IMPLICATIONS

The findings of this study have significant practical implications for educational institutions implementing metaverse-based language learning. Our results reveal a strong correlation between infrastructure quality and learning outcomes, supporting Akasaka et al.'s (2023) emphasis on technological readiness, suggesting that institutions should prioritize robust network infrastructure capable of supporting multiple simultaneous VR connections, regular technical maintenance, and backup systems for continued learning during technical difficulties.

The findings regarding digital literacy indicate the need for comprehensive training programs, aligning with Choudhary and Bansal's (2022) recommendations for technology integration. These programs should encompass structured training for both educators and students, ongoing technical support, and regular assessment of digital competency needs. The differential retention of language skills observed in our study suggests the necessity of hybrid learning approaches, building on recent studies of blended learning effectiveness (O'Byrne & Pytash, 2015). This approach should integrate metaverse-based activities with traditional language practice, incorporate regular speaking practice sessions in both virtual and physical environments, and provide structured peer interaction opportunities across platforms.

Furthermore, the accessibility challenges identified in our qualitative data, which align with recent findings by Alshammari (2020) on inclusive virtual learning, indicate that institutions should focus on developing adaptive interface options for diverse learner needs, providing alternative access methods for students with technical limitations, and creating inclusive virtual spaces that accommodate different learning styles.

CONCLUSIONS

This study looked at how metaverse-based platforms affected language learning and digital literacy in higher education: how they affected both short-term and long-term language proficiency, how digital literacy and academic performance were related, and how accessible the platforms were in environments with limited resources. Through a mixed-methods approach that included qualitative interviews (N=15) and an 8-week experimental intervention (N=60), we investigated these topics using pre-test, post-test, and retention measures at six months.

Both anticipated and surprising patterns were found in our data. Particularly in reading and writing, the experimental group's language proficiency significantly improved despite the metaverse's real-time communication capabilities, resulting in speaking skills surprisingly showing poorer retention. Despite notable improvements in digital competency, there was no discernible relationship between enhanced digital literacy and academic achievement in language acquisition.

This work has various constraints, though it offers insightful analysis of metaverse-based language learning. The sample size of 60 participants (30 per group) was chosen due to resource constraints, the intensive nature of the 8-week intervention, and the exploratory nature of this study. While this limits generalizability, it allows for in-depth analysis and serves as a pilot study to inform larger-scale research in the future. Metaverse technology may affect language acquisition in the long term, but the 8-week intervention may not capture this. The study may not be as applicable to other age groups or educational levels because it concentrated on undergraduate students. GPA is a metric of academic performance that may not fairly represent gains in particular language acquisition. Technical problems and different degrees of digital literacy among the participants could have affected the outcomes. The study lacked control for extraneous variables that could influence language acquisition outside of the metaverse context. Furthermore, the novelty impact of adopting new technology might have momentarily raised motivation, therefore exaggerating the short-term outcomes. The study took place at one institution, which would not fairly reflect varied educational environments and resource availability.

The study emphasizes the necessity of further long-term research to properly comprehend the effects of metaverse-based learning on academic performance and language competency. Future studies could investigate the connection between digital literacy and academic achievement in greater detail, maybe applying alternate criteria of academic success beyond GPA. To create more accessible and successful metaverse-based learning environments, multidisciplinary cooperation among language teachers, technologists, and learning scientists is much needed. To meet the different demands and ability levels of language learners, researchers should look at how adaptive learning systems inside metaverse settings may be used. Additional research should look at the transferability of digital capabilities gained in metaverse environments to real-world settings and other academic fields, as well as linguistic abilities. To guarantee uniformity among further research in this sector, consistent assessment instruments for evaluating language competency and digital literacy in immersive virtual environments should be developed. Training on the efficient use of metaverse-based learning tools should be included in academic courses in language education and educational technology, arming future teachers for this new pedagogical method. Future research should also examine how different pedagogical approaches and scaffolding strategies in metaverse environments affect both language acquisition and student well-being, including motivation, anxiety, and emotional engagement.

REFERENCES

Ak, O., Akbulut, M. Ş., Soydan, S., & Yildirim, E. (2024). Designing educational metaverses: A literature review to determine guidelines. *Interactive Learning Environments*, *33*(2), 925–943. https://doi.org/10.1080/10494820.2024.2365956

Akasaka, T., Arakawa, S., & Murata, M. (2023). On the service quality of cooperative VR applications in 5G cellular networks. In M. Yilmaz, P. Clarke, A. Riel, & R. Messnarz (Eds.), *Systems, software and services process improvement* (pp. 300–311). Springer. https://doi.org/10.1007/978-3-031-42310-9_22

Akbar, A., Mbonye, V., & Govender, T. (2024). Metaverse in higher education: Reshaping pedagogies and entrepreneurial ventures. In S. Inder, S. Dawra, S., K. L. Tennin, & S. Sharma (Eds.), *New business frontiers in the metaverse* (pp. 100–117). IGI Global.

Al-Adwan, A. S., Li, N., Al-Adwan, A., Abbasi, G. A., Albelbisi, N. A., & Habibi, A. (2023). Extending the Technology Acceptance Model (TAM) to predict university students' intentions to use Metaverse-Based Learning platforms. *Education and Information Technologies*, *28*(11), 15381–15413. https://doi.org/10.1007/s10639-023-11816-3

Alshammari, M. T. (2020). Design and evaluation of an adaptive framework for virtual learning environments. *International Journal of Advanced and Applied Sciences*, *7*(5), 39–51. https://doi.org/10.21833/ijaas.2020.05.006

Amin, N. H., Malik, N. M. A., & Akkaya, N. B. (2022). Development and validation of Digital Literacy Scale (DLS) and its implication for higher education. *International Journal of Distance Education and E-Learning*, *7*(1), 24–43. https://doi.org/10.36261/ijdeel.v7i1.2224

Azar, A. S., & Tan, N. H. I. (2020). The application of ICT Techs (mobile-assisted language learning, gamification, and virtual reality) in teaching English for secondary school students in Malaysia during COVID-19 pandemic. *Universal Journal of Educational Research*, *8*(11C), 55–63. https://doi.org/10.13189/ujer.2020.082307

Cali, U., Kuzlu, M., Karaarslan, E., & Jovanovic, V. (2022, November). Opportunities and challenges in metaverse for Industry 4.0 and beyond applications. *Proceedings of the IEEE 1st Global Emerging Technology Blockchain Forum: Blockchain & Beyond (iGETblockchain), Irvine, CA, USA,* 1–6. https://doi.org/10.1109/igetblockchain56591.2022.10087104

Chang, C., Kuo, H., & Du, Z. (2023). The role of digital literacy in augmented, virtual, and mixed reality in popular science education: A review study and an educational framework development. *Virtual Reality*, *27*(3), 2461–2479. https://doi.org/10.1007/s10055-023-00817-9

Chen, G., Jin, Y., & Chen, P. (2024). Development of a platform for state online education services: Design concept based on meta-universe. *Education and Information Technologies*, *29*, 23605–23629. https://doi.org/10.1007/s10639-024-12792-y

Chen, H. (2023). Gather in the metaverse: Learning outcomes, virtual presence, and perceptions of high- and low-achieving pre-service teachers of English as a Foreign Language. *Education and Information Technologies*, *29*(7), 8549–8577. https://doi.org/10.1007/s10639-023-12135-3

Chen, M. A., & Hwang, G. (2020). Effects of experiencing authentic contexts on English speaking performances, anxiety and motivation of EFL students with different cognitive styles. *Interactive Learning Environments*, *30*(9), 1619–1639. https://doi.org/10.1080/10494820.2020.1734626

Chen, Y., Smith, T. J., York, C. S., & Mayall, H. J. (2019). Google Earth Virtual Reality and expository writing for young English learners from a Funds of Knowledge perspective. *Computer Assisted Language Learning*, *33*(1–2), 1–25. https://doi.org/10.1080/09588221.2018.1544151

Chien, S., Hwang, G., & Jong, M. S. (2019). Effects of peer assessment within the context of spherical video-based virtual reality on EFL students' English-speaking performance and learning perceptions. *Computers & Education*, *146*, 103751. https://doi.org/10.1016/j.compedu.2019.103751

Choudhary, H., & Bansal, N. (2022). Addressing digital divide through digital literacy training programs: A systematic literature review. *Digital Education Review*, *41*, 224–248. https://doi.org/10.1344/der.2022.41.224-248

Damasceno, A., Silva, L., Barros, E., & Oliveira, F. (2024). Metaverse4Deaf: Assistive technology for inclusion of people with hearing impairment in distance education through a Metaverse-based environment. In O. Poquet, A. Ortega-Arranz, O. Viberg, I.-A. Chounta. B. McLaren, & J. Jovanovic (Eds.), *Proceedings of the 16th International Conference on Computer Supported Education* (pp. 510–517). SciTePress. https://doi.org/10.5220/0012700200003693

Dang, T. Q., Tran, P. T., & Nguyen, L. T. (2023). Are you ready for tapping into the metaverse in higher education? Integrated by dual PLS-SEM and ANN approach. In M. A. Al-Sharafi, M. Al-Emran, G. W.-H. Tan, & K. B. Ooi (Eds.), *Current and future trends on intelligent technology adoption* (pp. 63–84). Springer. https://doi.org/10.1007/978-3-031-48397-4_4

del Carmen Avendaño Porras, V., Olaya, C. I. B., & Cuervo, S. A. C. (2024). Exploring the impact of the metaverse on English language teaching: Perspectives of students from the University of Boyacá. *Journal of Infrastructure Policy and Development*, *8*(7), 4779. https://doi.org/10.24294/jipd.v8i7.4779

Diep, A. N., Zhu, C., Cocquyt, C., De Greef, M., & Vanwing, T. (2018). Adult learners' social connectedness and online participation: The importance of online interaction quality. *Studies in Continuing Education*, *41*(3), 326–346. https://doi.org/10.1080/0158037x.2018.1518899

Galindo-Manrique, A. F., Villarreal-Vera, V., Orozco-Bendímez, F. J., & García-Montoya, M. (2024). Adoption of the metaverse for higher education: Structural equation modeling approach in a business school context. *Journal of Social Studies Education Research*, *15*(2), 57–93.

Guo, H., & Gao, W. (2022). Metaverse-powered experiential situational English-teaching design: An emotion-based analysis method. *Frontiers in Psychology*, *13,* 859159. https://doi.org/10.3389/fpsyg.2022.859159

Hao, K., & Lee, L. (2019). The development and evaluation of an educational game integrating augmented reality, ARCS model, and types of games for English experiment learning: An analysis of learning. *Interactive Learning Environments*, *29*(7), 1101–1114. https://doi.org/10.1080/10494820.2019.1619590

Hennig-Thurau, T., Aliman, D. N., Herting, A. M., Cziehso, G. P., Linder, M., & Kübler, R. V. (2022). Social interactions in the metaverse: Framework, initial evidence, and research roadmap. *Journal of the Academy of Marketing Science*, *51*(4), 889–913. https://doi.org/10.1007/s11747-022-00908-0

Hsu, K., Barrett, N. E., & Liu, G. (2023). English for tourism and AR-assisted context-aware ubiquitous learning: A preliminary design-based research study. *Computer Assisted Language Learning*, 1-12 https://doi.org/10.1080/09588221.2023.2202701

Hwang, G., & Chien, S. (2022). Definition, roles, and potential research issues of the metaverse in education: An artificial intelligence perspective. *Computers and Education Artificial Intelligence*, *3*, 100082. https://doi.org/10.1016/j.caeai.2022.100082

İbili, E., Ölmez, M., İbili, A. B., Bilal, F., Cihan, A., & Okumuş, N. (2024). Assessing the effectiveness and student perceptions of synchronous online flipped learning supported by a metaverse-based platform in medical English education: A mixed-methods study. *Education and Information Technologies*, *29*, 18643–18673. https://doi.org/10.1007/s10639-024-12542-0

Jamrus, M. H. M., & Razali, A. B. (2021). Acceptance, readiness and intention to use Augmented Reality (AR) in teaching English reading among secondary school teachers in Malaysia. *Asian Journal of University Education*, *17*(4), 312. https://doi.org/10.24191/ajue.v17i4.16200

Jia, W., Pack, A., Guan, Y., Zhang, L., & Zou, B. (2023). The influence of game-based learning media on academic English vocabulary learning in the EFL context. *Computer Assisted Language Learning*, 1–25. https://doi.org/10.1080/09588221.2023.2276800

Jindal, P., Jindal, A., & Sharma, D. (2024). Role of metaverse in the education sector. In R. Aggarwal, P. Gupta, S. Singh, & R. Bala (Eds.), *Augmented reality and the future of education technology* (pp. 215–228). IGI Global. https://doi.org/10.4018/979-8-3693-3015-9.ch014

Kozlov, Y. A. (2024). Metaverse: a new reality in surgery. Review. *Russian Journal of Pediatric Surgery Anesthesia and Intensive Care*, *14*(1), 69–81. https://doi.org/10.17816/psaic1774

Kulal, A., Dinesh, S., Abhishek, N., & Anchan, A. (2024). Digital access and learning outcomes: A study of equity and inclusivity in distance education. *International Journal of Educational Management*, *38*(5), 1391–1423. https://doi.org/10.1108/ijem-03-2024-0166

Leaning, M. (2019). An approach to digital literacy through the integration of media and information literacy. *Media and Communication*, *7*(2), 4–13. https://doi.org/10.17645/mac.v7i2.1931

Li, M., & Yu, Z. (2023). A systematic review on the metaverse-based blended English learning. *Frontiers in Psychology*, *13,* 1087508. https://doi.org/10.3389/fpsyg.2022.1087508

Lu, X., Dai, G., Tian, L., & Liu, W. (2023). Student-centered education in metaverse: Transforming the language listening curriculum. In Y. Ke, Z. Wu, T. Hao, Z. Zhang, W. Meng, & Y. Mu (Eds.), *Communications in computer and information science* (pp. 478–491). Springer. https://doi.org/10.1007/978-981-99-5847-4_34

Ma, W. W. K., & Yuen, A. H. K. (2010). Understanding online knowledge sharing: An interpersonal relationship perspective. *Computers & Education*, *56*(1), 210–219. https://doi.org/10.1016/j.compedu.2010.08.004

Mandala, V., Jeyarani, M. A. R., Kousalya, A., M, P., & Arumugam, M. (2023, April). An innovative development with multidisciplinary perspective in metaverse integrating with blockchain technology with cloud computing techniques. *Proceedings of the 6th International Conference on Inventive Computation Technologies, Lalitpur, Nepal,* 1182-1187. https://doi.org/10.1109/icict57646.2023.10134108

Marín, V. I., & Castañeda, L. (2023). Developing digital literacy for teaching and learning. In O. Zawacki-Richter, & I. Jung (Eds.), *Handbook of open, distance and digital education* (pp. 1089–1108). Springer. https://doi.org/10.1007/978-981-19-2080-6_64

Nichols, T. P., & Stornaiuolo, A. (2019). Assembling "Digital Literacies": Contingent pasts, possible futures. *Media and Communication*, *7*(2), 14–24. https://doi.org/10.17645/mac.v7i2.1946

O'Byrne, W. I., & Pytash, K. E. (2015). Hybrid and blended learning. *Journal of Adolescent & Adult Literacy*, *59*(2), 137–140. https://doi.org/10.1002/jaal.463

Oliwa, R. (2020). *Design and management of the virtual learning environment for foreign language instruction in adult learner groups*. Peter Lang Verlag. https://doi.org/10.3726/b17657

Othman, A., Chemnad, K., Hassanien, A. E., Tlili, A., Zhang, C. Y., Al-Thani, D., Altınay, F., Chalghoumi, H., Al-Khalifa, H. S., Obeid, M., Jemni, M., Al-Hadhrami, T., & Altınay, Z. (2024). Accessible metaverse: A theoretical framework for accessibility and inclusion in the metaverse. *Multimodal Technologies and Interaction*, *8*(3), 21. https://doi.org/10.3390/mti8030021

Pagani, L., Argentin, G., Gui, M., & Stanca, L. (2016). The impact of digital skills on educational outcomes: Evidence from performance tests. Educational Studies, *42*(2), 137–162. https://doi.org/10.1080/03055698.2016.1148588

Perry, B. (2021). Gamified mobile collaborative location-based language learning. *Frontiers in Education*, *6*, 689599. https://doi.org/10.3389/feduc.2021.689599

Ponmani, M., & Geetha, R. (2022). Integration of Zone of Proximal Development (ZPD) and ICTs in language learning. In S. Mekala, & Geetha R. (Eds.), *Contemporary ELT strategies in engineering pedagogy* (pp. 237–251). Routledge. https://doi.org/10.4324/9781003268529-20

Prabakaran, N., & Patrick, H. A. (2024). Is metaverse intended for purchasing? An empirical investigation. *Journal of Metaverse*, *4*(2), 94–104. https://doi.org/10.57019/jmv.1485027

Puneet, S., Kumari, R., & Buragohain, S. (2024, March). Effectiveness of metaverse in accelerating higher education. *Proceedings of International Conference on Contemporary Computing and Communications, Bangalore, India,* 1–5. https://doi.org/10.1109/inc460750.2024.10649190

Roth, W., & Jornet, A. (2016). Genesis of the zone of proximal development. *Cultural psychology of education* (pp. 247–264). Springer. https://doi.org/10.1007/978-3-319-39868-6_11

Samaniego, J. M. (2024). Alfabetización digital crítica: genealogía, crítica fundacional y estado del arte [Critical digital literacy: Genealogy, foundational critique and state of art]. *Revista Colombiana De Educación*, *91*, 403–425. https://doi.org/10.17227/rce.num91-17025

Sathyamoorthy, M., Vanitha, C., & Dhanaraj, R. K. (2024). Metaverse: A vehicle in digital healthcare. In R. K. Dhanaraj, S. Vashishtha, M. Sathyamoorthy, B. Balusamy, & K. Cengiz (Eds.), *Metaverse technologies in healthcare* (pp. 1–15). Academic Press. https://doi.org/10.1016/b978-0-443-13565-1.00007-5

Selvarajan, A., Nagamani, S., A, S. K., Dommaraju, T., Gandhodi, H. V., & Karras, D. A. (2024). Emerging implications of metaverse healthcare analysis to the individual and the society. In A. Suresh Kumar, G. Ganesan, R. Sekaran, B. Krishnan, & N. Kousik (Eds.), *Ubiquitous computing and technological innovation for universal healthcare* (pp. 89–126). IGI Global. https://doi.org/10.4018/979-8-3693-2268-0.ch005

Syarifudi, Z., & Suharjito, S. (2020). Mobile based for basic english learning assessment with augmented reality. *Advances in Science Technology and Engineering Systems Journal*, *5*(2), 774–780. https://doi.org/10.25046/aj050297

Szűts, Z., & Vaughan, G. (2024). A new key competence: Teachers' methodological knowledge of augmented reality and its gaming potential. In V. Geroimenko (Ed.), *Augmented reality games II* (pp. 55–62). Springer. https://doi.org/10.1007/978-3-031-54475-0_3

Taggart, S., Roulston, S., Brown, M., Donlon, E., Cowan, P., Farrell, R., & Campbell, A. (2023). Virtual and augmented reality and pre-service teachers: Makers from muggles? *Australasian Journal of Educational Technology*, *39*(3), 1–16. https://doi.org/10.14742/ajet.8610

Tavares, V., & Somby, H. M. (2023). Virtual reality technology in Norwegian teacher education: Creating an innovative experience or another academic elite? In M. Bowdon, K. Yee, & W. Dorner (Eds.), *Ethical considerations of virtual reality in the collage classroom: Cross-disciplinary case studies of immersive technology implementation.* (pp. 70–82). Routledge. https://doi.org/10.4324/9781003329718-6

Teo, T., Khazaie, S., & Derakhshan, A. (2021). Exploring teacher immediacy-(non)dependency in the tutored augmented reality game-assisted flipped classrooms of English for medical purposes comprehension among the Asian students. *Computers & Education*, *179*, 104406. https://doi.org/10.1016/j.compedu.2021.104406

Tlili, A., Huang, R., Shehata, B., Liu, D., Zhao, J., Metwally, A. H. S., Wang, H., Denden, M., Bozkurt, A., Lee, L., Beyoglu, D., Altinay, F., Sharma, R. C., Altinay, Z., Li, Z., Liu, J., Ahmad, F., Hu, Y., Salha, S., . . . Burgos, D. (2022). Is metaverse in education a blessing or a curse: A combined content and bibliometric analysis. *Smart Learning Environments*, *9*, Article 24. https://doi.org/10.1186/s40561-022-00205-x

Tracy-Ventura, N., Huensch, A., Katz, J., & Mitchell, R. (2025). Is second language attrition inevitable after instruction ends? An exploratory longitudinal study of advanced instructed second language users. *Language Learning*, *75*(1), 42–76. https://doi.org/10.1111/lang.12665

Tyagi, V., Singh, H., Puri, N., & Tyagi, P. (2023). Exploring the potential of the metaverse in higher education: A bibliometric analysis. *Journal of Content, Community and Communication*, *17*, 219–233.

Ueno, A., Curtis, L., Wood, R., Al-Emran, M., & Yu, C. (2024). A review of the metaverse in higher education: Opportunities, challenges and future research agenda. In M. A. Al-Sharafi, M. Al-Emran, G. W. H. Tan, & K. B. Ooi (Eds.), *Current and future trends on intelligent technology adoption* (pp. 1–16). Springer. https://doi.org/10.1007/978-3-031-61463-7_1

Verma, A., Patil, P., Paliwal, J. P. M., Bakhare, R., Pillai, R., & Singh, M. (2024). Conceptualising the importance of metaverse in education: A bibliometric analysis. *Journal of Ecohumanism*, *3*(6), 470–483. https://doi.org/10.62754/joe.v3i6.4018

Vygotsky, L. S. (1978). *Mind in society: The development of higher psychological processes.* Harvard University Press.

Yaqob, M., & Hafez, M. M. (2023, February). Metaverse – An overview of daily usage and risks. *Proceedings of the OPJU International Technology Conference on Emerging Technologies for Sustainable Development, Raigarh, Chhattisgarh, India,* 1–6. https://doi.org/10.1109/otcon56053.2023.10113922

Yuan, J., Liu, Y., Han, X., Li, A., & Zhao, L. (2023). Educational metaverse: An exploration and practice of VR wisdom teaching model in Chinese Open University English course. *Interactive Technology and Smart Education*, *20*(3), 403–421. https://doi.org/10.1108/itse-10-2022-0140

AUTHORS

Mr. Nepoleon Prabakaran is a doctoral candidate at JAIN University investigating the intersection of technology adoption and consumer behavior. His primary research focuses on metaverse adoption patterns and consumer neuroscience applications in digital environments. As an Assistant Professor at CMS Business School (Bengaluru), he leverages his background in FMCG and banking sectors to explore practical dimensions of behavioral science. His interdisciplinary approach combines quantitative neurological data with qualitative behavioral insights, contributing to emerging scholarship on immersive technologies. Mr. Prabakaran has presented at international conferences and published in reputable journals, establishing himself as an emerging voice in digital consumer behavior research.

Dr. Harold Andrew Patrick is a distinguished Industrial and Organizational Psychologist with more than three decades of expertise at the intersection of academic research and corporate practice. Currently serving as Professor and Dean-Academics at CMS Business School, Jain University, his research contributions span organizational behavior and human resource development. With a prolific publication record of 80+ articles in peer-reviewed journals, Dr. Patrick has established himself as a significant voice in workplace psychology. His research has garnered multiple best paper awards at international conferences, reflecting the innovative nature of his scholarly inquiries. Dr. Patrick's research interests focus on human behavior applications in organizational settings, with particular emphasis on leadership development, team dynamics, and workplace effectiveness. His work bridges theoretical frameworks with practical implementations, informed by his extensive experience at the Infosys Leadership Institute and Christ University. As an elected member of the Society for Industrial and Organizational Psychology (SIOP), USA, he contributes to the global discourse on workplace psychology while maintaining strong connections to corporate research through his advisory roles across multiple academic institutions.

Dr. Jacqueline Kareem is an educational researcher at CHRIST (Deemed to be University) specializing in mathematics education and educational psychology. Her research examines student engagement, mathematics learning environments, and teacher efficacy, with 16+ publications in journals including Psychology in the Schools and Frontiers in Education. Dr. Kareem has presented at over 70 conferences and supervised doctoral research on mathematics education and learning disabilities. Her current projects investigate STEM education and classroom engagement dynamics. As a reviewer for Scopus-indexed journals and an Independent Assessor for the Karnataka Monitoring Authority, she contributes significantly to educational assessment and research methodology advancement.