iTELL Journal
Volume 2, Number 2, 2025, pp. 59-70

From *Computer-Assisted Language Learning* (CALL) to *Augmented Reality* (AR): Technological Interventions in Bilingual Language Learning

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ARTICLE INFO

Article History:
Received : Jan 26, 2025
Revised : June 25, 2025
Accepted : Nov 23, 2025
Available online : Dec 30, 2025

Keywords:
bilingual education, cultural understanding, language proficiency, learning outcomes, technology-enhanced language learning

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ABSTRACT

Bilingual education is a critical component of modern educational practices, aimed at fostering bilingualism and improving academic success. Technology-enhanced language learning (TELL) has emerged as a transformative tool in this domain. This paper explores TELL's impact on bilingual education by synthesising theoretical frameworks, examining diverse technologies, evaluating effectiveness, and addressing implementation challenges. The theoretical foundations include constructivism, sociocultural theory, and cognitive load theory. Constructivism highlights the active construction of knowledge through interactive technology-based environments, while sociocultural theory emphasises collaboration and cultural exchange. Cognitive load theory guides the efficient design of TELL materials to enhance learning outcomes. Technologies such as computer-assisted language learning (CALL), mobile apps, virtual reality (VR), augmented reality (AR), and online collaboration tools are instrumental in TELL. These platforms offer personalised learning experiences, immersive environments, and opportunities for synchronous and asynchronous interactions, significantly improving language proficiency, cultural understanding, and overall educational outcomes. Despite its potential, challenges like limited access to technology, varying digital literacy levels, and the need for teacher training hinder widespread adoption. Addressing these obstacles requires promoting equitable access, enhancing digital skills, and providing professional development for educators. Future research should prioritise innovative TELL approaches, long-term evaluations, and best practices for effective integration into bilingual education. By influencing technology and theoretical insights, TELL has the potential to revolutionise bilingual education, fostering interactive, engaging, and culturally enriched learning experiences while empowering global citizens in a digital age.

1 INTRODUCTION

In today's interconnected world, bilingual education has become a fundamental component of efforts to promote linguistic diversity and intercultural competence among learners (García & Wei, 2014). These programs aim not only to cultivate proficiency in two languages but also to improve academic performance, cognitive flexibility, and sociocultural awareness (Cummins, 2017; Bialystok, 2021). As globalisation and mobility intensify, the value of bilingual skills in academic, professional, and civic contexts continue to grow, prompting educators and policymakers to seek innovative strategies to support and enrich language learning (May, 2019). One such innovation is Technology-Enhanced Language Learning (TELL), which integrates digital tools to facilitate language acquisition and expand access to high-quality bilingual education (Golonka et al., 2014; Li et al., 2021).

The integration of technology in language teaching has led to an innovative approach toward traditional pedagogies by introducing new dimensions of engagement, interactivity, and learner autonomy (Lai, 2017). TELL includes, but is not limited to, Computer-Assisted Language Learning (CALL) systems, mobile apps, Virtual Reality (VR), Augmented Reality (AR), and online collaborative environments. These allow for customised, multimodal, and immersive learning experiences to take place (Wang & Vásquez, 2012; Reinders & White, 2016).

Such tools are especially expedient for bilingual learners with diverse linguistic, cognitive, and cultural needs (Taguchi, 2024).

Therefore, TELL principles are firmly embedded in pedagogical theories. Constructivism embraces experiential, learner-centred exploration (Bruner, 1966). By contrast, sociocultural theory places a central role on social interaction and cultural context (Vygotsky, 1978), while Cognitive Load Theory offers perspectives on how instructional materials align with human cognitive architecture (Sweller, 2011; Paas & Ayres, 2014). All three combined then provide evidence of TELL not only to promote deeper engagement and more authentic communication but also to enhance long-term language retention. Nevertheless, with its innovative potential, TELL does not come without challenges. Digital disparity, issues regarding data privacy, technological unfamiliarity, and inadequate preparation among the teaching community remain significant barriers to complete integration into educational frameworks (Rashid et al., 2018; Huang & Sun, 2023). Addressing these gaps requires stakeholder coordination: the educators, curriculum designers, policymakers, and the EdTech developers themselves, who have to ensure that TELL is created and used in a manner that is ethical, inclusive, and sustainable (Kim & Lee, 2022; Liu et al., 2023). As such, this paper critically examines the theoretical rationales, practical applications, effectiveness, and ethical considerations in using TELL in bilingual education, providing a way forward for maximizing its pedagogical value.

2 THEORETICAL FOUNDATIONS OF TELL IN BILINGUAL EDUCATION

Technology-enhanced language learning in bilingual education is rooted in a constellation of pedagogical and psychological theories which inform its strategic implementation and pedagogical value. These frameworks, such as constructivism, sociocultural theory, and cognitive load theory, shed light on the cognitive, social, and cultural aspects of language learning. Therefore, they pave the way for an informed and effective integration of digital tools into bilingual curricula (Li et al., 2021; Wang & Vásquez, 2012).

2.1 Constructivism

The constructivist theory posits that learners approach knowledge actively, connecting meaningfully with their environment to construct knowledge (Bruner, 1966; Piaget, 1970). In the TELL context, immersive, interactive, and exploratory experiences will lead students to drive their own learning. For instance, AI-supported online platforms and gamified language apps have been developed that utilise simulations, visual storytelling, and real-time feedback to enable learners to test new linguistic forms and cultural practices within authentic settings (Reinders & White, 2016). This learner-centred, inquiry-driven approach has been shown to enhance both retention and transfer of the language knowledge that has been acquired (Taguchi, 2024).

2.2 Sociocultural Theory

According to Vygotsky's sociocultural theory, social interaction and cultural context are at the centre of learning development, especially in the Zone of Proximal Development (ZPD) (Vygotsky, 1978). An environment like TELL, which incorporates online collaborative forums, virtual peer-to-peer exchanges, and real-time discussion boards, provides an arena for scaffolded learning and intercultural communication (Lai, 2017). Such virtual learning spaces allow learners from different backgrounds to co-construct knowledge and communicative competence via meaningful conversation, hence fostering intercultural awareness and inclusive practices in learning (García & Wei, 2014; Warschauer, 2000).

2.3 Cognitive Load Theory

Cognitive Load Theory focuses on optimising cognitive resources by minimising unnecessary mental load and enhancing the efficiency of working memory during learning tasks (Sweller, 2011; Paas & Ayres, 2014). In TELL, CLT-based instructional designs use scaffolding, chunking, and multimodal representations such as voice-to-text, infographics, and audio-visual cues, that promote comprehension while minimising extraneous processing. For example, AI-powered adaptive learning platforms also provide intelligent feedback loops in response to user input, improving learner outcomes through maintaining cognitive balance (Kim & Lee, 2022; Huang & Sun, 2023).

By synthesising these theoretical lenses, TELL not only fosters more personalised and interactive learning experiences but also creates culturally responsive, cognitively efficient, and socially engaging environments. These approaches have demonstrated substantial improvements in bilingual learners' proficiency, motivation, and cross-cultural competencies when strategically embedded in curricula (Guo et al., 2022; Bialystok, 2021).

3 TECHNOLOGIES UTILISED IN BILINGUAL EDUCATION

Technological innovation has significantly reshaped the landscape of bilingual education in recent years, providing opportunities for dynamic, flexible learning environments that enhance linguistic competence and intercultural understanding. Digital tools, ranging from CALL systems and immersive virtual and augmented

reality platforms, have also been important in supporting learners as they work toward becoming bilingual proficient in various skills (Golonka et al., 2014; Yang & Lee, 2021).

3.1 Computer-Assisted Language Learning (CALL) Platforms

CALL systems are multi-faceted platforms where multimedia content, grammar and vocabulary, interactive quizzes, and speaking activities are integrated into the learning environment. They can be adjusted to offer learners feedback that responds to their level of proficiency, which fosters autonomy and motivation (Chapelle, 2001). Studies have demonstrated that this type of CALL, such as Duolingo and Rosetta Stone, enhances vocabulary retention, grammar accuracy, and pronunciation due to its personalised, game-oriented approach (Munday, 2016; Nielson, 2011). Additionally, this is considered an asynchronous tool, but it is very feasible for diversified and remote learning environments (Stockwell, 2012).

3.2 Mobile Applications

With the proliferation of mobile learning applications, there has been an increase in language practice access, as one can learn beyond the confines of the classroom. These apps include various interactive exercises, flashcards, games, and speech recognition that can serve to help them improve their pronunciation and listening skills (Burston, 2015). Game-based learning, rewards, progress tracking, and streaks are generally included to enhance learner engagement (Godwin-Jones, 2011). HelloTalk and Memrise are among those emphasising peer-to-peer interaction, promoting social and cultural exchange through real-time messaging and voice chats with native speakers (Liu & Zhang, 2020).

3.3 Virtual Reality (VR) And Augmented Reality (AR)

Virtual Reality (VR) and Augmented Reality (AR) technologies create an experiential approach to learning by simulating scenarios that closely resemble real-life situations within authentic cultural contexts. For example, in VR environments, learners can engage in immersive simulations such as navigating a marketplace or participating in daily conversations, which helps expand contextual vocabulary and improve pragmatic fluency (Lin & Lan, 2015). AR tools, in contrast, enhance physical surroundings by overlaying contextual digital prompts, allowing learners to engage with vocabulary and grammar structures in real time (Ibáñez & Delgado-Kloos, 2018). Studies have shown that these tools significantly boost learners' motivation, speaking confidence, and cultural understanding (Parmaxi & Demetriou, 2020).

3.4 Online Collaboration Tools

Digital collaboration platforms such as Zoom, Microsoft Teams, Google Docs, and discussion forums support both real-time and asynchronous peer interactions. These tools encourage project-based learning, intercultural communication, and collaborative writing, all crucial for developing communicative competence among bilingual learners (Hampel & Stickler, 2012). Additionally, social media platforms like Facebook and Twitter offer informal learning spaces where learners can join global language communities, take part in cultural discussions, and gain exposure to authentic language use (Zourou, 2012).

By incorporating such a wide range of technologies into bilingual education, educators can design inclusive, interactive, and culturally responsive learning environments. These digital tools not only promote academic achievement and language growth but also help students develop vital 21st-century skills such as digital literacy, cross-cultural empathy, and collaborative problem-solving (Reinders & White, 2016; Lai, 2020).

4 EFFECTIVENESS OF TECHNOLOGY-ENHANCED LANGUAGE LEARNING (TELL) IN BILINGUAL EDUCATION

TELL has become a key approach in advancing bilingual education by enhancing linguistic proficiency, cultural competence, learner motivation, and overall educational outcomes. A growing body of research highlights the transformative potential of digital tools in bilingual and multilingual contexts, emphasising their ability to personalise instruction, promote intercultural dialogue, and boost engagement (Yang & Li, 2022; Lai, 2020).

4.1 Improved Language Proficiency

One of the most recognised benefits of TELL is its ability to strengthen fundamental language skills, reading, writing, speaking, and listening, through multimodal and interactive methods. Studies indicate that tools like language learning apps and CALL platforms greatly support vocabulary acquisition, pronunciation, and grammatical development by providing immediate feedback and structured practice (Li et al., 2021; Nielson, 2011). Adaptive learning technologies also personalise content to suit each learner's proficiency level, effectively addressing individual learning needs and accelerating language acquisition (Reinders & White, 2016).

4.2 Enhanced Cultural Understanding

TELL also deepens learners' intercultural awareness by exposing them to authentic media, virtual exchanges, and culture-rich tasks. Platforms like VR and online language communities allow learners to engage with diverse cultural settings in real time, broadening their understanding of linguistic variation and global perspectives (Parmaxi & Demetriou, 2020; Hampel & Stickler, 2012). Such experiences cultivate empathy and respect for cultural diversity, core competencies in today's multilingual societies (Godwin-Jones, 2018).

4.3 Increased Motivation and Engagement

Through the use of gamification and personalised features, TELL platforms effectively sustain learner motivation and engagement. Features like badges, leaderboards, and point systems are proven to enhance enjoyment and intrinsic motivation (Burston, 2015; Deterding et al., 2011). Meanwhile, real-time feedback and progress tracking acknowledge learners' efforts, boosting their sense of accomplishment and encouraging long-term commitment to mastering a second language (Yang & Lee, 2021).

4.4 Positive Learning Attitudes

TELL fosters learner autonomy and ownership of the educational process. Learners report higher satisfaction when lessons include interactive multimedia, peer collaboration, and adaptive content (Stockwell, 2012; Lai, 2017). These digital environments create supportive, inclusive learning communities that motivate learners to participate and collaborate, improving their confidence and overall outlook on education (Warschauer & Kern, 2000).

However, despite these advantages, challenges remain. Unequal access to technology across socio-economic and geographical contexts continues to hinder educational equity (OECD, 2020). Additionally, many teachers lack digital training and confidence in integrating TELL effectively into bilingual education (Kessler, 2018). Realising the full potential of TELL will require collaboration among educators, policymakers, and technology developers. Targeted initiatives that ensure equitable access, provide professional training, and promote inclusive design will be essential for the sustainable success of TELL in diverse linguistic and cultural contexts (Pinto et al., 2023; Kim & Reeves, 2022).

5 CHALLENGES IN IMPLEMENTING TECHNOLOGY-ENHANCED LANGUAGE LEARNING (TELL) IN BILINGUAL EDUCATION

While TELL has great potential to enhance bilingual education, some complications arise when it is implemented on a large scale. Even though it offers flexible, engaging, and data-driven instruction, there are critical barriers to access, skills, infrastructure, and institutional readiness. These are important issues to be addressed to ensure that digital learning ecosystems are inclusive and sustainable within linguistically diverse classrooms (Li et al., 2021; Kessler & Hubbard, 2017).

5.1 Access to Technology

Equitable access to technology remains one of the most challenging aspects of integrating TELL. Students from marginalised or rural communities often lack consistent access to internet-enabled devices and broadband connectivity, conditions that are vital for engaging in digital learning platforms. Limited school infrastructure and unstable electricity have created a more significant digital divide in several regions of the world, specifically Bangladesh situation in the Global South. There is a need for strategic collaboration among governments, NGOs, and private sector partners to invest in more affordable devices, community tech hubs, and the expansion of rural broadband.

5.2 Digital Literacy Skills

While gaining access to technology is a crucial first step, digital literacy presents a deeper and more complex challenge. Many educators and learners lack the technical proficiency and critical thinking skills necessary to fully benefit from TELL tools. Digital literacy involves more than just operating devices. It encompasses the ability to navigate digital platforms effectively, assess information credibility, communicate safely online, and adapt to emerging technologies (Ng, 2012; Spante et al., 2018). Research highlights that limited digital competence can negatively impact both engagement and learning outcomes (Hatlevik et al., 2018). To overcome this, educational institutions should introduce ongoing digital literacy programs that combine technical training with critical digital awareness, ensuring that instruction is relevant to local contexts and learner needs (Pangrazio & Selwyn, 2019).

5.3 Privacy and Security Concerns

As TELL increasingly relies on cloud-based systems and data analytics, concerns surrounding privacy and cybersecurity have become more prominent. Many AI-driven tools, such as Grammarly and Duolingo, collect users' personal data, including behavioural patterns and device information. Without adequate data encryption and informed consent, this information can be vulnerable to misuse (Hao, 2021; Floridi & Cowls, 2019). A notable example occurred in 2018 when a data breach in Grammarly's browser extension raised significant concerns about compliance with privacy regulations such as the GDPR and CCPA (TechCrunch, 2018). Consequently, strong data governance frameworks, ethical AI practices, and digital citizenship education are crucial to safeguarding learners' digital identities and ensuring responsible use of technology in education (Zuboff, 2019; Kim & Reeves, 2022).

6 ONGOING TEACHER TRAINING AND SUPPORT

Many teachers express hesitation when incorporating new technologies into their teaching practice, often due to insufficient training or limited institutional support (Kessler, 2018). Research shows that without structured professional development, educators may underuse or misuse TELL tools, reducing their effectiveness (Baran, Correia & Thompson, 2011). Furthermore, the absence of mentorship and ongoing guidance often results in short-lived adoption of digital practices. To counter this, teacher training programs should emphasise the development of Technological Pedagogical Content Knowledge (TPACK), offering practical workshops, peer mentoring, and continuous learning opportunities that build confidence and competence (Mishra & Koehler, 2006; Lai, 2020).

7 MOVING FORWARD: CREATING INCLUSIVE AND SUSTAINABLE TELL SYSTEMS

Overcoming the challenges associated with TELL requires a collaborative and system-wide approach involving educators, administrators, policymakers, and EdTech developers. Equitable infrastructure development, universal access to digital literacy education, robust data protection frameworks, and ongoing teacher support should form the foundation of all TELL initiatives. Through these collective efforts, the transformative potential of technology can be fully realised, empowering bilingual learners, promoting inclusion, and advancing educational equity in the digital age (Pinto et al., 2023; Lai & Morrison, 2022).

8 FUTURE DIRECTIONS AND RECOMMENDATIONS

As Technology-Enhanced Language Learning (TELL) continues to progress, its future development must be guided by rigorous research, ethical reflection, and inclusive design principles. The following recommendations draw from contemporary scholarship and aim to promote equitable, sustainable, and meaningful integration of TELL into bilingual education.

8.1 Invest in Longitudinal Research and Impact Evaluation

To reinforce the theoretical and empirical basis of TELL, further longitudinal studies are needed to examine its long-term effects on linguistic growth, intercultural competence, and socio-emotional development (Chun et al., 2021). Although current studies demonstrate the short-term advantages of TELL, there remains a lack of comparative research across different learner populations, educational settings, and technological tools (Golonka et al., 2014; Lai & Morrison, 2022). Future inquiries should also consider how TELL influences learners' motivation, self-efficacy, and identity formation in bilingual contexts (Thorne, 2020).

8.2 Cultivate Collaboration and Multistakeholder Knowledge Exchange

The successful adoption of TELL depends on collaboration between educators, linguists, technologists, and policymakers. Professional and academic networks, such as CALICO and EUROCALL, have played an important role in fostering dialogue, yet broader and more structured partnerships across sectors are still needed (Hockly, 2018; Kessler & Hubbard, 2017). Encouraging open access to best practices and co-creating localised TELL models can accelerate innovation while ensuring cultural and contextual relevance in bilingual education.

8.3 Prioritize Equity and Accessibility in TELL Deployment

Persistent inequalities in access to digital tools remain a major concern, especially for learners in rural, economically disadvantaged, or linguistically marginalised communities (Warschauer & Matuchniak, 2010; OECD, 2021). To address these disparities, governments and educational institutions must invest in digital infrastructure, provide affordable devices, and develop culturally relevant learning content (UNESCO, 2023). Moreover, inclusive design should be a central principle of all TELL initiatives, ensuring accessibility for students with disabilities and support for diverse linguistic and cultural identities (Pinto et al., 2023). Without deliberate attention to equity, TELL risks perpetuating the very inequalities it aims to eliminate.

8.4 Enhance Digital Literacy and Promote Ethical Technology Use

Developing digital literacy involves far more than teaching technical proficiency. It also requires nurturing critical awareness, ethical reasoning, and responsible online behaviour (Ng, 2012; Pangrazio & Selwyn, 2019). Teachers should be supported in embedding these dimensions into classroom instruction, helping students critically evaluate online information, safeguard their personal data, and interact responsibly with AI-powered tools such as Grammarly or ChatGPT (Floridi & Cowls, 2019; Hao, 2021). Professional training should also prepare educators to model ethical technology use and to facilitate classroom discussions on algorithmic bias, surveillance, and digital inclusion (Kim & Reeves, 2022).

8.5 Advocate for Policy Support and Financial Investment

Strong policy frameworks are essential for establishing TELL as an integral part of bilingual education. National and regional strategies should recognise digital competence as a basic educational right and align funding with pedagogical priorities (European Commission, 2020). Investment in teacher training, research, infrastructure, and public–private partnerships will be crucial to scaling access while maintaining educational integrity (Zhao, 2020). In addition, policy must enforce clear ethical standards for AI in education, ensuring the protection of student data and the preservation of linguistic diversity across digital platforms.

9 FUTURE PATHWAYS FOR TELL

The future of TELL lies in aligning research, equity, ethics, and policy to create an interconnected ecosystem that truly serves learners. Through coordinated action, stakeholders can unlock TELL's transformative potential, empowering bilingual students to thrive in a digitally connected and multilingual world. Such efforts will equip learners not only with language proficiency but also with intercultural sensitivity and digital fluency, which are essential for meaningful global participation. Ultimately, TELL's success depends not on technological sophistication alone, but on its ethical and inclusive implementation across educational contexts.

10 CONCLUSIONS

The integration of Technology-Enhanced Language Learning (TELL) into bilingual education holds immense transformative potential. It offers new possibilities for improving linguistic proficiency and promoting cultural diversity in multilingual academic environments (Chun et al., 2021; Lai & Morrison, 2022). This paper has explored the theoretical underpinnings, pedagogical applications, and emerging challenges associated with TELL, providing an informed foundation for future innovation in the field.

Grounded in core educational theories, constructivism, sociocultural theory, and cognitive load theory, TELL supports learner-centred, interactive, and immersive experiences (Vygotsky, 1978; Mayer, 2009; Piaget, 1972). These frameworks shape digital environments that promote active engagement, collaboration, and culturally situated learning. Research consistently demonstrates that such environments enhance language acquisition, intercultural competence, and learner autonomy (Golonka et al., 2014; Thorne, 2020).

Nevertheless, effective implementation continues to face challenges, including disparities in technology access, digital literacy, teacher readiness, and data security—particularly in under-resourced regions (Warschauer & Matuchniak, 2010; Kim & Reeves, 2022). Overcoming these barriers requires a coordinated and equity-driven approach that brings together educators, policymakers, researchers, and technology developers (UNESCO, 2023).

Looking ahead, the evolution of TELL in bilingual education must be guided by evidence-based research, interdisciplinary collaboration, and inclusive policy reform. Continued investments in infrastructure, teacher development, and digital equity will be essential to ensure that all learners—regardless of background—can access high-quality, culturally responsive learning opportunities (Pinto et al., 2023; European Commission, 2020).

Ultimately, TELL can redefine the future of bilingual education by merging technological innovation with ethical and inclusive practices. When thoughtfully implemented, it not only strengthens academic achievement but also fosters cross-cultural understanding and prepares learners for responsible global citizenship (Floridi & Cowls, 2019; Zhao, 2020).

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