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Research Article

ADAPTIVE AND RESILIENT LEARNING TECHNOLOGIES IN FORMAL AND INFORMAL EDUCATION: A SYSTEMATIC LITERATURE REVIEW

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Abstract

This study reviews the use of Mobile-Assisted Language Learning (MALL) and digital storytelling in multilingual education, focusing on research trends, teaching strategies, and their impact on inclusive and effective language learning. A systematic literature review was conducted using peer-reviewed studies published between 2020 and 2025 from major academic databases. The studies were analyzed using thematic coding and comparison. The findings show that MALL and digital storytelling improve learner engagement, motivation, intercultural competence, and language proficiency in diverse linguistic and cultural contexts. These approaches also support personalized learning, collaboration, and the development of critical literacy related to social justice and educational equity. The novelty of this review is its integrated view of mobile learning and digital storytelling as connected teaching approaches in multilingual and multicultural settings. By summarizing recent research, this study shows how technology-based learning supports learner autonomy, flexible learning processes, and inclusive teaching practices. The findings offer practical guidance for educators, policymakers, and instructional designers in developing curricula and professional training suited to multilingual classrooms.

Keywords: adaptive learning technologies; educational resilience; systematic literature review; technology-enhanced learning

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INTRODUCTION

The rapid transformation of educational environments driven by digitalization and changing learner needs has significantly influenced how learning takes place in formal and informal contexts (Selwyn, 2022). These changes create challenges for educational practices that require meaningful understanding and sustained learner engagement. When learning environments do not adapt to learner diversity or external disruptions, students may experience decreased motivation and interrupted learning. Therefore, there is an increasing need for learning technologies that support flexible, inclusive, and resilient educational practices (Kukulska-Hulme, 2020). In particular, mobile-assisted learning and digital storytelling offer opportunities to create interactive, learner-centered experiences that can enhance motivation, engagement, and intercultural competence. By integrating such technologies, educators can better address the varied needs of multilingual learners while promoting continuity and equity in education across different contexts.

In response to these challenges, adaptive learning technologies have gained increasing attention as mechanisms for personalizing learning pathways based on learners' performance, preferences, and engagement patterns. Empirical research indicates that adaptive and technology-enhanced learning environments can enhance learner autonomy and support deeper conceptual understanding by providing differentiated instructional scaffolding tailored to individual needs (Simarona, 2025). Similarly, learning analytics–driven systems have been shown to assist educators in monitoring learning progress and delivering timely feedback, which is critical for supporting complex cognitive and metacognitive processes across disciplines (Agustina et al., 2024). These findings suggest that digitally enabled adaptability can address individual learning differences while simultaneously supporting more informed instructional decision-making.

Alongside adaptability, the concept of educational resilience has become increasingly prominent, particularly in response to large-scale disruptions, technological inequities, and institutional constraints affecting educational systems worldwide. Resilient learning systems are characterized by their capacity to sustain instructional processes, ensure equitable access, and support learner persistence despite changing conditions (Rahmawati & Nugroho, 2023). Interruptions to learning trajectories can significantly undermine cumulative knowledge development and learner confidence, making resilience a critical consideration in both formal and informal education. Research on mobile learning and technology-supported informal learning environments further indicates that resilient digital platforms can help maintain learning continuity beyond traditional institutional boundaries (Naveed et al., 2023).

Although a growing body of literature has examined technology-enhanced learning approaches such as mobile learning, adaptive systems, and data-driven instructional support, existing research often treats adaptability and resilience as separate constructs or focuses on isolated technological interventions (Weidlich & Kalz, 2021). Recent reviews emphasize the effectiveness of specific tools or strategies but rarely provide an integrative synthesis of how adaptive and resilient learning technologies jointly influence learning processes and outcomes across formal and informal contexts (Alif Faresta et al., 2024). This fragmentation limits a comprehensive understanding of how technological systems can simultaneously support personalization, engagement, and learning continuity in diverse educational settings.

To address this gap, the present study conducts a systematic literature review guided by the PRISMA framework to synthesize empirical and conceptual research on adaptive and resilient learning technologies in formal and informal education contexts (Intelligent educational technologies in individual learning, 2025). This review aims to examine how these technologies are conceptualized and implemented, identify dominant technological and pedagogical trends, and analyze their reported impacts on learner engagement, conceptual

understanding, and learning continuity (Adaptive learning, instruction, and teaching in schools, 2025). In addition, the study explores implementation challenges and emerging research directions that may inform the development of more robust, inclusive, and equitable learning environments. To contextualize the focus of this review, Figure 1 presents a conceptual overview of how adaptive and resilient learning technologies influence key educational dimensions, including learner engagement, conceptual understanding, and educational equity across formal and informal learning contexts.

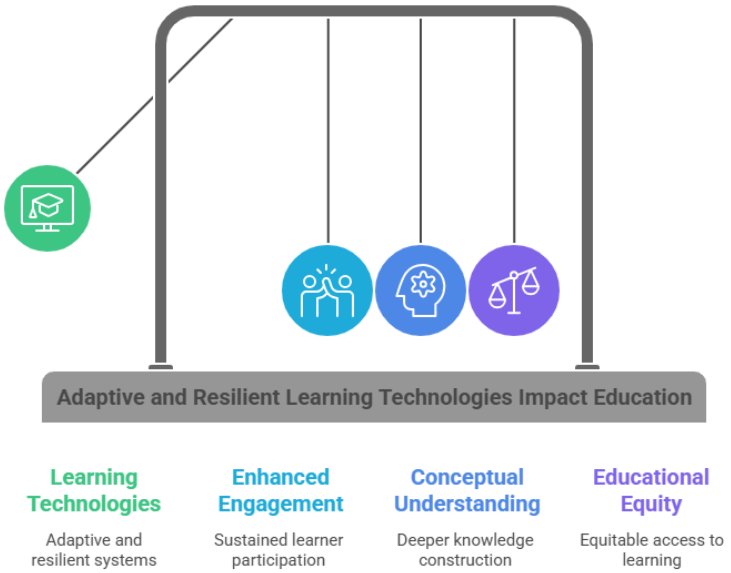

Figure 1 : Conceptual framework linking MALL and digital storytelling with adaptive and resilient learning outcomes

Figure 1 conceptualizes the integrated role of adaptive and resilient learning technologies in supporting effective learning across formal and informal educational contexts. The framework positions technology not merely as an instructional tool, but as a mediating system that enables sustained learner engagement, supports deeper conceptual understanding through adaptive scaffolding, and promotes educational equity by maintaining access and continuity under varying conditions. By illustrating the interdependence of engagement, understanding, and equity, the figure underscores that meaningful technology integration emerges from the alignment of adaptability and resilience rather than from isolated technological interventions. This conceptualization provides a coherent analytical lens for synthesizing empirical evidence and interpreting how learning technologies contribute to inclusive and sustainable educational practices.

For analytical clarity, this study adopts narrative operational definitions of key concepts underpinning the review. Adaptive learning technologies are defined as technology-enhanced systems that dynamically adjust instructional content, learning pathways, or feedback mechanisms in response to learners' characteristics, performance, and engagement patterns (Simarona, 2025). Educational resilience refers to the capacity of learning systems to sustain instructional continuity, equitable access, and learner participation despite disruptions or contextual constraints (Rahmawati & Nugroho, 2023). Formal education is conceptualized as structured learning conducted within institutional settings such as schools and universities, whereas informal education encompasses learning activities occurring outside these institutions, including online platforms, mobile applications, and self-directed learning environments (Naveed et al., 2023). Together, these conceptualizations provide a coherent analytical framework for synthesizing existing evidence.

Collectively, these arguments underscore the strategic importance of examining adaptive and resilient learning technologies as an integrated educational approach rather than as isolated

technological solutions. In contemporary learning environments characterized by diversity, complexity, and uncertainty, the convergence of adaptability and resilience becomes increasingly critical. By synthesizing evidence across formal and informal learning contexts, this study positions adaptive and resilient learning technologies as key enablers of sustained learner engagement, conceptual development, and educational equity. Accordingly, a systematic synthesis of existing literature is essential to clarify conceptual boundaries, consolidate empirical findings, and inform the design of future learning environments that are responsive, robust, and pedagogically grounded. Through this integrative perspective, the present study contributes to advancing research on technology-enhanced learning and to broader scholarly discourse on resilient and adaptive educational systems.

RESEARCH METHOD

Research Design

This study employs a qualitative approach using a systematic literature review (SLR) design to synthesize research on adaptive and resilient learning technologies in formal and informal education. The SLR design enables the structured integration of empirical and conceptual findings to identify patterns, trends, and theoretical implications across diverse educational contexts. Methodological scholarship highlights that systematic literature reviews are particularly effective for consolidating interdisciplinary evidence and generating integrative insights within educational technology research, as methodological rigor and conceptual synthesis are prioritized throughout the review process (Petticrew & Roberts, 2020). To ensure transparency and methodological robustness, the review followed the PRISMA 2020 guidelines, which currently represent the international standard for conducting and reporting systematic reviews (Page et al., 2021). Overall, this research design provides a rigorous and up-to-date methodological foundation for examining adaptive and resilient learning technologies across formal and informal learning environments.

Research Target/Subject

The research targets consist of peer-reviewed journal articles and conference proceedings that address adaptive learning technologies and educational resilience within formal and informal learning contexts. Emphasizing scholarly publications ensures that the reviewed studies are theoretically grounded, empirically supported, and methodologically sound. Recent qualitative research guidelines suggest that purposive sampling is an appropriate strategy in systematic reviews, as it allows researchers to prioritize conceptual relevance and analytical depth rather than sheer volume (Merriam & Tisdell, 2020). Accordingly, articles published between 2015 and 2024, written in English, and indexed in reputable academic databases were included in the review. Sources that lacked relevance, methodological clarity, or scholarly rigor were excluded in line with contemporary SLR best practices, which emphasize transparency and quality control throughout the selection process (Snyder, 2019; Xiao & Watson, 2020). Thus, the defined research targets ensure the relevance, credibility, and analytical value of the synthesized literature.

Research Procedure

The research procedure was conducted through a systematic and sequential process to ensure consistency, transparency, and analytical rigor. The process began with the identification of relevant studies through comprehensive searches of major academic databases using predefined keywords related to adaptive learning technologies, educational resilience, and formal and informal education. This stage was followed by an initial screening process involving the removal of duplicate records and the evaluation of titles and abstracts for relevance. Subsequently, full-text articles were assessed during the eligibility stage based on

clearly defined inclusion and exclusion criteria to ensure alignment with the research objectives. Recent methodological studies emphasize that multistage screening and selection procedures are essential for minimizing selection bias and enhancing the credibility of systematic reviews (Page et al., 2021; Xiao & Watson, 2020). Through this structured procedure, the review adhered to internationally recognized standards for systematic literature reviews.

Instruments, and Data Collection Techniques

The primary instrument used in this study was a structured document review matrix designed to systematically extract and organize relevant information from the selected studies. The matrix facilitated consistent data collection across articles, including information related to research focus, methodological approaches, types of learning technologies, educational settings, and reported outcomes. Contemporary qualitative research literature recognizes document analysis as an effective data collection technique for literature-based studies, particularly when synthesizing complex and interdisciplinary bodies of research (O'Cathain, 2019; Bowen, 2020). To enhance the reliability of the synthesis, extracted data were reviewed iteratively and cross-checked across studies in accordance with current qualitative synthesis practices (Onwuegbuzie et al., 2022). Consequently, the selected instruments and data collection techniques supported a systematic, transparent, and trustworthy review process.

Data Analysis Technique

Data analysis was conducted using thematic analysis in combination with qualitative content analysis to identify recurring patterns, themes, and conceptual relationships across the reviewed studies. This analytical approach allows for the interpretation of both explicit findings and underlying theoretical constructs within the literature. Recent developments in thematic analysis highlight its flexibility and suitability for synthesizing qualitative evidence in education and learning sciences research, particularly in systematic reviews (Braun & Clarke, 2021). To strengthen analytical trustworthiness, themes were refined through iterative comparison, constant reflection, and synthesis across sources, as recommended in contemporary qualitative analysis scholarship (Nowell et al., 2022). As a result, this analytical strategy enabled a coherent and comprehensive understanding of how adaptive and resilient learning technologies are conceptualized, implemented, and evaluated across formal and informal educational contexts. To enhance methodological transparency, the iterative process of thematic analysis employed in this study is visually summarized in Figure 2.

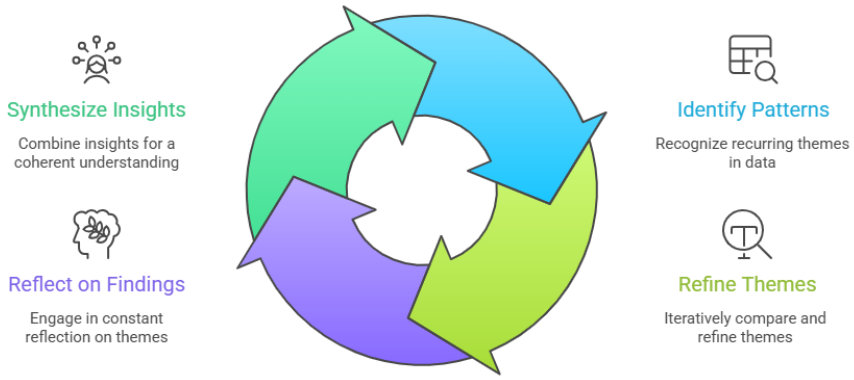

Figure 2 : Iterative Thematic Analysis employed Cycle

Figure 2 illustrates the iterative thematic analysis cycle adopted in this study to systematically synthesize qualitative evidence across the reviewed literature. The cycle begins with the identification of recurring patterns, followed by the refinement of themes through constant comparison across studies, reflective engagement with emerging interpretations, and

the synthesis of insights into a coherent analytical framework. This iterative process emphasizes the non-linear nature of qualitative analysis, where themes are continuously revisited and reinterpreted to ensure conceptual clarity and analytical depth. By integrating reflection and synthesis as integral stages, the framework supports analytical rigor and trustworthiness, enabling a nuanced understanding of how adaptive and resilient learning technologies are conceptualized, implemented, and evaluated across diverse educational contexts.

RESULTS AND DISCUSSION

Integration of Adaptability and Educational Resilience in Learning Systems

The review findings indicate that adaptability and resilience are increasingly positioned as interconnected characteristics in the development of learning technologies. Adaptability allows learning systems to dynamically adjust content and instructional strategies according to learners' needs, while resilience functions to maintain continuity of learning under changing or unstable conditions. In educational contexts, the integration of these two aspects is seen as a response to the complexity of learning environments and the heterogeneity of learner characteristics, positioning learning technologies as systems that support the sustainability of learning processes (Hodges et al., 2022). Consequently, adaptability and resilience form a conceptual foundation for the development of robust and sustainable learning systems.

Contribution of Adaptive Learning Technologies to Conceptual Understanding

The literature indicates that adaptive learning technologies make a significant contribution to enhancing learners' conceptual understanding and problem-solving skills, particularly by enabling instruction to respond dynamically to individual learning progress and cognitive needs (Alamri et al., 2020). Learning domains that require high levels of abstraction and the integration of complex knowledge representations such as mathematics, science, and engineering benefit substantially from personalized learning approaches that support differentiated pacing and scaffolding (Hwang et al., 2021). Recent studies further demonstrate that data-driven adaptive learning systems are capable of adjusting task difficulty and delivering timely, relevant feedback based on learner performance data, thereby supporting learners in systematically and progressively constructing understanding (Zhai et al., 2021). Collectively, these findings underscore the critical role of technology-based personalization in facilitating deeper knowledge construction and promoting meaningful learning rather than surface-level content acquisition (Chen et al., 2023).

Adaptive Technologies across Formal and Informal Learning Contexts

The analysis reveals differences in the implementation of adaptive technologies across formal and informal learning contexts. In formal education, adaptive technologies are typically integrated into structured learning systems aligned with curricula and assessments, whereas in informal settings, the emphasis is on flexibility, mobility, and learner autonomy. These differences reflect the diverse characteristics of learning environments but collectively expand opportunities for learning across varied situations and timeframes (Crompton et al., 2022). Thus, contextual diversity strengthens the role of adaptive technologies in supporting learning continuity.

Role of Learning Analytics in Supporting Learning Continuity

Learning analytics has emerged as a crucial component in maintaining continuity by monitoring learner progress and providing early detection of learning difficulties. Delays in identifying gaps can impact subsequent outcomes, and recent research indicates that learning analytics enables more responsive, data-driven pedagogical interventions (Ifenthaler & Yau,

2020). Accordingly, learning analytics functions as a strategic mechanism to preserve continuity in educational processes.

Educational Resilience as a Learner - Oriented Outcome

Beyond its systemic function, resilience is also reflected as a learner-oriented outcome, manifested through perseverance, self-regulation, and adaptive capacity in addressing learning challenges. Adaptive learning technologies support the development of these competencies through continuous feedback and opportunities for reflective learning. Recent studies suggest that technology support for metacognitive processes strengthens learner resilience (Martin et al., 2021), indicating that learner resilience is a key element in achieving long-term educational success.

Methodological Limitations and Research Gaps in Existing Studies

Despite demonstrating strong potential, this review identifies methodological limitations in previous studies, including a dominance of short-term investigations and limited integration between technological innovations and learning theories. These limitations constrain comprehensive understanding of long-term impacts and the sustainability of adaptive technology implementation. Recent systematic reviews emphasize the need for more holistic, discipline-oriented research approaches to strengthen the validity and relevance of findings (Bond et al., 2021). Therefore, enhancing research design and methodology remains an urgent requirement in the study of adaptive learning technologies.

Pedagogical Alignment in the Implementation of Adaptive Technologies

The findings indicate that the successful implementation of adaptive and resilient learning technologies is strongly influenced by alignment with pedagogical design. Adaptive technologies have optimal impact when integrated into instructional approaches emphasizing reasoning, active engagement, and formative assessment. Recent research confirms that systemic integration of technology, pedagogy, and content is a prerequisite for meaningful learning outcomes (Mishra et al., 2021). Consequently, pedagogical alignment is critical in maximizing the potential of adaptive technologies.

Institutional and Contextual Factors Affecting Sustainability

Institutional and contextual factors also affect the sustainability and scalability of adaptive learning technologies. Digital infrastructure readiness, teacher competencies, and policy support determine the extent to which technology can be consistently integrated into learning environments. International studies indicate that institutional capacity building and professional development for educators significantly contribute to the successful implementation of educational technologies (OECD, 2021). Hence, a systemic approach is essential for the sustainable adoption of innovations in learning.

Toward an Integrative Framework for Adaptive and Resilient Learning

Overall, the results highlight the need for an integrative conceptual framework that systematically connects technological adaptability, educational resilience, and learner needs in order to address the increasing complexity of digital learning ecosystems (Zhao & Watterston, 2021). Such a framework ensures that technological development is not treated as an isolated innovation, but instead aligns coherently with pedagogical objectives and the epistemological requirements of specific learning domains (Kim & Hannafin, 2023). Recent literature further emphasizes that the sustainable transformation of education depends on the systemic integration of technology, pedagogy, and content, as fragmented adoption often leads to short-term gains without long-term instructional impact (Lim et al., 2023). Through the application of an integrative framework, learning processes can be guided more coherently, supporting adaptive instructional design, institutional sustainability, and learning outcomes that extend

beyond immediate performance measures toward long-term educational development (Zawacki-Richter et al., 2024).

Equity and Accessibility in Adaptive and Resilient Learning

The discussion also indicates that adaptive and resilient learning technologies have important implications for equity and accessibility. Disparities in access to learning resources and instructional support remain significant challenges. Adaptive technologies provide opportunities to mitigate these gaps by offering flexible and responsive learning pathways tailored to learner needs. Recent research emphasizes that inclusive-oriented design of learning technologies contributes to increased participation and sustained engagement (UNESCO, 2022). Thus, considerations of equity and accessibility extend the role of adaptive technologies as strategic instruments in inclusive education.

Summary of Insights

The findings collectively highlight that adaptive learning technologies and educational resilience are mutually reinforcing elements essential for enhancing learning outcomes. Adaptability enables systems to tailor content and strategies to diverse learner needs, while resilience ensures continuity and sustainability across varying conditions. Adaptive technologies, including data-driven personalization and learning analytics, facilitate deeper understanding, learner autonomy, self-regulation, and persistence. The effectiveness of these technologies is maximized when aligned with pedagogical design and supported by institutional readiness, professional development, and inclusive policies. Furthermore, differences in implementation across formal and informal contexts illustrate the importance of contextual flexibility, while equity-oriented designs expand access and participation. Taken together, these insights underscore the necessity of an integrative framework that connects technological adaptability, educational resilience, pedagogical alignment, and contextual factors to support sustainable, equitable, and effective learning experiences.

CONCLUSION

This study highlights that adaptive learning technologies and educational resilience are mutually reinforcing components essential for improving learning outcomes across diverse educational contexts. Adaptability enables learning systems to tailor instructional strategies and content dynamically according to learner needs, while resilience ensures continuity and stability in the face of changing or disruptive conditions. Together, these elements support conceptual understanding, problem-solving abilities, learner autonomy, and self-regulation, emphasizing their critical role in effective and sustainable learning environments. The findings further indicate that successful implementation depends on the alignment of technology with pedagogical design, institutional support, professional development, and inclusive policies. Differences between formal and informal learning contexts demonstrate the importance of flexibility and responsiveness, while equity-focused design ensures broader access, participation, and engagement. Based on these insights, it is recommended that future research pursue longitudinal and interdisciplinary studies to explore the long-term impacts and sustainability of adaptive and resilient learning technologies. Additionally, developing integrative frameworks that systematically link technological adaptability, educational resilience, pedagogical strategies, and contextual factors will provide a comprehensive foundation for advancing equitable, effective, and sustainable learning systems.

AUTHOR CONTRIBUTIONS

Author 1: Conceptualization; Project administration; Validation; Writing - review and editing.

Author 2: Conceptualization; Data curation; In-vestigation.
Author 3: Data curation; Investigation.

CONFLICTS OF INTEREST

The authors declare no conflict of interest.

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