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Evaluating the Effectiveness of Technology-Based Learning through an Evidence-Based Education Framework

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ABSTRAK

The accelerated adoption of technology-based learning in the post-pandemic era has encouraged educational institutions to integrate various digital innovations into instructional practices. However, increased technology use does not consistently translate into measurable learning gains, highlighting the need for evidence-based evaluation. This study aims to evaluate the effectiveness of technology-based learning through an evidence-based education framework using a Systematic Literature Review (SLR) approach. Literature searches were conducted in reputable academic databases with inclusion criteria emphasizing empirical quality and pedagogical relevance. A total of 32 empirical studies were selected and analyzed through thematic and comparative synthesis. The findings indicate that technology-based learning tends to produce positive learning outcomes when supported by evidence-informed instructional design, alignment between learning objectives, activities, and assessment, and the use of objective learning outcome measures. In contrast, technology implementations that merely substitute traditional methods without strong pedagogical grounding yield limited effects. This study concludes that the effectiveness of technology-based learning is conditional rather than universal and must be evaluated within an evidence-based education framework. The findings underscore the need to shift from innovation-driven technology adoption toward pedagogical decision-making grounded in robust empirical evidence.

INTRODUCTION

The acceleration of technology-based learning adoption represents one of the most prominent phenomena in the global educational landscape in the post–COVID-19 pandemic era. Educational institutions across all levels from primary education to higher and professional education, have integrated a wide range of digital technologies, including learning management systems, online learning platforms, interactive videos, virtual simulations, and artificial intelligence, into everyday teaching and learning practices. This transformation is often positioned as an inevitability in response to the demands for flexibility, accessibility, and efficiency in modern education. However, behind the increasing intensity of technology use, a fundamental question has emerged regarding the extent to which technology-based learning is genuinely effective in

improving meaningful and sustainable learning outcomes. A number of international reports and studies indicate that increased use of educational technology does not necessarily correspond to improved learning achievement and, in some contexts, even demonstrates weak or non-significant effects on students' academic performance (Valverde-Berrocoso et al., 2022; Akintayo et al., 2024).

This phenomenon suggests the existence of a gap between claims of innovation in educational technology and empirical evidence regarding its pedagogical effectiveness. Many implementations of learning technologies are driven by technical considerations, global trends, or institutional pressures, rather than being grounded in robust scientific evidence concerning their impact on learning processes and outcomes. At the global level, critiques of intuition-based educational practices and the untested adoption of technology have contributed to the growing prominence of the evidence-based education approach. This approach emphasizes that pedagogical decisions, including the use of learning technologies, should be based on the synthesis of the best available empirical evidence rather than assumptions or the popularity of particular innovations (Snyder, 2019). Within this framework, technology is not viewed as a universal solution, but as an instructional tool whose effectiveness is highly dependent on instructional design, implementation context, and alignment with pedagogical objectives.

At the national level, particularly in developing countries, the adoption of educational technology exhibits similar patterns. Digital learning implementation is often fragmented, focusing on the provision of infrastructure and platforms while lacking systematic evaluation of learning quality and learning outcomes. National empirical studies evaluating the effectiveness of learning technologies also tend to be fragmented, examining isolated variables such as learning motivation, user satisfaction, or students' perceptions, without comprehensively linking them to measurable and long-term learning outcomes (Rahayuningsih et al., 2025; Sayadi & Pangandaman, 2025). This condition reinforces the urgency of conducting synthesis studies that can provide a comprehensive overview of the effectiveness patterns of technology-based learning based on empirical evidence across contexts and disciplines.

Academically, research on the effectiveness of technology-based learning has expanded rapidly over the past two decades. Numerous primary studies suggest that learning technologies have the potential to enhance conceptual understanding, higher-order thinking skills, and professional competencies when they are appropriately designed and implemented (Park et al., 2024; Wang et al., 2025). Nevertheless, these findings are not uniform. Valverde-Berrocoso et al. (2022), through a systematic review of educational technology and student performance, demonstrated that the effects of technology are highly contextual and influenced by pedagogical factors rather than merely by the type of technology employed. Similar conclusions were reported by Akintayo et al. (2024), who emphasized that the positive impact of educational technology in higher education strongly depends on theory-driven instructional integration.

Despite the increasing number of systematic reviews and scoping reviews related to technology-based learning, many of these studies still exhibit conceptual and methodological limitations. First, numerous reviews focus their analyses on specific types of technologies or particular disciplinary fields, such as medical or nursing education, without situating their findings within a broader pedagogical evaluation framework (Arqub et al., 2024; Donkin et al., 2023). Second, several reviews adopt

descriptive–narrative approaches and do not explicitly employ an evidence-based education framework to assess the quality and relevance of empirical evidence (Cleland et al., 2025). Third, there is a tendency to equate technological effectiveness with user satisfaction or short-term improvements, thereby overlooking the sustainability of learning and knowledge transfer.

The research gap addressed in this study can be clearly identified through at least three major prior works. Valverde-Berrocoso et al. (2022), in Educational Technology and Student Performance: A Systematic Review, concluded that learning technologies have the potential to improve academic performance, yet did not integrate their findings within a systematic evidence-based education framework. Akintayo et al. (2024), in Evaluating the Impact of Educational Technology on Learning Outcomes in the Higher Education Sector, emphasized the importance of outcome-based evaluation but did not link variations in outcomes to evidence quality and pedagogical design. Meanwhile, Park et al. (2024), through a GRADE-based meta-analysis, evaluated the effectiveness of immersive technologies but focused on nursing education and did not position evidence-based education as a cross-context evaluative framework. Consequently, there remains a lack of systematic literature reviews that comprehensively evaluate the effectiveness of technology-based learning through the integration of empirical evidence, instructional design, and learning outcomes within an explicit evidence-based education framework.

Based on this research gap, the novelty of this study lies in three main aspects. Conceptually, this study positions evidence-based education as the primary evaluative framework for assessing the effectiveness of technology-based learning. Analytically, it synthesizes findings across studies to identify effectiveness patterns and pedagogical conditions that support successful technology integration. Methodologically, this study employs a systematic literature review with inclusion criteria emphasizing the quality of empirical evidence, enabling a more rigorous and transparent evaluation. Therefore, the objective of this study is to evaluate the effectiveness of technology-based learning through the synthesis of empirical evidence using an evidence-based education framework

METHODOLOGY (Times New Roman, 12, bold, space 1)

This study employed a Systematic Literature Review (SLR) design using an evidence-based education approach to evaluate the effectiveness of technology-based learning. The SLR method was selected because it enables a systematic and transparent synthesis of empirical findings from multiple primary studies while minimizing selection and interpretation bias (Snyder, 2019). The evidence-based education approach was used as an analytical framework to assess the extent to which the use of learning technologies is supported by high-quality empirical evidence that is relevant to pedagogical objectives.

The literature search strategy was conducted using reputable academic databases, namely Scopus, Web of Science, and Google Scholar. The search was performed using combinations of keywords such as *technology-based learning*, *technology-enhanced learning*, *digital learning*, *learning effectiveness*, and *evidence-based education*. The selected articles were limited to peer-reviewed journal publications reporting empirical findings on the effectiveness of technology-based learning, both in general education and professional education contexts. Opinion papers, editorials, non–peer-reviewed institutional reports, and articles that did not report learning outcomes were excluded from the review.

The study selection process followed the PRISMA flow systematically, beginning with identification and continuing through screening, eligibility assessment, and final inclusion. The selection process is illustrated in the following PRISMA flow diagram:

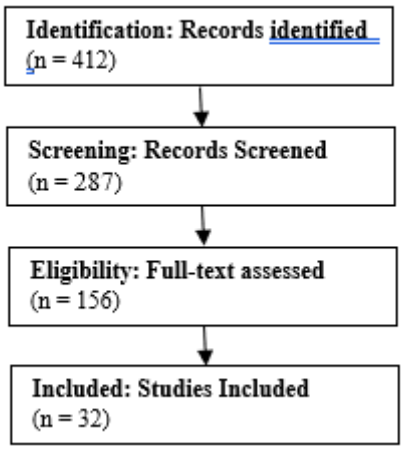

Figure 1. PRISMA Flow Diagram of the Systematic Literature Review

At the eligibility stage, the methodological quality of the studies was assessed based on the clarity of the research design, the validity of the instruments used, and the relevance of the reported learning outcomes. Data were analyzed through thematic synthesis and cross-study comparative analysis, with findings classified according to the type of technology employed, instructional design, and the learning outcomes measured. Procedural transparency and consistency in evidence quality assessment criteria were maintained to ensure the validity and reliability of the review findings.

RESULTS AND DISCUSSION

Patterns of Effectiveness of Technology-Based Learning Based on the Synthesis of Empirical Evidence

The systematic synthesis of empirical studies indicates that technology-based learning generally has the potential to positively impact learning outcomes, particularly in the cognitive domain and higher-order thinking skills. However, this effectiveness is neither universal nor automatic. Valverde-Berrocoso et al. (2022) emphasize that the relationship between educational technology and learning performance is complex and mediated by pedagogical factors, rather than determined solely by the presence or sophistication of technology. This finding is reinforced by Akintayo et al. (2024), who report that although most studies indicate improvements in learning outcomes, the magnitude of effects varies substantially across contexts, educational levels, and instructional designs.

One consistent pattern emerging from the evidence synthesis is that learning technologies tend to be more effective when used to support conceptual understanding and higher-order cognitive skills rather than mere factual knowledge transfer. Studies integrating technology with active learning approaches, such as case-based learning, problem-based learning, or project-based learning, more frequently report meaningful gains in students' analytical and problem-solving abilities (Donkin et al., 2023; Wang et

al., 2025). This pattern suggests that technology functions optimally when positioned as a medium that facilitates deep cognitive processing rather than as a passive content delivery tool.

In the context of professional education, particularly health education, empirical evidence demonstrates relatively strong but still contextual patterns of effectiveness. Park et al. (2024), through a GRADE-based meta-analysis, found that immersive technologies such as virtual simulations and immersive learning environments exert a moderate positive effect on clinical competence and procedural understanding among nursing students. However, these effects are strongly influenced by intervention duration, the degree of curricular integration, and instructional design quality. Similar findings are reported by Arqub et al. (2024) in prosthodontics education, emphasizing that technology-enhanced learning is effective when aligned with clearly defined clinical learning objectives.

Conversely, several studies report weak or non-significant outcomes, particularly when technology is implemented merely as a substitute for conventional instructional methods without corresponding pedagogical redesign. Valverde-Berrocoso et al. (2022) note that passive uses of digital platforms or instructional videos often fail to produce significant differences compared to traditional face-to-face instruction. These findings challenge deterministic assumptions that technology inherently improves learning quality and reinforce the argument that effectiveness must be evaluated based on how technology is pedagogically enacted in practice.

Variations in effectiveness are also evident across educational levels. Studies conducted in higher education and professional education tend to demonstrate more consistent positive effects than those in primary and secondary education. This pattern may be explained by adult learners' greater cognitive readiness, learner autonomy, and reflective capacity, which enable more effective engagement with learning technologies (Lee et al., 2025; McMullen et al., 2022). In contrast, technology-based learning at earlier educational levels often requires stronger pedagogical support and instructional scaffolding to yield positive learning outcomes.

From an evidence-based education perspective, these patterns indicate that the effectiveness of technology-based learning cannot be separated from the quality of the underlying empirical evidence. Studies employing robust methodological designs, such as randomized controlled trials or quasi-experimental designs, tend to report more measurable and consistent outcomes than descriptive or perception-based studies (Wang et al., 2025; Park et al., 2024). This underscores the importance of evaluating learning technology effectiveness not merely by the number of studies reporting positive impacts, but by the methodological rigor and pedagogical relevance of the available evidence.

Accordingly, the synthesis of empirical evidence in this review addresses the research objective by demonstrating that technology-based learning possesses significant but conditional effectiveness. Consistent positive effects emerge when technology is integrated within theory-driven instructional designs, aligned with meaningful learning outcomes, and evaluated using evidence-based approaches. These findings further

suggest that debates on the effectiveness of learning technologies should shift from an emphasis on technical innovation toward pedagogically grounded, evidence-based evaluation.

The Role of the Evidence-Based Education Framework in Explaining Variations in Technology-Based Learning Outcomes

The evidence-based education framework provides a strong conceptual foundation for understanding why the effectiveness of technology-based learning varies significantly across studies, educational contexts, and instructional designs. In contrast to technological determinism, which assumes that the mere presence of technology automatically enhances learning quality, evidence-based education positions technology as a component of a broader pedagogical system that must be evaluated based on empirical evidence, instructional alignment, and contextual relevance (Snyder, 2019). The synthesis of studies reviewed in this research demonstrates that variations in learning outcomes are not anomalies, but rather logical consequences of differences in pedagogical design quality and the strength of the underlying evidence.

One of the key findings emerging from the synthesis of empirical evidence is that learning technologies function most effectively when positioned as instructional supports rather than primary drivers of learning. Studies reporting significant improvements in learning outcomes generally integrate technology within active learning strategies, such as problem-based learning, case-based learning, team-based learning, and flipped learning (Cleland et al., 2025; Rahayuningsih et al., 2025). In these contexts, technology enhances higher-order cognitive processes by facilitating discussion, problem solving, and reflection, processes that are consistently identified in the evidence-based pedagogy literature as central determinants of meaningful learning.

Conversely, technology interventions oriented toward the substitution of conventional instructional methods (for example, replacing face-to-face lectures with passive instructional videos) tend to yield limited impacts on learning outcomes. Valverde-Berrocoso et al. (2022) demonstrate that technology use without accompanying instructional redesign does not confer significant advantages over traditional approaches. These findings indicate that the effectiveness of technology-based learning is determined not by the digital medium itself, but by how technology is employed to support evidence-informed learning goals and instructional activities.

The evidence-based education framework also emphasizes the importance of instructional alignment in explaining variations in learning outcomes. Instructional alignment refers to the consistency among learning objectives, teaching strategies, learning activities, and assessment methods. Akintayo et al. (2024) highlight that studies demonstrating strong learning effects typically articulate explicitly how technology is used to support clearly defined and measurable learning objectives. In contrast, studies lacking such alignment often fail to demonstrate significant learning gains, even when employing relatively sophisticated technologies.

Beyond pedagogical considerations, evidence-based education provides a framework for evaluating variations in learning outcomes based on the quality of empirical evidence. Park et al. (2024), through a GRADE-based meta-analysis, show that although many studies report positive effects of learning technologies, the quality of evidence ranges from low to moderate. This variation has direct implications for the level of confidence that can be placed in reported findings and underscores the need for critical interpretation of claims regarding technological effectiveness. Evidence-based education demands that evaluations of effectiveness be grounded in robust research designs, methodological transparency, and replication across contexts.

To clarify how the evidence-based education framework explains variations in technology-based learning outcomes, the synthesis of findings from this systematic literature review is summarized into key evaluative dimensions presented in Table 1. This table maps the relationships among instructional design characteristics, evidence quality, and their implications for learning effectiveness.

Table 1. Evidence-Based Evaluation Dimensions of Technology-Based Learning Effectiveness

Evaluation Dimension	Key Characteristics Identified in the Reviewed Studies	Implications for Learning Outcomes
Pedagogical Alignment	Clear alignment between learning objectives, instructional strategies, and technology use	More consistent and meaningful learning gains
Instructional Role of Technology	Technology used as instructional and cognitive support rather than content replacement	Enhanced higher-order thinking and conceptual understanding
Quality of Empirical Evidence	Experimental or quasi-experimental designs with validated instruments	Greater reliability and credibility of findings
Outcome Measurement	Emphasis on objective cognitive and skill-based outcomes	More valid assessment of learning effectiveness
Contextual Integration	Adaptation to learner characteristics and disciplinary context	Reduced outcome variability across settings

Analysis of Table 1 indicates that variations in the effectiveness of technology-based learning can be systematically explained through differences in these evaluative dimensions. Studies that fulfill most of the dimensions within the evidence-based education framework tend to report learning outcomes that are stronger, more consistent, and transferable to other contexts. For example, Wang et al. (2025) demonstrate that interactive video-based learning in medical education produces significant improvements in clinical reasoning skills when technology is integrated in alignment with learning objectives and performance-based evaluation methods. In contrast, studies that emphasize technological aspects alone without pedagogical alignment often report ambiguous or non-significant outcomes.

The evidence-based education framework also highlights the importance of selecting appropriate learning outcome indicators. Many studies in educational technology continue to rely on subjective indicators such as learner satisfaction or

perceptions, which, although informative, do not always reflect actual improvements in competence (Morris et al., 2021). Studies that employ objective indicators, such as standardized tests or performance assessments, provide a stronger and more consistent evaluative basis for assessing the effectiveness of technology-based learning (Lee et al., 2025). Accordingly, evidence-based education encourages a shift in evaluative focus from perception-based measures toward measurable learning achievements.

In the context of professional education, particularly health education, the role of evidence-based education becomes increasingly critical. Estalella et al. (2023) and Pupic et al. (2023) show that learning technologies are effective when used to support the development of practice-based competencies and evidence-informed clinical decision making. However, this effectiveness declines significantly when technology is adopted without clear integration into the curriculum and competency frameworks. These findings underscore that learning technologies must be situated within an evidence-based pedagogical ecosystem in order to generate sustainable learning impacts.

Overall, this discussion addresses the research objective by demonstrating that the evidence-based education framework is able to comprehensively explain variations in technology-based learning outcomes. The framework reveals that technological effectiveness is not an inherent characteristic of digital tools, but rather the result of pedagogical integration, the quality of empirical evidence, and the relevance of the learning context. Therefore, the evaluation of learning technologies should be directed toward analyzing the pedagogical conditions that enable technology to function effectively, rather than toward claims of innovation alone.

Implications of the Systematic Synthesis for the Practice and Evaluation of Technology-Based Learning

The systematic synthesis of the literature reviewed in this study provides significant theoretical and practical implications for how technology-based learning should be designed, implemented, and evaluated. The main findings of this SLR indicate that the effectiveness of technology-based learning cannot be separated from the quality of the underlying empirical evidence and the degree of pedagogical alignment in its implementation. Accordingly, the implications of this synthesis are relevant not only to educational researchers, but also to policymakers and practitioners directly involved in the adoption of learning technologies.

From a theoretical perspective, the findings of this study reinforce the position of evidence-based education as a crucial evaluative paradigm in educational technology research. Many studies on learning technologies have traditionally been driven by an innovation assumption, namely that the use of new technologies will inherently improve learning quality. However, cross-study synthesis demonstrates that this assumption is not consistently supported by empirical evidence (Valverde-Berrocoso et al., 2022; Akintayo et al., 2024). In this regard, evidence-based education functions as a corrective framework that situates technology in a functional relationship with learning theory, instructional design, and measurable learning outcomes.

Another theoretical implication concerns the need to shift the focus of educational technology research from normative questions toward analytical ones. Rather than asking

whether a particular technology is effective, evidence-based research should explore under what pedagogical conditions that technology produces positive learning impacts. Findings from the reviewed studies indicate that variations in learning outcomes can be explained by differences in instructional design, evidence quality, and contextual suitability, rather than by the type of technology alone (Park et al., 2024; Wang et al., 2025). This approach creates opportunities for the development of more precise conceptual models for evaluating technology-based learning.

From a practical standpoint, this systematic synthesis has direct implications for decision making in the adoption of educational technologies. The SLR findings emphasize that adopting learning technologies without evidence-based evaluation carries the risk of ineffective investment in terms of cost, time, and learning impact. Studies reporting weak or non-significant learning outcomes generally indicate that technology was implemented as a technical solution without adequate pedagogical integration (Cleland et al., 2025; Morris et al., 2021). Therefore, policymakers should prioritize empirical evidence as the primary basis for designing educational technology policies.

Another practical implication is the need to develop stricter and more contextualized standards for evaluating the effectiveness of technology-based learning. Cross-study synthesis reveals substantial variation in the indicators used to assess effectiveness, ranging from learner satisfaction to performance-based competency outcomes. Evidence-based education requires that effectiveness evaluation focus on meaningful and sustainable learning outcomes, such as conceptual understanding, higher-order thinking skills, and professional competencies (Lee et al., 2025; Estalella et al., 2023). Such evaluation standards are essential to ensure that learning technologies genuinely contribute to improving educational quality.

In the context of implementation within educational institutions, the findings of this study highlight the importance of positioning learning technologies within a cycle of continuous, evidence-based improvement. Technology should not be viewed as a one-time intervention, but rather as part of a reflective process involving evidence-informed planning, controlled implementation, outcome evaluation, and continuous adjustment. Studies reporting positive outcomes generally demonstrate the presence of evaluative processes and instructional design adjustments based on empirical data (Rahayuningsih et al., 2025; Pupic et al., 2023). This approach aligns with the principles of evidence-based education, which emphasize institutional learning and data-driven decision making.

Another implication relates to the development of educators' capacity to implement technology-based learning. The literature synthesis indicates that educators' pedagogical competence plays a key role in determining the effectiveness of learning technologies. The same technology can yield markedly different outcomes depending on how educators design learning activities, facilitate interaction, and evaluate learners' achievements (Akintayo et al., 2024; Valverde-Berrocoso et al., 2022). Consequently, professional development for educators should be directed not only toward technical proficiency in using technology, but also toward an understanding of evidence-based pedagogical principles.

Overall, this discussion demonstrates that the systematic synthesis of educational technology literature makes an important contribution to bridging the gap between research and practice. By employing the evidence-based education framework, this study offers a conceptual and empirical foundation for evaluating the effectiveness of technology-based learning in a more critical and contextualized manner. These findings further reinforce the argument that the future of educational technology lies not in the rapid adoption of innovation, but in the capacity of educational systems to learn from evidence and apply it reflectively.

CONCLUSION

This study concludes that the effectiveness of technology-based learning cannot be understood in a universal or deterministic manner, but rather must be evaluated through an evidence-based education framework that links empirical evidence, pedagogical design, and learning outcomes. The results of the systematic literature review indicate that learning technologies consistently produce positive impacts on learning outcomes when they are integrated with instructional designs grounded in learning theory, clear learning objectives, and evidence-based evaluation. In contrast, technology implementation oriented toward technical innovation without a strong pedagogical foundation tends to result in limited or non-significant impacts.

Theoretically, the findings of this study affirm the importance of positioning evidence-based education as the primary evaluative framework in educational technology research. This approach enables a more critical analysis of variations in learning outcomes and encourages a shift in research focus from normative questions toward the analysis of pedagogical conditions that support technological effectiveness. Practically, this study recommends that policymakers and educational practitioners use empirical evidence as the main basis for the adoption and evaluation of learning technologies, and that effectiveness evaluation be treated as an integral part of the technology implementation cycle in education.

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