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Systematic Review

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Leveraging Digital Tools to Enhance Education for Sustainable Development in Higher Education

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Abstract

The integration of digital technologies into higher education presents opportunities to strengthen Education for Sustainable Development (ESD) and advance the Sustainable Development Goals (SDGs). This study employed a Systematic Literature Review to examine how digital tools enhance ESD delivery and develop sustainability competencies in higher education. Peer-reviewed studies published between 2018 and 2025 were analysed from Scopus, Web of Science, ERIC, Google Scholar, and JSTOR. Findings indicate that Learning Management Systems, virtual and augmented reality, simulation software, Geographic Information Systems, collaborative platforms, and data analytics enhance student engagement, critical thinking, problem-solving, and collaboration. Blended, experiential, and learner-centred pedagogies grounded in Constructivist Learning Theory were particularly effective. However, inadequate infrastructure, digital literacy gaps, and limited access remain significant barriers, especially in developing countries. The study proposes a Digital Education for Sustainable Development Adoption Model (DEAM) and recommends investments in infrastructure, capacity building, and inclusive policies to advance SDGs 4 and 13

Keywords

Education for Sustainable Development (ESD), Digital Technologies, Higher Education, Sustainability Competencies and Digital Education for Sustainable Development Adoption Model (DEAM)

1. Introduction

Education for Sustainable Development (ESD) has become central to preparing learners to address the interconnected environmental, social, and economic challenges of the twenty-first century. Beyond transmitting sustainability knowledge, ESD seeks to develop the competencies, values, attitudes, and actions needed to promote sustainable development. Its importance is reflected in the United Nations 2030 Agenda, particularly Sustainable Development Goal (SDG) 4.7, which calls for learners to acquire the knowledge and skills required to advance sustainable development (United Nations, 2015; UNESCO, 2020). Higher education institutions play a critical role in achieving this objective because they prepare future professionals, researchers, educators, policymakers, and leaders. Universities are therefore expected to create learning environments that enable students to understand complex systems, anticipate future challenges, evaluate competing values, collaborate across disciplines, and develop practical solutions to sustainability issues. These abilities are reflected in sustainability competencies such as systems thinking, anticipatory, normative, strategic, interpersonal, and integrated problem-solving competencies (Wiek *et al.,* 2011; Brundiers *et al.,* 2021). Rapid digital transformation has created new opportunities to support these competencies. Digital technologies, including Learning Management Systems, virtual and augmented reality, simulation software, Geographic Information Systems (GIS), collaborative platforms, learning analytics, and artificial intelligence, have expanded access to flexible, interactive, and learner-centred education. These technologies facilitate collaboration, visualisation of complex systems, access to authentic data, and engagement with real-world sustainability challenges (Alenezi, 2023; Pinto & Leite, 2020). The potential of digital technologies is particularly significant for ESD because sustainability issues are interdisciplinary, complex, and often characterised by uncertainty. Simulation tools enable students to evaluate the consequences of alternative decisions, while GIS supports the analysis of environmental and social issues such as climate change, resource distribution, and land-use change. Virtual learning environments and collaborative platforms also connect learners with experts and communities beyond institutional boundaries. When integrated effectively, digital technologies can strengthen critical thinking, collaboration, communication, problem-solving, and digital literacy, all of which contribute to sustainability competencies (Cebrián *et al.,* 2020; Wekerle *et al.,* 2022).

However, technology alone does not guarantee meaningful learning or sustainability outcomes. Research consistently shows that the educational value of digital technologies depends on instructional design and pedagogical approaches rather than on the technologies themselves. Digital tools are most effective when they support active learning through inquiry, collaboration, reflection, and problem-solving instead of passive information delivery (Wekerle *et al.,* 2022). Consequently, learner-centred pedagogies such as blended learning, project-based learning, experiential learning, inquiry-based learning, collaborative learning, and flipped classrooms provide an important link between digital technologies and ESD. These approaches encourage students to investigate authentic sustainability challenges, apply knowledge in real contexts, and collaboratively develop solutions, consistent with Constructivist Learning Theory (Braßler & Sprenger, 2021). Despite growing interest in digital transformation and sustainability education, evidence on their integration remains fragmented. Existing reviews of digital learning largely examine technological innovations and conventional educational outcomes,

whereas ESD research primarily focuses on sustainability competencies and pedagogical practices without adequately considering digital technologies (Pinto & Leite, 2020; Brundiers *et al.,* 2021). Consequently, there is limited synthesis regarding which digital tools best support ESD, how they should be integrated pedagogically, and how they contribute to sustainability competency development.

These challenges are particularly evident in developing countries, where inadequate infrastructure, limited internet connectivity, high data costs, insufficient access to digital devices, and digital literacy gaps constrain technology-enhanced learning. Effective digital education also depends on institutional support, curriculum alignment, educator competence, and professional development (Basilotta-Gómez-Pablos *et al.,* 2022; Inamorato dos Santos *et al*., 2023). In Africa, digital transformation has expanded access to higher education and increased instructional flexibility, but implementation continues to be shaped by financial constraints, institutional capacity, policy support, and equity considerations (Ajani, 2024; Babalola & Genga, 2024). The Ghanaian experience reflects both the opportunities and challenges of digital transformation. The COVID-19 pandemic accelerated the adoption of online and blended learning across universities, improving flexibility and continuity in teaching. Nevertheless, challenges related to internet connectivity, access to devices, institutional preparedness, student participation, and digital competence remain significant (Yeboah, 2022; Kumi-Yeboah *et al.,* 2023; Kayi, 2024). While these studies provide valuable insights into digital learning, they pay limited attention to how digital technologies can specifically support Education for Sustainable Development and the development of sustainability competencies. This study addresses this gap by systematically reviewing evidence on the use of digital technologies to enhance ESD in higher education. Specifically, it examines: (1) the digital tools and technologies used to support ESD; (2) their influence on student learning outcomes and sustainability competencies; and (3) the pedagogical approaches that facilitate their effective integration. The study makes three key contributions. First, it synthesises evidence from the intersecting fields of digital education and sustainability education. Second, it highlights the central role of learner-centred pedagogy in mediating the relationship between digital technologies and sustainability learning outcomes. Third, it proposes a Digital Education for Sustainable Development Adoption Model (DEAM) that illustrates how digital tools, pedagogical approaches, learning outcomes, and sustainability competencies interact within institutional and contextual environments. The model incorporates factors such as digital infrastructure, institutional support, digital literacy, funding, equity, and policy, providing a context-sensitive framework to guide future research, curriculum development, and policy for higher education, particularly in Africa and other developing-country contexts.

2.1 Theoretical Framework: Constructivist Learning Theory

Constructivist Learning Theory provides the theoretical foundation for this study by explaining how learners actively construct knowledge through experience, interaction, and reflection rather than passively receiving information. The theory, originally developed by Jean Piaget and subsequently extended by Lev Vygotsky, has been widely applied in higher education research to explain learner-centred and technology-enhanced learning environments (Dzaiy & Abdullah, 2024). Constructivism views learning as a dynamic cognitive and social process in which learners develop understanding by integrating new experiences with prior knowledge through inquiry, collaboration, and problem-solving. Piaget's cognitive constructivism emphasises that learning occurs through the processes of assimilation and accommodation, whereby individuals continuously modify their cognitive structures in response to new experiences. In contrast, Vygotsky's sociocultural perspective highlights the role of social interaction in knowledge construction, arguing that learning is enhanced through collaboration and guided support within the learner's Zone of Proximal Development (ZPD) (Karagianni, 2024). Together, these perspectives suggest that effective learning environments should encourage active participation, collaboration, reflection, and authentic problem-solving. The principles of Constructivist Learning Theory closely align with the objectives of Education for Sustainable Development (ESD). Sustainability education requires learners to analyse complex environmental, social, and economic challenges, evaluate alternative perspectives, and develop practical solutions. Consequently, ESD increasingly adopts learner-centred pedagogies that promote experiential learning, inquiry, collaboration, and critical reflection (AlAfnan & Dishari, 2024). These pedagogical approaches encourage learners to develop higher-order cognitive skills and sustainability competencies rather than merely acquiring factual knowledge.

Recent studies indicate that digital technologies have significantly expanded opportunities to implement constructivist learning environments within higher education (Wekerle et al., 2022). Technologies such as Learning Management Systems (LMS), virtual and augmented reality, simulation software, Geographic Information Systems (GIS), collaborative platforms, artificial intelligence applications, and learning analytics provide interactive environments that enable learners to investigate sustainability problems, analyse authentic data, collaborate across geographical boundaries, and engage in experiential learning activities (Velmurugan et

al., 2026). Rather than serving solely as information delivery platforms, these technologies facilitate active knowledge construction and collaborative learning. The literature further demonstrates that the educational benefits of digital technologies depend largely on the pedagogical approaches through which they are implemented. Blended learning, project-based learning, experiential learning, inquiry-based learning, collaborative learning, and flipped classroom approaches have consistently been identified as effective strategies for integrating digital technologies into higher education because they promote learner engagement, reflection, collaboration, and authentic problem-solving (Leow & Neo, 2023). These approaches are particularly relevant to ESD because they encourage learners to investigate real-world sustainability challenges while developing systems thinking, critical thinking, communication, collaboration, and responsible citizenship competencies required for sustainable development (Castaño et al., 2025). The literature therefore suggests that Constructivist Learning Theory provides a coherent explanation of the relationship between digital technologies, pedagogy, and sustainability learning outcomes. Digital technologies create opportunities for active and collaborative learning; however, their effectiveness depends on learner-centred pedagogical strategies that encourage inquiry, interaction, and experiential learning. This perspective provides an appropriate theoretical lens for understanding how digital technologies can support Education for Sustainable Development in higher education. Within the context of the present study, Constructivist Learning Theory informs all three research objectives. First, it explains how digital technologies create interactive learning environments that support ESD. Second, it provides a theoretical basis for understanding how learner engagement with digital technologies contributes to improved learning outcomes and the development of sustainability competencies. Third, it explains why learner-centred pedagogical approaches mediate the relationship between digital technologies and sustainability learning outcomes. Accordingly, the proposed Digital Education for Sustainable Development Adoption Model (DEAM) is grounded in the assumption that digital technologies influence sustainability competencies indirectly through pedagogical practices that facilitate active knowledge construction, collaboration, reflection, and contextual learning.

2.2 Conceptual Framework: Digital Education for Sustainable Development Adoption Model (DEAM)

Building on Constructivist Learning Theory and evidence from the literature on digital education and sustainability education, this study proposes the Digital Education for Sustainable Development Adoption Model (DEAM) as a conceptual framework for explaining the integration of digital technologies into Education for Sustainable Development within higher education. The model synthesises existing evidence on technology-enhanced learning, learner-centred pedagogy, and sustainability competencies to explain the mechanisms through which digital technologies contribute to sustainability learning. The DEAM is based on the premise that the availability of digital technologies alone does not automatically improve educational outcomes. Rather, the educational value of digital tools depends on the pedagogical approaches through which they are integrated into teaching and learning. Learner-centred pedagogies serve as the primary mechanism through which digital technologies influence learning outcomes and the development of sustainability competencies. The model also recognises that contextual factors, including institutional support, digital infrastructure, digital literacy, funding, and policy environments, influence the successful implementation of technology-enhanced ESD. The framework comprises four interrelated components. The first component consists of digital tools and technologies, including Learning Management Systems, virtual and augmented reality, simulation software, Geographic Information Systems, collaborative platforms, artificial intelligence applications, and learning analytics. These technologies provide flexible and interactive learning environments that facilitate access to sustainability knowledge, authentic learning experiences, collaboration, and engagement. The second component comprises learner-centred pedagogical approaches, which mediate the relationship between digital technologies and learning outcomes. Consistent with Constructivist Learning Theory, the literature identifies blended learning, collaborative learning, experiential learning, project-based learning, inquiry-based learning, and flipped classroom approaches as particularly effective strategies for promoting active participation, critical reflection, knowledge construction, and collaborative problem-solving. These pedagogies enable students to apply digital technologies in addressing authentic sustainability challenges, thereby enhancing both educational outcomes and sustainability competencies. Collectively, the DEAM provides a theoretically grounded and context-sensitive framework for understanding how digital technologies, when supported by appropriate pedagogical practices and enabling institutional conditions, contribute to effective Education for Sustainable Development in higher education. The framework also offers practical guidance for curriculum development, institutional planning, and policy formulation, particularly in African and other resource-constrained higher education contexts.

2.2.3 Learning Outcomes

The Digital Education for Sustainable Development Adoption Model (DEAM) proposes that positive learning outcomes emerge through the interaction between digital technologies and learner-centred pedagogical

approaches rather than through technology use alone. Consistent with Constructivist Learning Theory, digital technologies enhance learning when they are integrated into instructional strategies that promote active participation, inquiry, collaboration, and reflection. The literature indicates that pedagogically appropriate use of digital technologies increases student engagement, strengthens critical thinking and problem-solving abilities, improves communication and collaborative skills, enhances digital literacy, and promotes creativity and innovation (Wekerle et al., 2022; Leow & Neo, 2023). Furthermore, technology-enhanced learning environments enable students to develop a deeper understanding of sustainability concepts by providing opportunities to analyse authentic data, simulate complex environmental systems, and engage with real-world sustainability challenges. These learning outcomes collectively prepare learners to apply theoretical knowledge to environmental, economic, and social problems within diverse professional and societal contexts.

2.2.4 Sustainability Competencies

The development of sustainability competencies represents the ultimate outcome of the proposed DEAM. Building on the sustainability education literature, the model assumes that improved learning outcomes facilitate the acquisition of competencies required to address complex sustainability challenges. These competencies include systems thinking, anticipatory, strategic, critical thinking, and interpersonal competencies, together with ethical responsibility, responsible citizenship, and sustainable decision-making (Wiek *et al.,*2011; Brundiers *et al.,*2021). Collectively, these competencies enable learners to understand the interrelationships among environmental, social, and economic systems, anticipate future challenges, evaluate alternative solutions, collaborate effectively with diverse stakeholders, and implement sustainable actions. The development of these competencies contributes directly to the objectives of Education for Sustainable Development and supports the achievement of Sustainable Development Goal 4 (Quality Education), while indirectly advancing broader sustainable development goals, including climate action and responsible resource management.

2.2.5 Contextual and Institutional Factors

The DEAM further recognises that the successful integration of digital technologies into Education for Sustainable Development is shaped by broader institutional and contextual conditions. Although digital technologies and learner-centred pedagogies constitute the core mechanisms of the model, their effectiveness depends on the availability of enabling institutional environments. The literature consistently identifies technological infrastructure, reliable internet connectivity, institutional policies, leadership support, funding, and access to digital resources as critical determinants of successful technology integration (Basilotta-Gómez-Pablos *et al*., 2022; Inamorato dos Santos *et al.,* 2023). Equally important are the digital competencies of educators and students, ongoing professional development opportunities, and institutional capacity to design and implement technology-enhanced curricula. The model also acknowledges the importance of equity and inclusion, particularly within developing-country contexts where disparities in digital access and technological resources remain substantial. Limited infrastructure, high internet costs, inadequate digital devices, and unequal levels of digital literacy may restrict learners' participation in technology-enhanced education and reduce the effectiveness of digital ESD initiatives. Consequently, institutional commitment to inclusive policies, investment in digital infrastructure, and capacity-building initiatives is essential for ensuring equitable access to digital learning opportunities. Within the DEAM, these contextual and institutional factors function as enabling or constraining conditions that influence the relationships among digital technologies, pedagogical approaches, learning outcomes, and sustainability competencies. The framework therefore provides a context-sensitive perspective that is particularly relevant to higher education institutions in Africa and other resource-constrained settings, where institutional readiness and policy support remain critical to the successful implementation of digital Education for Sustainable Development.

2.2.6 Description of the Digital Education for Sustainable Development Adoption Model (DEAM)

The Digital Education for Sustainable Development Adoption Model (DEAM) proposes that digital tools and technologies serve as the primary enablers of technology-enhanced learning. However, their effectiveness depends largely on the pedagogical approaches employed by educators. Learner-centred pedagogies mediate the relationship between digital technologies and learning outcomes by promoting active engagement, collaboration, and experiential learning. Positive learning outcomes subsequently lead to the development of sustainability competencies, which equip students with the knowledge, skills, attitudes, and values necessary to address

contemporary sustainability challenges. The entire process is influenced by institutional and contextual factors that determine the extent to which digital technologies can be effectively adopted and utilised. Consequently, DEAM provides a holistic framework for understanding the mechanisms through which digital technologies contribute to Education for Sustainable Development in higher education. The model also offers practical guidance for educators, administrators, and policymakers seeking to strengthen digital transformation initiatives and promote sustainable development within higher education institutions. Figure 1 shows a proposed digital Education for Sustainable Development model.

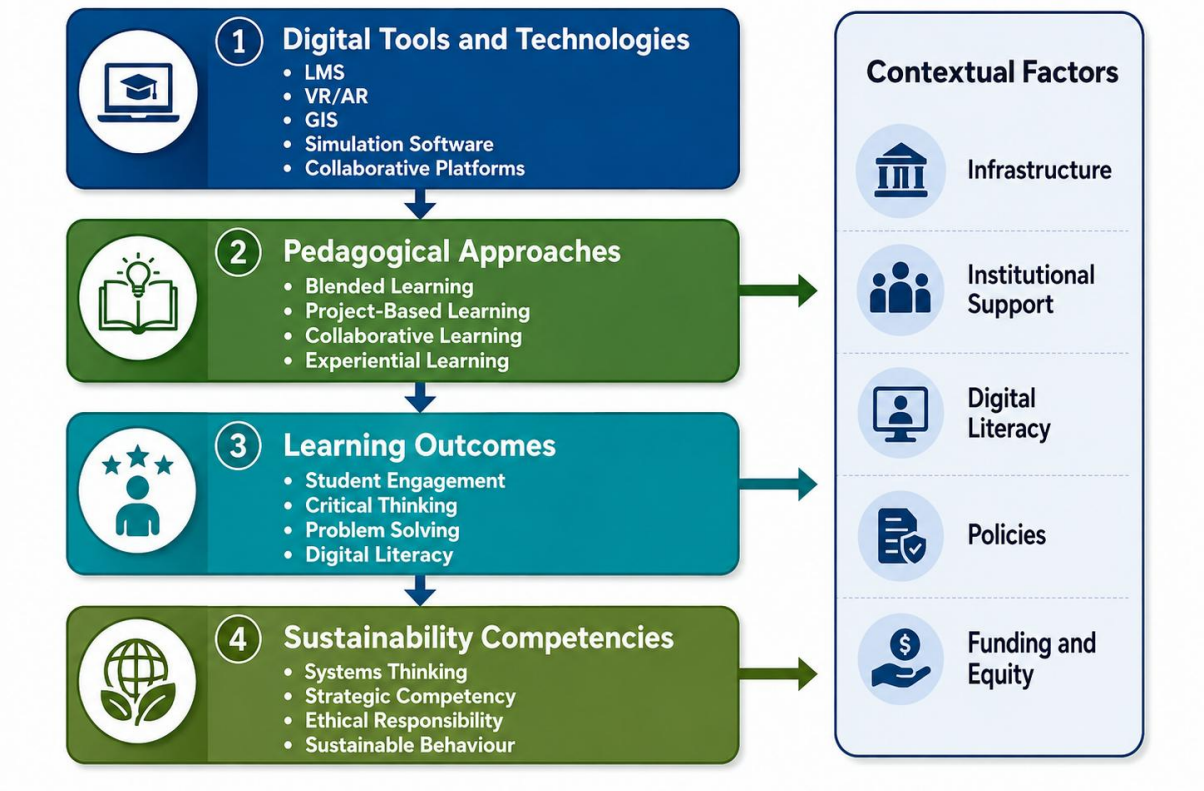


Figure 1. Proposed Digital Education for Sustainable Development Adoption Model (DEM)

3. Methodology

3.1 Research Design

This study employed a Systematic Literature Review (SLR) to synthesise evidence on the use of digital technologies in enhancing Education for Sustainable Development (ESD) within higher education. The SLR approach was selected because it provides a rigorous, transparent, and replicable process for identifying, evaluating, and synthesising existing research while minimising selection bias. The review followed established systematic review guidelines and adopted a thematic synthesis approach to analyse the evidence.

3.2 Search Strategy

A comprehensive literature search was conducted across Scopus, Web of Science, ERIC, ScienceDirect, JSTOR, and Google Scholar. Peer-reviewed journal articles published between 2018 and 2025 were considered to capture recent developments in digital transformation and sustainability education. Search terms combined keywords related to digital technologies and ESD using Boolean operators, including "digital technologies" AND "higher education", "Education for Sustainable Development" AND "higher education", "technology-enhanced learning"

AND "sustainability education", and "digital learning" AND "sustainability competencies". Additional manual searches of reference lists were conducted to identify relevant studies.

3.3 Eligibility Criteria

Studies were included if they: (i) were peer-reviewed journal articles published in English between 2018 and 2025; (ii) examined digital technologies within higher education; (iii) addressed Education for Sustainable Development or sustainability education; and (iv) reported evidence on digital tools, pedagogical approaches, learning outcomes, or sustainability competencies. Conference papers, dissertations, editorials, duplicate records, studies published before 2018, and articles unrelated to digital technologies or ESD were excluded.

3.4 Study Selection

Study selection followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) process, comprising four stages: identification, screening, eligibility, and inclusion. Records retrieved from the databases were screened for duplicates before titles and abstracts were reviewed against the inclusion criteria. Eligible full-text articles were then assessed for methodological relevance, and only studies meeting all selection criteria were included in the final review.

3.5 Data Extraction and Analysis

Relevant data were extracted using a structured data extraction form that captured study characteristics, research design, digital technologies investigated, pedagogical approaches, learning outcomes, sustainability competencies, and key findings. The extracted data were analysed using thematic analysis, enabling the identification of recurring patterns across the literature. Four overarching themes emerged: (i) digital technologies supporting ESD; (ii) the effects of digital technologies on learning outcomes and sustainability competencies; (iii) pedagogical approaches facilitating digital ESD; and (iv) barriers to implementation. The findings were interpreted through the lens of Constructivist Learning Theory and informed the development of the Digital Education for Sustainable Development Adoption Model (DEAM).

3.6 Quality Assessment and Ethical Considerations

The quality of the included studies was assessed based on their methodological rigour, relevance to the review objectives, and publication in reputable peer-reviewed journals indexed in recognised academic databases. As the study relied exclusively on secondary data from published literature, ethical approval was not required. Nevertheless, all sources were appropriately acknowledged in accordance with accepted standards of academic integrity and scholarly practice.

3.8 Limitations of the Study

Although the Systematic Literature Review approach provides a comprehensive synthesis of existing knowledge, the study is subject to certain limitations. First, the review was restricted to English-language publications, which may have excluded relevant studies published in other languages. Second, the dependence on published literature may introduce publication bias because studies reporting significant findings are more likely to be published. Third, the exclusion of conference proceedings and grey literature may have limited the inclusion of emerging evidence. Despite these limitations, the systematic procedures employed enhanced the credibility and robustness of the findings. Figure 2 shows the systematic literature review process adopted.

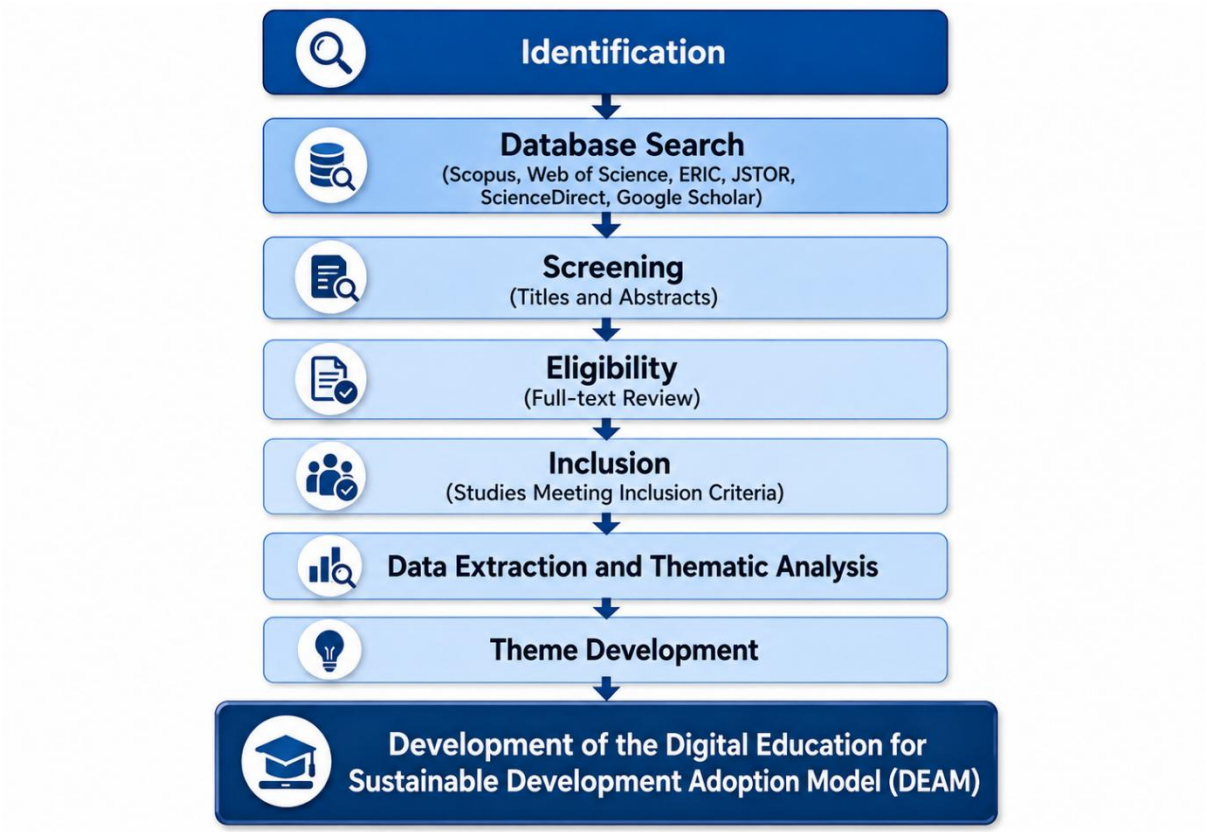


Figure 2: Summary of the Systematic Literature Review

4.0 Findings

The thematic analysis of the reviewed studies revealed four interrelated findings concerning the use of digital technologies in enhancing Education for Sustainable Development (ESD) in higher education. Overall, the evidence indicates that digital technologies have significant potential to improve sustainability education when integrated with learner-centred pedagogical approaches and supported by enabling institutional conditions. The review shows that higher education institutions increasingly utilise a wide range of digital technologies to support ESD. Learning Management Systems (LMS), including Moodle, Blackboard, Canvas, and Sakai, emerged as the most widely adopted platforms for organising learning resources, facilitating communication, and supporting flexible and collaborative learning. Other frequently reported technologies include virtual and augmented reality, simulation software, Geographic Information Systems (GIS), collaborative platforms, learning analytics, and artificial intelligence applications. These technologies create interactive learning environments that enable students to visualise complex sustainability concepts, analyse environmental and socio-economic data, participate in simulations, and collaborate across disciplinary and geographical boundaries. Consequently, digital technologies enhance access to learning resources while promoting active engagement and experiential learning. The findings further demonstrate that the educational benefits of digital technologies extend beyond improved access to learning. Across the reviewed studies, technology-enhanced learning was consistently associated with increased student engagement, improved academic performance, and greater participation in learning activities. Digital learning environments also promoted higher-order cognitive skills by strengthening critical thinking, problem-solving, communication, collaboration, creativity, and digital literacy. Through simulations, collaborative projects, and inquiry-based activities, students were able to investigate authentic sustainability challenges, evaluate alternative solutions, and apply theoretical knowledge to practical contexts. These learning experiences contributed to the development of key sustainability competencies, including systems thinking, strategic thinking, ethical awareness, responsible citizenship, and informed decision-making. The findings therefore support the proposition that digital technologies contribute to sustainability competency development by enhancing learning outcomes. The review also indicates that the effectiveness of digital technologies depends largely on the pedagogical approaches through which they are implemented. Simply introducing digital tools into teaching does not automatically improve educational outcomes. Instead, learner-centred pedagogies mediate the relationship between technology use and meaningful learning. Blended learning emerged as the most widely adopted approach because it combines the flexibility of online learning with the interaction provided by face-to-

face instruction. Experiential learning, project-based learning, inquiry-based learning, collaborative learning, and flipped classroom approaches were similarly identified as effective strategies for integrating digital technologies into ESD. These pedagogical approaches encourage active participation, collaboration, reflection, and authentic problem-solving, enabling learners to construct knowledge through experience and social interaction. The findings therefore reinforce the assumptions of Constructivist Learning Theory by demonstrating that meaningful learning occurs when students actively engage with digital technologies through inquiry and collaboration rather than passive content consumption.

Although considerable progress has been made in the adoption of digital technologies within higher education, the review reveals persistent contextual challenges, particularly across African countries. The COVID-19 pandemic accelerated digital transformation and encouraged universities in Ghana, South Africa, Kenya, Nigeria, and other African countries to expand online learning and digital instructional platforms. Nevertheless, the integration of digital technologies specifically to support Education for Sustainable Development remains limited. Major barriers include inadequate technological infrastructure, unreliable internet connectivity, limited access to digital devices, insufficient funding, institutional capacity constraints, and disparities in digital literacy among educators and students. These challenges continue to constrain the effective implementation of technology-enhanced sustainability education and contribute to persistent digital inequalities within higher education institutions. Despite these constraints, the literature highlights substantial opportunities for strengthening digital ESD across Africa. Increasing investment in information and communication technologies, expanding internet connectivity, growing institutional commitment to digital transformation, and supportive national digitalisation policies provide favourable conditions for enhancing sustainability education. However, realising these opportunities requires strategic investment in digital infrastructure, educator capacity development, institutional support, and inclusive policies that ensure equitable access to digital learning resources. Collectively, these findings demonstrate that the successful integration of digital technologies into Education for Sustainable Development depends on the interaction among digital tools, learner-centred pedagogies, positive learning outcomes, and enabling institutional conditions. This evidence provides empirical support for the proposed Digital Education for Sustainable Development Adoption Model (DEAM), which conceptualises how digital technologies, mediated by appropriate pedagogical approaches and supported by favourable contextual factors, contribute to improved learning outcomes and the development of sustainability competencies in higher education.

5.0 Discussion

This study examined how digital technologies enhance Education for Sustainable Development (ESD) in higher education by exploring the digital tools employed, their influence on learning outcomes and sustainability competencies, and the pedagogical approaches that facilitate their effective integration. The findings demonstrate that digital technologies can significantly strengthen sustainability education when implemented through learner-centred pedagogies and supported by enabling institutional environments. These results reinforce the assumptions of Constructivist Learning Theory and provide empirical support for the proposed Digital Education for Sustainable Development Adoption Model (DEAM). The findings indicate that digital technologies, including Learning Management Systems, virtual and augmented reality, simulation software, Geographic Information Systems, collaborative platforms, learning analytics, and artificial intelligence, have expanded opportunities for interactive, flexible, and experiential learning. However, their educational value depends less on their availability than on how they are used to support inquiry, collaboration, reflection, and authentic problem-solving. This finding aligns with Constructivist Learning Theory, which views learning as an active process of knowledge construction rather than passive information acquisition. Accordingly, the DEAM conceptualises digital technologies as foundational inputs whose educational value is realised through effective pedagogical integration.

The review further demonstrates that digital technologies contribute to improved learning outcomes by increasing student engagement, critical thinking, problem-solving, collaboration, communication, creativity, and digital literacy. More importantly, these outcomes facilitate the development of sustainability competencies, including systems thinking, strategic thinking, ethical responsibility, and informed decision-making. These competencies are essential for addressing complex sustainability challenges and advancing the objectives of Education for Sustainable Development. The findings therefore support the proposition that digital technologies influence sustainability competencies indirectly through enhanced learning experiences. A key contribution of the study is the identification of learner-centred pedagogy as the primary mechanism linking digital technologies with sustainability learning. Blended learning, experiential learning, project-based learning, inquiry-based learning, collaborative learning, and flipped classroom approaches consistently emerged as effective strategies for integrating technology into ESD. These approaches encourage active participation, collaboration, and reflection, thereby creating conditions for meaningful learning. This finding extends existing digital education research by

demonstrating that educational transformation depends not simply on technological adoption but on the alignment of technology with appropriate pedagogical practices. The review also highlights important contextual challenges, particularly within African higher education. Although universities have accelerated digital transformation following the COVID-19 pandemic, inadequate infrastructure, unreliable internet connectivity, funding constraints, institutional capacity limitations, and disparities in digital literacy continue to impede the effective implementation of digital ESD. At the same time, increasing investments in information and communication technologies and national digitalisation initiatives present significant opportunities for expanding technology-enhanced sustainability education. These findings underscore the need for context-sensitive approaches that address both technological and institutional barriers.

The proposed Digital Education for Sustainable Development Adoption Model (DEAM) provides an integrated framework for understanding these relationships. Unlike technology-centred models, the DEAM demonstrates that digital technologies, learner-centred pedagogies, learning outcomes, sustainability competencies, and contextual factors operate as interconnected components. By incorporating institutional support, digital infrastructure, policy, funding, and digital literacy, the model offers a comprehensive explanation of how digital transformation can enhance sustainability education, particularly within resource-constrained higher education systems. The findings have important practical and policy implications. Higher education institutions should complement investments in digital infrastructure with continuous professional development, curriculum redesign, and institutional policies that promote learner-centred digital pedagogy. Governments should prioritise reliable internet connectivity, equitable access to digital resources, and capacity-building programmes that strengthen the digital competencies of educators and students. Institutional strategies should also integrate sustainability principles into teaching, research, and community engagement while promoting interdisciplinary collaboration and quality assurance mechanisms that recognise sustainability competencies. Furthermore, policies should emphasise equity by addressing disparities in digital access among disadvantaged learners and institutions. Strengthening partnerships among governments, universities, industry, and development organisations can mobilise financial resources, technological expertise, and innovation to support digital ESD initiatives. Within this context, the DEAM provides a practical framework for curriculum development, institutional planning, and policy formulation, particularly in Ghana and other developing countries.

Overall, the study demonstrates that the successful integration of digital technologies into Education for Sustainable Development requires a holistic approach that combines appropriate technologies, learner-centred pedagogies, supportive institutional environments, and inclusive policy frameworks. Such an approach will strengthen the capacity of higher education institutions to develop graduates equipped with the knowledge, skills, and sustainability competencies needed to contribute to the achievement of Sustainable Development Goal 4 (Quality Education), Sustainable Development Goal 13 (Climate Action), and the broader 2030 Agenda for Sustainable Development.

6. 0 Conclusion

This study examined how digital technologies can enhance Education for Sustainable Development (ESD) in higher education through a Systematic Literature Review informed by Constructivist Learning Theory. The findings indicate that digital technologies including Learning Management Systems, simulation software, virtual and augmented reality, Geographic Information Systems, collaborative platforms, and artificial intelligence can significantly improve student engagement, critical thinking, collaboration, problem-solving, digital literacy, and the development of sustainability competencies. The review further demonstrates that the educational value of digital technologies depends on their integration with learner-centred pedagogies, particularly blended, experiential, project-based, inquiry-based, and collaborative learning. Accordingly, technology alone is insufficient to advance sustainability education; meaningful outcomes require effective instructional design, institutional support, and enabling learning environments.

The study also highlights persistent barriers in developing countries, including inadequate digital infrastructure, limited internet connectivity, resource constraints, and digital literacy gaps. Addressing these challenges requires sustained investment in digital infrastructure, capacity building, and supportive institutional and policy frameworks. The study makes three key contributions. First, it extends the application of Constructivist Learning Theory by demonstrating how digital technologies support active knowledge construction and sustainability learning. Second, it emphasises pedagogy as the critical mechanism linking digital technologies to learning outcomes. Third, it proposes the Digital Education for Sustainable Development Adoption Model (DEAM), which integrates digital technologies, learner-centred pedagogies, learning outcomes, sustainability competencies, and contextual factors into a unified framework. Overall, the study concludes that the successful integration of digital

technologies into ESD requires a holistic approach that combines technological resources, learner-centred pedagogy, institutional commitment, and context-sensitive implementation strategies. Such an approach will strengthen higher education's contribution to achieving Sustainable Development Goal 4 (Quality Education) and Sustainable Development Goal 13 (Climate Action).

6.1 Recommendations

Based on the findings, this study recommends that governments and higher education institutions prioritise investments in digital infrastructure, including reliable internet connectivity, digital learning platforms, and information and communication technology resources, to enhance equitable access to technology-enabled learning. Universities should strengthen the digital and pedagogical competencies of academic staff through continuous professional development in technology-enhanced teaching, instructional design, and learner-centred pedagogies. Greater emphasis should be placed on blended, experiential, project-based, collaborative, and inquiry-based learning to maximise the educational value of digital technologies and promote sustainability competencies. Institutional policies should integrate digital transformation and Education for Sustainable Development into curricula, strategic plans, and quality assurance systems. Such integration should be supported by inclusive policies that reduce digital inequalities by improving access to affordable internet services, digital devices, and accessible learning platforms, particularly for disadvantaged learners.

The study further recommends stronger collaboration among governments, higher education institutions, industry, and development partners to mobilise financial resources, technological expertise, and innovative practices that support digital ESD initiatives. Finally, policymakers and university leaders are encouraged to adopt the Digital Education for Sustainable Development Adoption Model (DEAM) as a guiding framework for integrating digital technologies, learner-centred pedagogies, learning outcomes, sustainability competencies, and contextual factors. The model provides a practical and context-sensitive approach for advancing digital transformation and strengthening higher education's contribution to the Sustainable Development Goals.

6.2 Recommendations for Future Research

Future studies should empirically validate the Digital Education for Sustainable Development Adoption Model (DEAM) using quantitative, qualitative, or mixed-method approaches. Comparative studies involving higher education institutions across different African countries would also provide deeper insights into context-specific factors influencing digital ESD adoption. Furthermore, future research could explore the role of emerging technologies such as artificial intelligence, learning analytics, and virtual reality in promoting sustainability competencies among university students.

6.3 Funding Declaration

This research received no specific grant or financial support from any funding agency in the public, commercial, or not-for-profit sectors. The authors conducted the research independently without external funding.

6.4 Clinical Trial Number: ***NOT APPLICABLE***

6.5 Ethics, Consent to Participate, and Consent: ***NOT APPLICABLE***

6.6 Data availability statement in the Manuscript: ***NOT APPLICABLE***

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