A conceptual research framework for sustainable digital learning in higher education

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Abstract

The integration of digital technologies in Higher Education (HE) has dramatically changed the way students learn, however it has also raised critical concerns about the sustainability aspects of digital learning. Although a considerable amount of literature has been published on digital learning and Sustainable Development (SD) in HE, further research is needed to establish a comprehensive research framework which synthesises and organises the knowledge in this area. This paper draws on a critical review of the literature to develop a conceptual research framework on sustainable digital learning in HE from an Information Systems' lens. The proposed framework is the outcome of a thorough integrative review, followed by a thematic analysis of relevant sources which outlines common research themes in the literature and identifies major areas for future research. The proposed framework provides researchers and educators with valuable insights on the use of digital technologies to promote SD in HE and highlights the importance of sustainability awareness. It further defines focus areas and future research directions which can guide their research, thereby assisting in building a coherent body of knowledge in this research area.

Keywords: Digital learning, Higher education, Sustainability, Research framework, Sustainable development goals

Introduction

In recent years, numerous studies were conducted to investigate sustainability, one of the grand challenges that faces humanity today (Purvis et al., 2019). Sustainability issues which include major crises such as climate change, waste production and many others, are complex in nature and have interlinked root causes. Hence, it is very challenging to examine these problems from the lens of one discipline. The interdisciplinary nature of Information Systems (IS) allows it to play a pivotal role in addressing sustainability problems, thus contributing to the efforts made to mitigate its negative impacts on

organisations, corporations, and educational institutions. This is evident in the continuing calls for IS scholars to contribute valuable research including solution-oriented studies that emphasize the role of IS in addressing sustainability issues (Watson et al., 2010). Sources such as Malhotra et al. (2013) argue that the IS discipline has an obligation to make a tangible contribution to the challenges of sustainability. Hence, many IS researchers have turned their attention to the issue of sustainability, creating new subfields and areas of investigation such as "Green IS", "Responsible IS", "Energy Informatics" and others. Recent IS studies along with the emerging COVID-19 research commonly identify the rapid transitions toward "digital learning environments" in Higher Education (HE) as an excellent opportunity to achieve sustainability goals. However, studies such as Bulturbayevich (2021) argue that the transformation of Higher Education Institutions (HEIs) into digital learning and the increased adoption of digital technologies in Teaching and Learning (T&L) approaches may raise various challenges which is much broader than most institutions realise.

As HEIs are becoming fundamentally dependent on integrating digital technologies to achieve their organisational objectives, there is a growing need to develop comprehensive frameworks to support an effective adoption of contemporary technologies in HE environments. IS researches such as Peppard and Ward (2004) have for long emphasized the importance of developing IS-based strategies and frameworks which balance the demands for organisational change with the supply of Information Technology (IT) enablers. In the context of sustainability in HE, IS-based frameworks have a determinantal impact on achieving sustainability goals within digital learning environments. The spur in HEIs' initiatives and approaches to integrate Sustainable Development (SD) into their learning environments will necessitate an understanding of the antecedence and factors that impacts the planning, design, and evaluation of sustainable digital learning environments. These issues at the intersection of organisations, information, people, and the natural environment are best addressed by an IS-based framework which remains to be addressed in this study area. Such framework would capture the SD policies, organisational needs of HEIs, educators and students' roles and technology specifications, all whilst taking into account the requirements and challenges of SD in HE.

Research objectives

The primary objective of this study is to propose a novel conceptual research framework for sustainable digital learning which provides a comprehensive approach to investigating and promoting sustainable digital learning in HE. The study investigates how researchers and educators can realise the full potentials of digital technologies to make a better HE learning environment, all whilst addressing major sustainability issues. In order to achieve the objectives of this research, the following Research Questions (RQs) were developed:

- RQ1 What are the factors triggering as well as hindering the adoption of digital learning in HE?
- RQ2 What are the major challenges and barriers to sustainable digital learning in HE?
- RQ2 Are there any established research frameworks that focus on sustainable digital learning transformations in HE?

To address the above questions, the paper begins with a review of the major theories underpinning the adoption of digital learning in HE. It then investigates common practices of digital learning transformations in HE. Next, an integrative review is conducted to examine relevant studies in this area. The integrative review is followed by a rigorous thematic analysis to develop an IS-based conceptual research framework. The authors consolidate the concepts and themes identified across the study and present them in the proposed framework to structure and codify knowledge in this area.

Literature review

Although integrating digital technologies in educational settings seems a natural endeavour, it has always been coupled with major challenges and concerns. As Jonassen et al. (2008) puts it, "the history of educational technology documents a long and often difficult process of mutual adaptation, hesitation, and integration". In the context of sustainable digital learning, the literature reveals a significant divide in views among researchers. Nonetheless, the recent COVID-19 global pandemic forced and accelerated the digital learning transformation in HEIs. The rapid transition to full online learning models in HEIs offers a valuable opportunity to examine the impacts of digital learning on SD in HE. Hence, this paper is focused on the sustainable use of digital technologies in HE's learning environments, taking into account recent HE's digital learning transformation practices in response to the COVID-19 pandemic.

Theoretical background for HE's digital learning

The literature suggests that implementing digital technologies as T&L tools in HE classrooms is driven by the shift toward adopting learner-centred environments within universities (Liburd & Christensen, 2013). As explained by researchers such as Freeman et al. (2014), this approach comes under the umbrella of active learning, in which the student interacts and participates in the learning process as opposed to passive learning where it is mostly a one-way learner's effort. According to researchers such as Laurillard (2009), while digital technologies can inspire an abundance of new and innovative approaches to teaching and learning, they are not typically designed with T&L in mind. Nonetheless, digital learning technologies are the fundaments of online learning and blended learning approaches in HE. Hence, researchers such as Yamagata-Lynch (2014)

investigated the use of digital learning technologies in the context of synchronous and asynchronous online learning, others such as Lai (2011) outlined their use within formal and informal learning contexts. Previous studies applied active learning theories as well as technology adoption theories as the theoretical basis of digital learning in HE. Investigation of current research revealed the following three prominent theories which were applied to examine digital learning in HE: Connectivism, Technology Acceptance Model (TAM) and Constructivism.

Connectivism: As Siemens (2005) puts it, "connectivism is a model of learning that acknowledges the shifts in learning and provides better understanding of needs and skills required for learners to excel in the digital era". This theory integrates principles explored by other theories, namely chaos, network and complexity and self-organisation theories, and focuses on the impact of technology on knowledge and learning and how they are managed (created, accessed, stored and retrieved) (Siemens, 2004).

TAM: Is applied primarily to investigate users' acceptance of ISs (Lee et al., 2003). It is based on two major variables that are assumed to determine a user's acceptance of Information Systems: Perceived Usefulness (PU) and Perceived Ease of Use (PEOU). The literature includes various studies such as Dasgupta et al. (2002) that attempts to extend TAM so it can be applied to investigate changes in learning environments within universities such as e-learning, e-collaboration, and others.

Constructivism: Constructivist-based approaches such as problem-based, inquiry-based and cooperative learning are very common in current digital learning literature. Constructivism suggests that learners construct their own understandings, thus, developing knowledge by themselves as explained by Bereiter (1994) and Hein (1991). Hence, learners construct or reconstruct knowledge based on their already existing knowledge base, thus, reconciling new information with their previous ideas and experiences to form new or enhanced understanding (Bransford et al., 2000).

Digital learning practices in HE

Digital technologies' use by HEIs can be traced back to the 1980s when universities embarked on integrating administrative systems such as student management systems, exam systems and others within their administrative environments (Bygstad et al., 2022). Hence, HEIs have spent long years establishing digital technologies for T&L purposes. The use of digital technologies in HE classrooms or "the digital learning space" is a very complex phenomenon, which needs further empirical and theoretical studies to primarily examine its impact on the students' learning process. Despite the proliferation of digital learning technologies over the years, the literature has yet to establish a solid theoretical framework for classifying HE digital learning tools. Nonetheless, the following attempt was made to compile a list of commonly utilized digital technologies in HE.

- Digital collaboration tools: Including web-based tools and services which allow online collaboration and interactions between users in real-time. These include video conferencing tools and social media platforms which are primarily used to facilitate collaboration among students HE classrooms (Hamadi et al., 2021).

- Mobile digital tools: Including mobile-based services and tools which are designed primarily to run on mobile devices such as cell phones, tablets, and the like.

- Digital game-based tools: This is characterised as the use of digital game design elements to achieve learning outcomes within HE classrooms, primarily to promote student involvement and engagement.

- Industry 4.0 tools: This includes the integration of Industry 4.0 technologies in HE learning context by utilizing Big Data (BD), Internet of Things (IoT), Cloud Computing (CC), Artificial Intelligence (AI) and Augmented Reality (AR) aspects in T&L approaches.

- Digital course management tools: This is mainly made of Learning Management Systems (LMSs), and the provision of digital materials, such as PowerPoints, video presentations, to manage, deliver and communicate the learning content, outcomes, assignments, and exams in HE context. In addition, it includes tools that facilitate Massive Online Open Classrooms (MOOCs).

HE and sustainability

Sustainability, as a concept, has been excessively investigated in the literature. It is often used interchangeably with the Triple Bottom Line (TBL) - a sustainability-related construct that was coined by Elkington in 1994, which can be broken into the 3P formulation "people, planet and profits" (Elkington, 2013). Sustainability is broadly understood as "meeting the resource and services needs of current and future generations without compromising the health of the ecosystems that provide them" (Morelli, 2011). The three aspects of the TBL are strongly linked and often overlap especially when sustainability is investigated in the context of SD (Daly, 2017). SD can be understood as a development that is socially, economically, and environmentally sustainable, or as Daly (2017) puts it "a development without throughput growth beyond environmental carrying capacity and which is socially sustainable". Recent research such as Khan et al. (2021) suggested that in order to reap the advantages of TBL, Circular Economy and Sustainable Business Models, SD should be considered as a comprehensive, policy-led strategy that prioritizes the utilization of Industry 4.0 to attain sustainable value through efficient resource utilization and the simultaneous optimization of both business and societal value.

The literature on HE and sustainability has always suggested that universities play a pivotal role in advancing sustainability through cross-sector collaborations (Trencher et al., 2014). Many studies in this area fall into three major tracks: education for sustainability,

sustainable digital transformation, and sustainable digital learning practices. Education for sustainability can be seen in researches that aim to address the integration of sustainability components into the curriculum of discipline-specific courses (Figueiró & Raufflet, 2015). Sustainable digital transformation research focuses on the digital practices and solutions adopted by HEIs to achieve sustainability goals such as United Nations (UN)'s Sustainable Development Goals (SDGs) (Moghaddam et al., 2019). Lastly, sustainable digital learning research aim to investigate the integration of sustainable solutions and designs, including digital technologies in HE classroom environments. The later can also be seen in studies such as Greenland et al. (2022) which emphasize the role of HE stakeholders' attributes such as students' varying knowledge and perceptions of sustainability in achieving sustainable management education designs. Nonetheless, sustainability in the context of HE's T&L practices can be broadly defined as the properties of digital learning practice "that evidently addresses current educational needs and accommodates continuous adaptation to change, without outrunning its resource base or receding in effectiveness" (Stepanyan et al., 2010).

Critiques of digital learning

Recent studies such as Daniela et al. (2018) found that technology enhanced learning improves students' comprehension, active participation and academic performance. Among other aspects, increased flexibility, providing greater access to information, enhancing student-student and student-lecturer interactions, supporting student's life satisfaction were outlined as common advantages to digital learning in HE (Arnold et al., 2021). Although studies such as Grand-Clement (2017) supported the use of digital technologies in learning, they posited that the future should not be driven by technology. Despite the overwhelming literature that supports the use of digital technologies as T&L tools in HE, researchers such as Arnold et al. (2021) raised critical concerns regarding digital learning. Table 1 shows a sample of studies which outlined major challenges and concerns for digital learning in HE.

Challenges of digitalisation on sustainability

Studies such as Secundo et al. (2022) suggest that the increased use of digital technologies can play a vital role in achieving SD goals. Moreover, changing mobility patterns which was noted during the COVID 19 pandemic had positive environmental effects at global and local levels (Dellink et al., 2021). Arnold et al. (2021) found that many respondents were happy about not having to commute as it provided relief from traffic as well as "social relief in terms of saving time and gaining independence". Sayaf et al. (2021) found that integrating Information and Communications Technology (ICT) into instructional strategies could improve students' satisfaction and intention to continue using ICT for

Table 1 Major challenges of digital learning in HE

Challenge/concern	Sources
Technical barriers	Ahel & Lingenau (2020); Aristovnik et al. (2020); Dick et al. (2020)
Digital competence of students and instructors	Longhurst et al. (2020)
Personal distractions	Arnold et al. (2021); Zickerick et al. (2021)
Workload concerns	Aristovnik et al. (2020); Márquez-Ramos (2021)
Negatively affecting students' overall performance	Bygstad et al. (2022); Junco & Cotten (2012)

digital learning as sustainability. Telukdarie and Munsamy (2019)'s findings suggest that "the cost of a virtual classroom is lower than that of a traditional classroom as the energy demand and personnel hours are lower". However, digitalisation is not always viewed as an enabler of SD. The debate around the contributions of digitalisation to sustainability is notable in the current literature. Previous studies suggested that there is a need to properly clarify the relationship between digitalisation and sustainability Sacco et al. (2021). Other researchers such as Van der Velden (2018) suggested that the unsustainability of digital technologies may also undermine claims made about its positive role for SD. Table 2 (below) presents a sample of research findings which raised concerns regarding digitalisation's impacts on sustainability.

Table 2 Major challenges of digital learning on sustainability

Sources	Findings
Arnold et al. (2021)	"Energy and material rebound effects" are to be expected when increased digital consumption occurs especially during a pandemic.
Aksin-Sivrikaya & Bhattacharya (2017)	The manufacturing and use of electronic devices has consequences both on the society and the environment, including e-waste and human rights.
Alharthi et al. (2018)	Social sustainability is significantly affected by the cultural and gender diversity of users; thus, it should not be ignored during requirements engineering activities for eLearning systems.
Gensch et al. (2017)	The issue of increased electricity consumption of data centres and telecommunication networks which is associated with higher greenhouse gas (GHG) emissions.
Hilty & Bieser (2017)	"A major risk for the development of ICT sector's own footprint is that this positive trend is compensated or even overcompensated for by an increasing number of devices per capita and decreasing service lifetimes of the devices".
Nielsen et al. (2015)	"Digitalisation of education has significantly changed the relationship between the teacher and the student", thus, teaching methods should be more interactive and attractive.
Wildemeersch & Jütte (2017)	Digitalisation defines a new place and qualifications of teachers in the education system, thus influencing the human factor in education.
Ahel & Lingenau (2020)	The challenge is to provide an efficient digital learning solution that addresses future learners with diverse heterogenic group, and different aspirations and user behaviours.

Sustainable digital learning in HE

Methods

The paper adopts an integrative review which allows the analysis of findings from a heterogeneous research sample which includes various research methodologies. It involves the evaluation and synthesis of a selected research sample and data on a specific topic or research question. As Whittemore and Knafl (2005) puts it, "rigorously developed integrative reviews allow for various perspectives on a phenomenon to be synthesized into a systematic knowledge base". This method was found to best suit the objectives of this research, as we intend to examine diverse research approaches to promote sustainable use of digital technologies in HE classrooms. This paper adopts Whittemore and Knafl (2005)'s five methodological stages, including problem identification, literature search, data evaluation, analysis, and presentation.

Search strategy

A search of published primary articles was conducted on June 26, 2022, and updated July 18, 2022. Through a university online library, six databases were accessed and searched as follows: ACM Digital Library, Web of Science, IEEE Xplore, Scopus, ProQuest Central and ScienceDirect. Only studies written in English and published between 2010 and 2022 were included. Sources such as commentaries, letters to editors, dissertations, monographs were excluded from the initial search. The authors used various combinations of Boolean phrases/keywords to search the databases, illustrated as follows:

- [[Abstract: "higher education"] OR [Abstract: "university" "universities"]] AND [Abstract: "sustainability"] AND [Abstract: digital]
- (TITLE ("higher education") AND TITLE (sustainability) AND TITLE (learning))
- ti ("higher education") AND ti (sustainability) AND ti (learning)
- ("Document Title": "higher education") AND ("Document Title": sustainability) AND ("Abstract": universities)

The initial search resulted in over 185 articles excluding secondary research to be screened for inclusion in the integrative review as shown in Figure 1. It was evident that majority of the relevant research were conducted after 2015 and shows that this area of research is in its infancy with more research are yet to surface.

Selection criteria

The initial search produced a sample of articles including a large number of duplicates and studies with irrelevant research outcomes which were all excluded. The studies were

included for review if they met the predefined inclusion criteria shown in Table 3. In total, 15 articles that were identified for inclusion in this review after screening the full text as shown in Figure 1.

Table 3 The research's predefined inclusion criteria

Question	Check
1. Was the focus of the study on digital technologies' use in HE?	
2. Did the study directly address digital technologies' use as L&T tools?	
3. Did the study address sustainability issues within HE L&T environments?	
4. Were the sources used in the build-up for the study considered credible, recent, and relevant for the purpose of addressing current concerns in sustainable digitalisation and HE?	
5. Were the study's methods considered credible and valid for the purpose if addressing the research questions?	
6. Was the data gathering methods used in the study (if applicable) considered appropriate, reliable, and accurate?	
7. Did the findings address the research questions directly?	
8. Has the study produced/supported unique results in this area of research?	

Fig. 1 Process flow used in identifying relevant academic sources
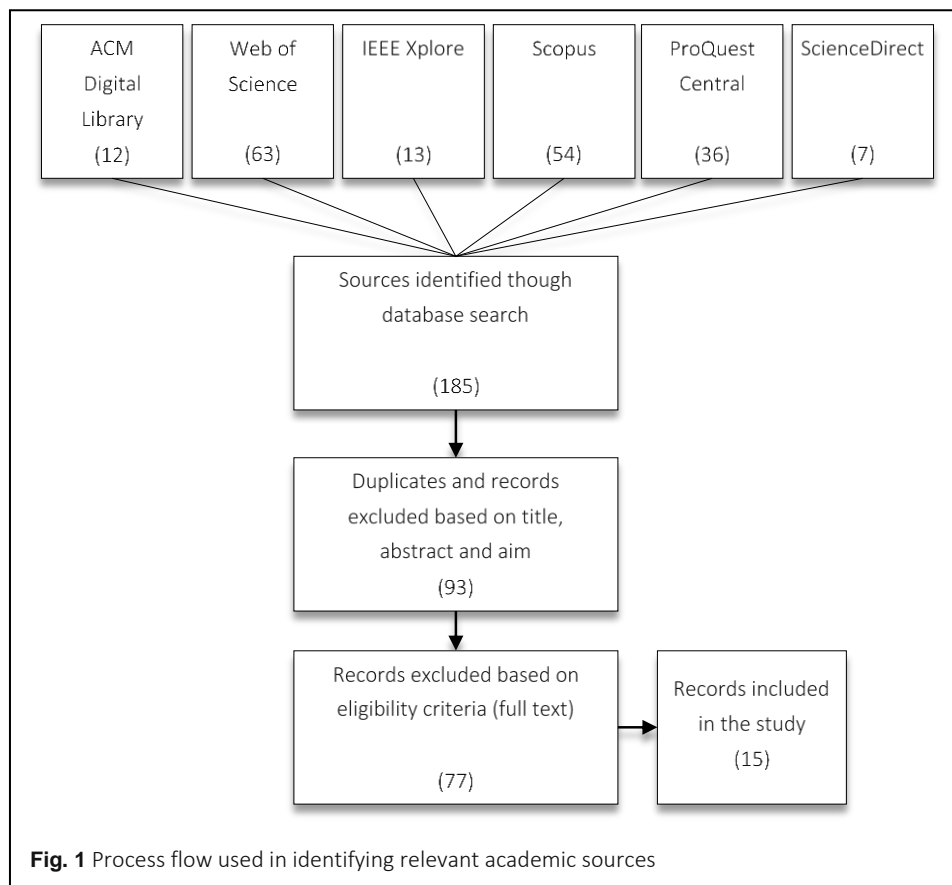
The analysis of sources identified in the integrative review

A thematic content analysis was conducted on the integrative review's results (Table 4) to identify common patterns and themes in the research sample. Prior to this, the research team developed a codebook based on reviewing the selected studies to create codes and definitions. The codes were applied to the data collected primarily from the findings and discussion sections of the research sample. The coding process was ongoing throughout the analysis phase to ensure that the categories are accurate and capture the important patterns in the data. After each coding iteration, the authors discussed all discrepancies in the coding and reached consensus on the final codes which were: public policies and regulations, HEIs' organisational aspects, digital technologies, HE programmes and curriculums, sustainability awareness, and challenges and barries to SD (Table 5).

The proposed research framework

The majority of the reviewed studies were developed based on self-reported methods such as surveys and lack real analysis of outcomes. Hence, rigorous analytical research is needed to examine the relationships, determinants and factors that influences sustainable digital learning's initiatives in HE classrooms.

   The thematic analysis of the research's sample identified common research aims, HE factors and sustainability dimensions in this area. We suggest that these various aspects can be consolidated in the proposed conceptual framework (Figure 2) to provide a holistic view of the components necessary for a sustainable digital learning environment in HE. The framework enables a comprehensive examination of the relationships between the identified levels and factors, thereby promoting an adequate understanding of sustainable digital learning in HE. The framework includes three levels as follows, Macro-level: Public Policy Impact, Mezzo-level: HE Administration Level, Micro-level: HE Classroom Environment.

   Macro factors include policies at the national and international levels, UN's SDGs and the impact of international sustainability committees and agreements. The factors at the mezzo level include HEIs' policies and strategies, programme management and available services and resources. Lastly, at the micro level, the following major factors were identified: administrative use, course management and deliver, and formal pedagogical use. The relationship between the macro, mezzo and micro factors and sustainability dimensions is depicted in a double-headed arrow which signifies that the adoption of digital learning technologies is congruent with the requirements of SD in HE. Nonetheless, major challenges of digitalisation on sustainability and the common identified barriers to digital

Table 4 A summary of the integrative review results

Author/Year	Primary aim of the study	Major outcomes	Major findings
Caniglia et al. (2018)	SD in HE	A "glocal" model for transnational collaboration in HE for SD.	Thinking glocally in HE for SD can help take full advantage of the underutilized opportunities of transnational collaboration.
García-Peñalvo (2021)	Digital transformation in HE	A theoretical framework of IT processes related to learning technology which uses ethical, service, technological infrastructure, and pedagogical model pillars.	"The digital transformation of teaching should imply the right technological decisions made by people and for people, in order to achieve a more inclusive, participative, and human university supported by technology."
Aleixo et al. (2016)	SD in HE	A review of institutional websites for Public HEIs.	Majority of reviewed HEIs communicate their SD practices actively. SD practices vary considerably among HEIs. SD in Portuguese HEIs is still in its early stages.
Figueiró & Raufflet (2015)	Sustainability in HE	A systematic analysis of 63 articles published in international HE and management education journals.	Very few studies integrate the three levels of educational philosophy – teaching, program design, and learning and highlight the need for curriculum change.
Barkalov et al. (2021)	Digital education for SD	A review of open sources, public analytical and reporting materials, and a SWOT analysis of the formation of digital education.	There is a need to update the structure and content of existing educational programmes, systematic work to create new educational programmes, the qualifications of graduates to meet the growing needs of the labour market.
Petronzi & Petronzi (2020)	Sustainable blended approach in HE	Proposed an Online and Campus (OaC) model that incorporates campus, synchronous and asynchronous learning experiences.	Providers must consider how to motivate and support students in engaging with digital and asynchronous materials. This requires structure and guidance to support academics in designing a blended module, which aligns the course objectives with the content to ensure a more meaningful and clearly defined learning experience.
García-Morales et al. (2021)	Digital transformation in HE	A synthesis of insights that can be applied to the digitalisation of education.	To move toward a sustainable model for online learning, universities should use technology to re-invent teaching processes, transform assessment activities, change the use and roles of traditional Faculties and Schools (providing specific training), and focus on value through the reinvention and self-renewal of the service model.
Alharthi et al. (2019)	Sustainable eLearning systems	A systematic review of the sustainability meta-requirements for eLearning systems.	Identified 18 high-level sustainability requirements for eLearning systems including Personalisation, Learner-Centred Features, Collaboration, Leadership Development, Privacy and Security, Analysis of the Learning Progress, and others.

Colás-Bravo et al. (2021)	Sustainability in HE	A systematic review that intended to identify how sustainability is applied in HE.	Sustainability development areas were identified, linked to teaching digital competence, such as inclusion, educational quality, or lifelong learning.
Crawford & Cifuentes-Faura (2022)	Sustainability in HE	A systematic review on sustainability during the COVID-19 pandemic.	There is a need to rebuild efforts to focus on the SD Goals, particularly considering the evolving HE landscape during COVID-19.
Alonso-García et al. (2019)	Sustainability in HE	A systematic review on teaching practices with ICTs.	Among the results, the emerging trend of good practices with ICT, the use of a Virtual Learning Environment (VLE) as the main technology in good practices, and the majority of good practices in the development of SDG #4 (Quality Education) are highlighted.
Abad-Segura et al. (2020)	Sustainable management in HE	A bibliometric study of 1,590 articles during the 1986–2019 period.	The USA is the country with the most academic publications and international collaborations in its studies. Global research has followed a growing trend, with optimal publication levels in recent years.
Brinia & Davim (2020)	Designing pedagogy for SD in HE	A review on innovative pedagogy for SD in HE.	SD has never taught in an experimental, artful, and design-based way in HE for teaching students how to design their future and the future of our planet in order to be sustainable.
Leal Filho et al. (2018)	SD in HE	A review on the challenges for planning the SD in HE.	Universities' SD efforts are hindered by lack of institutional support and planning and limited emphasis on approaches, such as problem-based learning.
Janakiraman et al. (2018)	Game-based learning for sustainability	A review on digital games' use as Environmental Sustainability Education tools.	Sustainability education should be project-based and experience-based to encourage 'learning by doing' and promote behaviour change.

Table 5 Qualitative codebook

Themes	Definition	Subthemes
1. Public policies and regulations	Includes codes for the different governance initiatives which impact sustainability in HE	1. UN's sustainability goals and committees including SDGs 2. Sustainability goals, policies, and regulations at the national level 3. International sustainability committees and collaborations
2. HEIs' organisational aspects	Includes codes for various organisational aspects of HEIs that impact sustainability initiatives	1. HEI's sustainability strategies and internal policies 2. Investments in sustainable resources and technologies including funding sustainability-related projects 3. Investments in sustainability programmes and training for staff 4. Collaborations between HEIs on sustainability issues
3. Digital technologies	Includes codes for issues related to digital technologies within HE classroom environments	1. Online learning strategies and models including course designs 2. Digital competence of staff and students 3. Challenges of digitalisation on classroom learning
4. HE programmes and curriculums	Includes codes for topics related to "education for sustainability" in HE	1. Incorporating SD as part of existing courses 2. Teaching sustainability courses in HE 3. Re-designing and re-structuring teaching activities to align with SDGs
5. Sustainability awareness	Includes codes for topics related to sustainability awareness among staff and students in HE	1. Engagement with sustainability related programmes and training 2. Access to support services and resources relating to sustainability awareness
6. Challenges and barries to SD	Includes codes for topics related to challenges to SD in HE	1. Addressing sustainability requirements for digital learning technologies 2. Concerns/negative impacts of digital learning on sustainability dimensions including social, economical, environmental, technical, and human

Fig. 2 A conceptual research framework for sustainable digital learning in HE
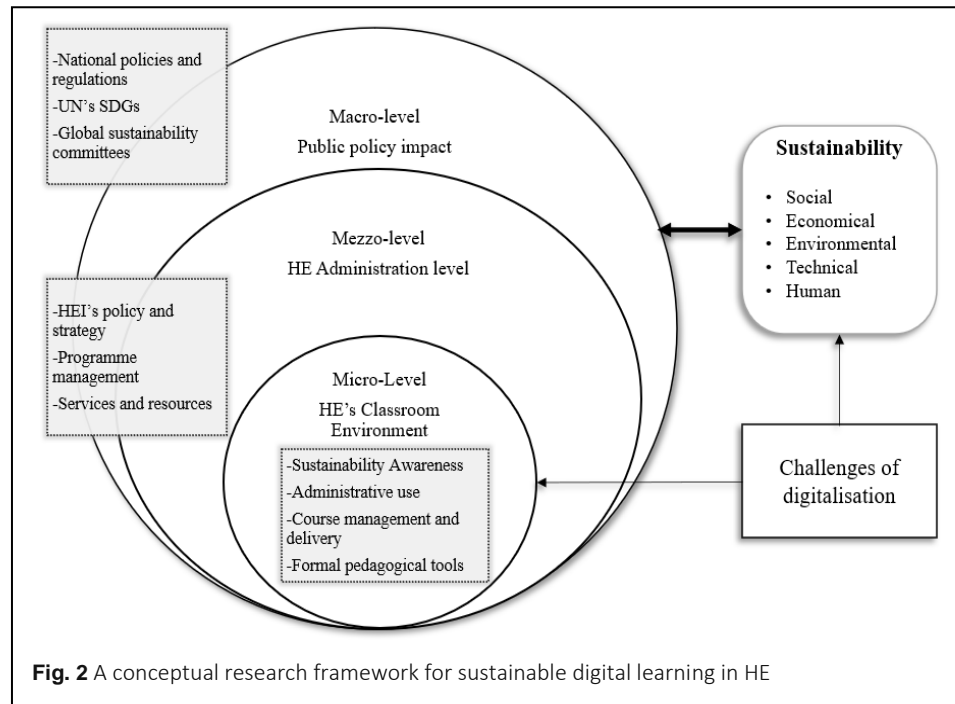
learning should be examined and analysed for their impact on digital learning adoption and SD initiatives in HE. The framework examines the interactions between the identified three levels from a top-down approach.

In what follows, a detailed description of the framework is provided which explains the levels, factors, dimensions, and relationships identified in the thematic analysis of Table 4's results.

Macro perspectives of sustainable digital learning

The HE sector is one of the most dynamic sectors that is influenced by public policies at the national and global levels. The macro level in the proposed framework includes fundamental factors and issues of public policy initiatives which impact digitalisation in HE. In 2015, the UN General Assembly adopted 17 SDGs as part of a new Agenda for SD (Assembly, 2015). Since then, the UN SDGs became a universal framework for positive action by participating governments to solve grand humanitarian challenges and achieving SD by 2030. The SDGs emphasize the role of quality education in achieving SD and recognises the importance of implementing effective strategies that addresses societal challenges all while tackling sustainability issues. There is a considerable body of literature on "SDGs in HE", which is fostered by several high-ranking international journals with a focus on sustainability in HE context.

The literature includes studies such as Adams et al. (2018) which outline public (international and national) policies as a major driver of HE's adoption of sustainability

strategies. Researchers such as Ketlhoilwe et al. (2020) identified HEIs as one of the prominent actors with a critical role to achieving the objectives of SDGs. Nonetheless, HEIs are at the forefront of pursuing the SDGs and aligning themselves to the principles of sustainability, especially by adopting sustainability policies (Adams et al., 2018). The role of HEIs as "agents of change" and major actors in achieving SDGs is evident in the growth of HE conferences, associations, networks and committees that aims to embed the UN's SDGs in their institutional agendas (Leal Filho et al., 2019). Thus, policy contributions at the international, regional and national level are viewed to have a profound impact on the implementation of sustainability initiatives in the HE sector (Ryan et al., 2010). Furthermore, the proliferation of international conferences and communities along with UN led programs that aims at promoting Education for Sustainable Development (ESD) have been instrumental in promoting sustainability initiatives in the HE sector. There is a growing body of research that emphasize the use of digital technologies in HE to tackle sustainability issues and ultimately achieve SDGs (Lange, 2019). Hence, policies and regulations at this level should present a road map for HEIs to guide the implementation of effective SD initiatives including the adoption of sustainable digital technologies in classroom environments. The policies and regulations at this level should also be reflected in the strategies and policies at the mezzo level.

Examining the interactions between the levels of the framework allows a better understanding of digital technologies use to achieve SDGs. Despite the considerable research that exists in this area, the literature fells short to examine and evaluate the interaction between factors identified in the framework's three levels. Hence, there is a need for future empirical studies to investigate the interactions between the various factors outlined in the framework. In addition, future research should aim to assess and evaluate the effectiveness of policies and regulations at this level in promoting practical sustainability initiatives within HEIs. Nevertheless, we add the following question: What government policies and industry standards will impel HEIs toward greater sustainability responsibility?

Mezzo-level HE administration level

The middle level in the framework identifies several factors at the HE administration level which drives the adoption of digital technologies in classroom environments. As found in the reviewed studies, HE administration factors namely strategies and policies, programme management and available services and resources have a profound impact on the adoption of digital technologies as T&L tools (Aleixo et al., 2016; Figueiró & Raufflet, 2015; García-Morales et al., 2021; García-Peñalvo, 2021). Scholars such as Aleixo et al. (2016) found that although SD practices can vary considerably among HEIs, the majority of HEIs tend to actively incorporate and communicate their SD initiatives as part of their strategies.

Studies such as Leal Filho et al. (2018) suggest that the increase in digital technologies' use in HE classrooms as a major part of SD initiatives in the HE sector. Some of the common initiatives implemented by HEIs can be classified into eight "sustainability categories", namely built environment, energy, food, and gardens, greenhouse gas emissions, natural environment, resource and waste management, transport, and water (Sen et al., 2021). In addition, there is a growing body of literature on the topic of "education for sustainability." Research in this area such as Crawford and Cifuentes-Faura (2022) suggest that there is a need for HE institutions to update their programmes and curriculums to incorporate SD as part of their courses. Although, the literature does not provide a common definition for "education for sustainability", it can be broadly understood as the incorporation of learning contents and courses within HE's programmes with a focus on addressing sustainability concepts and dimensions.

Despite the plethora of studies in this area, the literature lacks an established framework which guides the implementation of sustainability practices within HE's programmes. Hence, studies on "education for sustainability" are limited to isolated practices and initiatives which can only work under predefined contexts. Nonetheless, several studies form the research sample outlined the importance of HEIs' resources and support services in facilitating the adoption of digital technologies in classroom environments (Petronzi & Petronzi, 2020). HEIs' resources and services are not limited to the acquisition and sourcing of technological solutions, it also includes providing support services in the form of instructional designer teams or "educational specialists" who can aid with the analysis, design, development, implementation, and evaluation of effective digital learning solutions.

Future research should further investigate the interactions between the different factors at the macro and mezzo levels. This is anticipated to contribute valuable knowledge in this research area and provide HEIs with valuable insights which can be used to refine their sustainability strategies and policies. The importance of the mezzo level as an intermediate level between policies at the national and global level (macro) and HE classroom T&L practices (micro) allows it to act as a mediator and disseminator of sustainability awareness in HE contexts. The strategies and policies at the mezzo level should support a comprehensive sustainability agenda where T&L practices (at the micro level) should be aligned to. Future studies are needed to examine and evaluate the effectiveness and competences of HE sustainability agendas and its impact on sustainable digital learning.

Micro-level HE classroom environment

In order to achieve SD in HE, educators should aim to align their T&L practices (micro) with their HEIs' sustainability agendas and goals (mezzo). This collective effort will ensure a consistency between sustainability strategies and T&L practices in HE. In addition, it will enable a better interpretation and evaluation of HE sustainability strategies and policies'

impacts in practice. Hence, educators need to be well-informed and involved with their HEIs' sustainability agendas. This can be achieved by attending inductions and training sessions which aims to promote educators' competences in sustainability issues. Nonetheless, educators should aim to design and develop T&L activities which promote sustainability awareness among students in HE classrooms. The literature includes studies such as An and Yang (2022) which emphasize the critical role that students' sustainability awareness plays in achieving SD. There is a need for educators to revisit and re-design T&L activities in view of their HEIs' sustainability agendas to educate students about sustainability issues and encourage them to act about it. Hence, more research is needed to investigate the impact of T&L practices in promoting sustainability awareness among HE students. In addition, future theoretical and empirical studies on the design of sustainable T&L activities are needed to establish this concept in HE. Above all, future studies are needed to investigate the different factors and antecedents which influence the integration of sustainable digital technologies in HE classrooms. At the micro-level of the framework, three major implementations of digital technologies in HE classrooms were identified as follows: course management tools, formal T&L tools and for administrative use by faculty and other HEIs' departments.

Course management tools: Most reviewed studies in the literature examined the use of digital technologies as part of course management tools such as LMSs. HEIs have invested enormous resources in providing educators and students with access to LMSs which provide easy-to-use online tools for presenting content, distributing assignments, enabling discussions, and conducting assessments. Studies such as Alharthi et al. (2019) investigated the sustainability aspects and requirements that need to be fulfilled by LMSs in the HE sector. Other studies such as Petronzi and Petronzi (2020) investigated the design and implementation requirements of sustainable LMSs.

Digital technologies as T&L tools: It is important to distinguish between digital technologies as "pedagogical tools" that directly affect T&L and course management tools that are primarily used as vehicles for the delivery and provision of course learning content. Digital technologies as T&L tools are characterised as computer-based or web-based learning tools which are used to provide learners with pedagogical fundamentals, and ultimately enhancing their learning outcomes. The phenomenal expansion of online digital learning in HE in recent years saw an increase in the adoption of digital tools as part of course designs and T&L in courses which are conducted online or in many cases as part of blended learning approaches. Most studies in this area such as Colás-Bravo et al. (2021) examined the use of digital technologies as supplementary pedagogical tools. The implementation of digital technologies as powerful T&L tools has also been investigated as solutions to overcome challenges of the latest global pandemic COVID-19.

Administrative use: Refers to the process of using digital technologies to automate and streamline administrative tasks within HEIs. This includes activities such as student enrolment, course registration, and record-keeping. It also includes digital systems which are used to provide real-time data and analytics, allowing HEIs' administrators to make informed decisions and improve their strategies. Digitalisation in HE also raises concerns about data privacy and security, digital exclusion, and the potential loss of human connection and interaction (García-Peñalvo, 2021). Therefore, further empirical studies are needed to understand how HEIs can balance the benefits and risks of digitalisation and ensure that they align with their broader mission and values.

Sustainability dimensions

The framework outlines five dimensions of sustainability in the context of HE's classroom environments. The dimensions were identified based on the thematic analysis of the research sample and include social, economic, environmental, human, and technical. The social dimension of sustainability was emphasized by most of the reviewed studies. As García-Peñalvo (2021) puts it "digital transformation is a social requirement of governments, companies, and institutions", and it should take into account the associated risks of digitalisation, especially the unethical use of technology, which "leads to the dark side of transformation processes". The social dimension is one of the major pillars of sustainability, and researchers should examine the societal factors and variables that impact sustainability in HE contexts. In particular, the social impacts of digital learning on HEIs and its major stakeholders including students, educators, and the community. Researchers such as Colás-Bravo et al. (2021) suggest that SD in HE should also be linked to teaching digital competence, such as inclusion, educational quality or lifelong learning. Other researchers such as Alonso-García et al. (2019) emphasize the issue of "good practices" with digital technologies including involvement, motivation, and skills development to achieve SDGs, namely SDG#4. Hence, there is a need to examine these identified social aspects of digital learning along with others from the literature to provide valuable knowledge this area.

The economic dimension includes studying the impacts of the rapid digital transformation on HEIs financial capacities, including return on investment analysis of implementing emerging technologies in classroom environments. Researchers such as Figueiró and Raufflet (2015) suggest that there is a need for curriculum updates and changes to equip graduates with the changing needs of the labour markets. Future research should be conducted to investigate the economic impacts that may result from changes to HE's programmes and curriculum. Examining the interactions and relationships between changing HE's programmes, digital learning, graduate numbers, and the growing needs of the labour market should provide valuable insights to support SD planning in HE.

The environmental sustainability dimension is a critical element in HE contexts. Sustainable digital technologies in HE classrooms should aim to address environmental sustainability challenges. Recent studies such as Janakiraman et al. (2018) suggest that digital technologies in the form of game-based learning play an integral role in changing learners' attitudes toward environmental sustainability. There are great potentials of digital technologies' adoption to promote environmental sustainability awareness among tertial-level learners. Accordingly, designing and implementing effective digital learning spaces in HE needs further investigation by future research in this area.

For the human dimension of sustainability, there is a need to investigate the collaborations and interactions between HEIs at the national and international level. Caniglia et al. (2018) among other studies emphasize the importance of HEIs collaborations and networking at the national and transnational level to achieve SD. In addition, future research should examine the important role of the "human factor" in influencing current and future SD initiatives. This can be achieved by examining HE's programmes and practices' competences in educating students about sustainability issues and encourage them to act about it. Brinia and Davim (2020) suggest that HEIs should value students' responsibility and creativity, thus teaching SD in an experimental, artful, and design-based approaches for students to be able to design their future and the future of our planet in a sustainable way.

The technical dimension can be primarily addressed through the planning, design, and development process of digital learning solutions in HE. In addition, it can be examined in the use of technology to re-invent teaching processes including assessment activities in HE classrooms (García-Morales et al., 2021). There is a need for more empirical studies to investigate and propose sustainability requirements for digital learning technologies which builds on the available green software engineering research and extend its findings to address the specific needs of HE's T&L such as students' engagement and collaboration. The reviewed research sample includes studies such as Alharthi et al. (2019) which identified several high-level sustainability requirements such as personalisation, learner-centred features, collaboration, leadership development, privacy and security, analysis of the learning progress and others. These requirements among others should be the focus of future research that aims to build sustainable digital learning software in HE. The technical dimension should also take into account issues such as users' motivation and support, learning experience, compatibility with other learning systems, and adaptability in terms of supporting synchronous and asynchronous learning modes (Petronzi & Petronzi, 2020).

Challenges of digitalisation

When examining the implementation of sustainable digital learning technologies, it is critical to address the challenges associated with digitalisation in HE. HEIs will need to

overcome many challenges, such as resistance of some university members and educators, lack of available resources to support sustainable activities, workload concerns, the capabilities of academic staff to support learning transformation processes and other common challenges shown in Table 1. Above all, a major concern is the capability of tertiary educators to plan, design and implement digital technologies in support of students' learning. This challenge needs a special attention due to the fact that students' success directly correlates with the educator's competences (Ronzhina et al., 2021). Educators can be highly experienced and skilled in their disciplines, however, may not necessarily be capable of designing and implementing digital technologies in their classrooms. In this case, digital learning can have an adverse effect on the students' learning process.

At the same time, challenges of digitalisation on sustainability should be evaluated to understand the impact it has on SD initiatives by HEIs. The literature includes various studies which raise concerns over digitalisation's impact on the various sustainability dimensions namely social, economic, and environmental (Bautista-Puig & Sanz-Casado, 2021; Wamsler, 2020). In the context of HE, the human dimension has been acknowledged as a critically element in sustainability integration at HE (Kapitulčinová et al., 2018). Nonetheless, the "technical" dimension is as equally important to the TBLs' dimensions. Hence, to achieve SD objectives in the context of HE, it is imperative to investigate the impacts of digitalisation on the five identified dimensions of sustainability as depicted in the framework. This paper identified common challenges of digitalisation on sustainability in Table 2. Future studies are needed to investigate the impact of digitalisation's challenges on digital learning environments and to propose effective mitigation strategies.

Implications of the findings

The results of this study have several implications for both researchers and practitioners in the area of sustainable digital learning in HE. For researchers, the proposed IS-based framework (Figure 2) presents a valuable guide for future research and adds to the body of knowledge in this area. It identifies antecedents and factors which emerged from the thematic analysis of the research's sample. It identifies major research directions and provide a start point for developing future research agendas in this area as discussed in the section "The proposed research framework". For practitioners, the findings highlight the importance of incorporating sustainability related topics and activities in teaching which can play a significant role in promoting sustainability awareness among students. Educators may want to consider incorporating sustainability-based activities into their lesson plans, such as project-based learning and experiments, to enhance students' awareness of sustainability topics.

Moreover, the results of this study have implications for educational policies and decision-making processes in the HE sector. The findings suggest that HEIs should

prioritize sustainability in the design, implementation, and evaluation of digital learning initiatives and engage all stakeholders, including students, educators, and technology providers to promote sustainable digital learning. This may involve investing more in sustainable educational resources such as materials and equipment, providing funding and resources for sustainability-related activities and projects, and offer professional development opportunities in the form of training workshops for staff and students on sustainability topics.

Limitations

As more empirical and theoretical analysis studies are required to establish a comprehensive research framework in this area, much of what is discussed in this article is speculative, and open to critique, debate and revision. Empirical and theoretical studies are needed to further investigate the links between the identified levels and relationships of the proposed framework. In addition, the examined research sample was all conducted and published in the USA or European countries.

Conclusion

Using an integrative review method, we identified peer-reviewed publications which focused on sustainable digital learning in HE. The proposed research framework provides a synthesis of research aims and findings of the research sample which were depicted in a three-tier architecture including macro, mezzo and micro levels. The framework outlines major factors in each level and defines the relationships that should be critically studied and analysed in this area. We posit that strategies related to HE digital initiatives should aim to make good use of the opportunities offered by digital technologies all whilst considering the challenges associated with digitalisation on sustainability and HE's classroom environments. Major future research directions and questions were discussed throughout the section "The proposed research framework" in this paper.

Abbreviations
AI: Artificial Intelligence; AR: Augmented Reality; BD: Big Data; CC: Cloud Computing; GHG: Greenhouse Gas; HE: Higher Education; HEIs: Higher Education Institutions; IoT: Internet of Things; IS: Information Systems; IT: Information Technology; LMS: Learning Management Systems; MOOCs: Massive Online Open Classrooms; PEOU: Perceived Ease of Use; PU: Perceived Usefulness; RQs: Research Questions; SD: Sustainable Development; SDGs: Sustainable Development Goals; T&L: Teaching and Learning; TAM: Technology Acceptance Model; TBL: Triple Bottom Line; UN: United Nations.

Authors' contributions
The first author was the lead in this research. He designed the study, carried out the research methods, performed the analysis, developed the framework, and wrote the manuscript with support of the second author. The second author contributed to the planning and overall research as well as the discussion of the results and proofreading the manuscript.

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Declarations

Competing interests
The authors declare that they have no competing interests.

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