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Integrating Sustainable Media and HCI in Online Learning: Evidence from a Systematic Literature Review

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Abstract

Purpose of the study: This study aims to identify, analyze, and synthesize the relationship between digital learning media design, Human–Computer Interaction (HCI) dimensions, and the sustainability of online learning implementation by developing an integrated conceptual framework based on evidence from existing scientific literature.

Methodology: This study employed a Systematic Literature Review (SLR) following the PRISMA guidelines. Literature was retrieved from the Scopus database covering publications from 2016–2026. A total of 365 records were identified, with 140 eligible studies included after screening. Data were analyzed using OpenRefine, Biblioshiny (RStudio), VOSviewer, and Elicit AI for metadata cleaning, bibliometric analysis, and evidence synthesis.

Main Findings: The findings indicate that integrating sustainable digital learning media with HCI principles improves learning outcomes, learner motivation, engagement, and user experience. Usability, accessibility, and user experience quality strongly influence technology acceptance and continued use. Institutional support, educator competencies, infrastructure readiness, and inclusive access are also identified as essential factors supporting the sustainable implementation of online learning.

Novelty/Originality of this study: This study proposes an integrated conceptual framework linking sustainable digital learning media, Human–Computer Interaction, and the sustainability of online learning implementation. By combining bibliometric analysis and systematic evidence synthesis, it provides a comprehensive perspective that integrates technological, pedagogical, and sustainability dimensions to support effective and long-term educational technology adoption.

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INTRODUCTION

The transformation of digital education has become a global phenomenon driven by technological advancements, the expansion of digital infrastructure, and the need for more flexible and widely connected learning. This change not only presents an alternative channel for delivering materials, but also demands a paradigm shift in learning design, interaction design, and policy governance that is able to support an inclusive and sustainable digital education ecosystem (Candrawaty et al., 2022). In online learning, digital learning media (e.g. multimedia, videos, and

interactive platforms) function as a means of delivering content and facilitating learning activities that affect student engagement and understanding (Waang, 2023; Elmi et al., 2024). Empirical evidence suggests multimedia such as images, videos, animations, and interactive quizzes can improve focus and engagement which contributes to retention and understanding, but its implementation also faces barriers such as resource limitations, digital literacy gaps, connectivity, content quality, and distractions (Panjaitan et al., 2023). Interactive media development studies (e.g. Prezi-based e-learning, H5P interactive video, interactive multimedia, and e-comics) also reported improved responses and/or learning outcomes in the context studied, thus reinforcing the role of media as a key component of the digital learning experience (Farach et al., 2022; Kartimi et al., 2023).

Sustainable Media in Education emphasizes that learning media not only needs to be effective in improving learning outcomes, but also sustainable in terms of use, maintenance, long-term access, and environmental and pedagogical impact. Key principles include usage sustainability, maintainability, long-term accessibility, and pedagogical sustainability that ensure media remains relevant over time (Fadlan et al., 2022; Rizqiyana et al., 2022; Bonok et al., 2024), as well as support for the continuity of learning after the initial launch (K. Wijayanto et al., 2021; Nucifera et al., 2022; Cahyono, 2024) Media design should also pay attention to the relationship with HCI, especially usability, user experience, and accessibility because good usability increases long-term use intent while poor design can hinder sustainable adoption (Sutoyo & Rahayu, 2022; Mardiah, 2024; Fatmawati, 2021). The integration between sustainable media and HCI is seen as crucial to ensure that media is not only effective in content but also durable in learning practices, with quality evaluations such as WebQual 4.0 and a focus on service interactions that affect the sustainability of media utilization. Shirley (Sari & Tyaningsih, 2024; Kurniawati & Hadi, 2024). Practical implementation demands cross-dimensional evaluation indicators (HCI: SUS, UX, accessibility; sustainability: content maintenance, monitoring, operational costs) as well as educator training and infrastructure improvements for sustainable media in the digital learning ecosystem (Nucifera et al., 2022; Silvester et al., 2023). In summary, sustainable media is a framework that combines the effectiveness of learning with its continuity of use and pedagogical relevance, supported by user-friendly interaction design to ensure the continued adoption in the future of digital education (Fadlan et al., 2022; B. Wijayanto et al., 2022; Sutoyo & Rahayu, 2022; Cahyono, 2024).

Sustainability in the use of digital learning media is an important concern, especially in the post-pandemic era. This sustainability is generally understood in operational and pedagogical contexts, namely the ability of platforms and media to continue to be used through institutional support, human resource readiness, and effective management of learning practices. However, such definitions of sustainability still rarely include environmental aspects such as energy efficiency or carbon footprint (Dimulescu, 2023; Walker & Voce, 2023; Laufer et al., 2021). Evidence suggests that the use of e-learning platforms can continue post-pandemic with increased interface satisfaction and a decrease in technical constraints, but the sustainability of digital learning innovations remains contingent on teacher capacity/competence and ongoing institutional support (Dimulescu, 2023, Walker & Voce, 2023). The literature also confirms that digital education can be a "bridge builder" or "divider" depending on the inequality of access at the individual level of the institution, so sustainability needs to be understood in an inclusive manner (not widening the gap) (Laufer et al., 2021; Williamson, 2021). The role of Human-Computer Interaction (HCI) in online learning today goes beyond just improving interfaces, by encouraging interaction design that optimizes usability, UX, and accessibility for inclusive and sustainable learning; Recent studies show that the application of HCI curriculum frameworks that integrate human–computer design theory with modern teaching practices can accelerate the adoption of digital media in various educational contexts (Qin et al., 2025; ithiely et al., 2025; Facciotti et al., 2025). In addition, the use of XR and metaverse technologies allows for a more immersive learning experience, but demands serious considerations regarding privacy, ethics, and accessibility to avoid a decline in online learning inclusivity (Wang et al., 2025). Empirically, usability evaluations through tools such as SUS on LMS show that improved ease of use and responsive UI/UX design contribute to increased usage intent as well as long-term satisfaction, which is essential for remote learning retention colored by infrastructure constraints (Hakimi et al., 2025; Feng, 2025). The integration of WebQual Quality of Service as a media quality evaluation framework enriches understanding of how content quality,

service interaction, and technology support affect its sustainable adoption and pedagogical impact (Nyaga et al., 2025; Swiderski, 2025). In practical terms, HCI's design suggestions for online learning include a focus on learnability, UI consistency, accessibility, and continuous monitoring of student engagement through human-oriented learning analytics, so that digital media can evolve adaptively as curriculum needs and learning contexts change (González & Ledo, 2025; Corrales et al., 2025; Ribeiro, 2025).

Technologies such as the Technology Acceptance Model (TAM) show that increased use of e-learning platforms correlates with increased perceptions of ease of use and interface satisfaction, as well as reduced technical issues, which confirms the relevance of usability in e-learning success (Ahmad & Abdullah, 2021). Comparative studies of platforms also show significant differences in learning experiences between platforms (e.g. MS Teams vs social network sites), including the issue of instructional support and the quality of assessment and feedback, thus confirming that the quality of the User Experience is not only determined by technical features but also by the design of learning interactions (Sobaih et al., 2021). The need for integration arises because the sustainability of the use of media platforms in the long term is influenced by two sides at once: (i) institutional support and teacher capacity to sustain post-pandemic innovation, and (ii) the quality of usability, user experience that encourages acceptance and adequate learning experience (Walker & Voce, 2023; Dimulescu, 2023). Evidence suggests that while institutions can increase TEL's investment and support for more flexible and inclusive learning designs, the sustainability of innovative practices does not automatically occur without instructional competence and faculty capacity (Walker & Voce, 2023); Meanwhile, increasing usability (ease of use and reduced technical issues) can support the sustainability of using e-learning platforms (Dimulescu, 2023). Thus, the integration of sustainable media (operational-pedagogical and inclusive) with HCI (usability, User Experience, accessibility) becomes relevant to improve the quality of learning experience while maintaining the sustainability of implementation (Walker & Voce, 2023; Laufer et al., 2021); Dimulescu, 2023).

Over the five years from 2020 to 2024, various studies show the existence of three main directions in the study of the topic. First, research on the effectiveness of digital media that pays attention to the impact of multimedia, video, and interactive media on the level of engagement and learning outcomes (Kartimi et al., 2023; Sabila et al., 2024). Second, research in the field of HCI and UX that explores how technology is accepted and user experience, focusing on aspects of ease of use, satisfaction with the interface, participation rate, and quality of evaluation (Dimulescu, 2023; Sobaih et al., 2021; Ahmad & Abdullah, 2021). Third, post-pandemic research that focuses on the sustainability of digital learning innovations and the risk of inequality that arises due to the development of educational technology (Walker & Voce, 2023; Williamson, 2021; Laufer et al., 2021). Similarly, previous systematic literature reviews have provided deeper understanding regarding digital learning adoption, technology acceptance, and sustainability challenges. However, these reviews generally examine specific perspectives and do not fully capture the broader research development patterns or the interaction between digital learning media, HCI dimensions, and sustainability factors. Studies on digital learning media effectiveness mainly focus on improving learning outcomes and engagement through specific formats such as video, interactive multimedia, and e-comics. (Panjaitan et al., 2023). Meanwhile, UX and HCI studies emphasize usability and user experience across different platforms. On the other hand, sustainability studies highlight institutional support, digital transformation, and access inequality but rarely connect these issues with learning media design and HCI dimensions in an integrated framework (Walker & Voce, 2023; Laufer et al., 2021). Therefore, the integration of digital learning media, HCI, and sustainability perspectives remains insufficiently explored.The main gap that appears is that studies of the effectiveness of digital learning media tend to focus on improving learning outcomes and engagement in specific formats (e.g. video, e-comics, interactive multimedia) (Panjaitan et al., 2023; Wahyuni et al., 2023; Sabila et al., 2024), while the User Experience study in platform acceptance focuses more on usability and cross-platform user experience (Dimulescu, 2023; Sobaih et al., 2021). On the other hand, post-pandemic studies emphasize the sustainability of innovation and the issue of inequality, but do not always link these findings to the design of specific learning media and HCI dimensions in an integrated manner (Walker & Voce, 2023; Laufer et al., 2021; Williamson, 2021). Previous bibliometric studies on digital education and sustainability have

provided valuable insights into publication trends, research productivity, influential authors, keyword relationships, and thematic development. However, these studies mainly focus on mapping the structure and evolution of the research field rather than explaining the conceptual relationships between digital learning media design, Human–Computer Interaction (HCI) dimensions, and sustainability implementation. Therefore, bibliometric studies alone may not sufficiently explain the factors influencing the long-term adoption and sustainability of digital learning environments (Walker & Voce, 2023; Dimulescu, 2023; Wahyuni et al., 2023).

To address this research gap, this study combines bibliometric analysis and Systematic Literature Review (SLR). Bibliometric analysis is used to identify research trends, thematic clusters, intellectual structures, and knowledge development patterns, while SLR provides critical analysis of research findings, challenges, and implementation factors. The combination of these approaches enables a more comprehensive understanding by identifying not only what topics have been studied and how they have evolved, but also why certain factors influence the sustainability of digital learning implementation. Thus, this study differs from previous bibliometric and systematic review studies by integrating quantitative mapping and qualitative synthesis to establish a comprehensive framework connecting digital learning media design, HCI dimensions, and sustainability factors.

The urgency of this research is getting stronger along with the increasing adoption of online learning and the rapid development of post-pandemic educational technology, which has the potential to widen the gap if not managed in an inclusive manner (Williamson, 2021; Laufer et al., 2021; Cone et al., 2021). At the same time, evidence shows that the quality of digital learning experiences is influenced by participatory support, as well as the feedback assessments that are an important part of the User Experience (Sobaih et al., 2021), while the sustainability of digital learning innovation depends on TEL investment, institutional support, and teacher competence and capacity (Walker & Voce, 2023). Therefore, the need for effective and sustainable online learning demands a synthesis of evidence that bridges the design of learning media, the quality of User Experience and usability, and the sustainability factors of implementation (Walker & Voce, 2023; Dimulescu, 2023; Waang, 2023). The logical novelty based on the gap above is to compile a study that integrates (a) digital learning media design, (b) HCI dimensions (usability, User Experience, accessibility, engagement), and (c) sustainability of post-pandemic implementation (institutional support, teaching capacity, access inclusivity) in one analytical framework (Walker & Voce, 2023; Laufer et al., 2021). Based on this, this study is directed to systematically examine the relationship between digital learning media design, HCI (usability, UX, accessibility, and engagement) dimensions, and the sustainability of post-pandemic digital learning implementation which includes institutional support, teaching capacity, and access inclusivity. The Systematic Literature Review (SLR) approach is used to map trends, impacts, challenges, and opportunities in the integration of educational technology comprehensively. In the Indonesian context, this approach is also relevant to highlight the urgency of using digital technology as well as access and infrastructure challenges.

METHOD

The method used in this study is a Systematic Literature Review (SLR). The research entitled "Integrating Sustainable Media and Human-Computer Interaction (HCI) in Online Learning: Evidence from a Systematic Literature Review" aims to identify, analyze, and synthesize various research findings related to sustainable media integration and Human-Computer Interaction (HCI) in online learning. The SLR method was selected because it provides a structured, transparent, and reproducible approach for collecting, evaluating, and synthesizing previous research findings. This study follows the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) framework, which includes four main stages: identification, screening, eligibility assessment, and inclusion.

The data collection process was carried out using the main keywords compiled based on the research focus, namely sustainable media, digital sustainability, Human-Computer Interaction, and online learning. The search strategy was developed using the following search string:

("sustainable media" OR "digital sustainability") AND ("human-computer interaction" OR HCI) AND ("online learning" OR "e-learning")

All primary data were obtained from the Scopus database, which was selected as the main database because it provides extensive coverage of peer-reviewed scientific publications and reliable metadata for bibliometric analysis. In addition, Google Scholar was used as a supporting source to identify additional relevant studies and minimize the possibility of missing important literature. However, only studies that fulfilled the predefined inclusion and exclusion criteria were considered for the final analysis.

The article search process was conducted with restrictions on the publication year range from 2016 to 2026. This period was selected to capture the initial development and recent trends related to digital sustainability, Human-Computer Interaction, and its application in online learning, thereby providing a more comprehensive overview of research development in this field.

The obtained articles were then downloaded in CSV format. To facilitate data management, all CSV files from the search results were combined into one ZIP file using the files2zip.com platform. After that, the ZIP file was extracted for further data processing. The data were then processed using the OpenRefine application. This stage aimed to clean the dataset from duplication, inconsistencies, and potential metadata errors that could influence the accuracy of the analysis.

The article selection process was conducted based on predefined inclusion and exclusion criteria. The inclusion criteria consisted of: (1) publications within the 2016–2026 period; (2) articles written in English; (3) peer-reviewed journal articles and conference proceedings; (4) studies discussing digital learning media, sustainable digital learning, Human-Computer Interaction, usability, user experience, accessibility, or online learning implementation; and (5) studies providing sufficient methodological and empirical information relevant to the research objectives.

The exclusion criteria included: (1) duplicate publications; (2) articles without accessible full-text documents; (3) studies unrelated to digital learning, HCI, sustainability, or online learning contexts; (4) non-academic publications such as editorials, book reviews, and opinion papers; and (5) studies that did not provide sufficient information for evidence synthesis.

Furthermore, a quality assessment procedure was conducted to evaluate the relevance and methodological quality of the selected studies before the final synthesis process. Each article was assessed based on research relevance, methodological clarity, contribution to the research topic, and availability of sufficient findings for analysis. Studies that did not meet the quality assessment requirements were excluded from further synthesis.

Furthermore, the cleaned data were analyzed using Biblioshiny, which is the visual interface of the bibliometrix package in the RStudio software. The analysis included bibliometric interpretation such as keyword metadata (DE), key information datasets, publication growth per year, number of annual citations, Three-Field Plot diagrams, most relevant journal sources, Sources' Local Impact, identification of core sources based on Bradford's Law, cumulative publication appearance, author productivity over time, country of origin of corresponding authors, and scientific production distribution by country.

Data visualization was also carried out using the VOSviewer application to produce bibliometric maps in the form of Network Visualization and Overlay Visualization. This visualization was used to examine relationships among keywords, authors, and documents in a more interactive and comprehensive manner.

The next stage involved the use of Elicit AI, an artificial intelligence-based platform used to support the literature review process, research question development, and evidence-based decision-making. Before the data were processed using Elicit AI, the previously obtained CSV files were re-screened to ensure compatibility between article metadata and available PDF documents. Elicit AI was used as a supporting tool for evidence synthesis, while the interpretation and final conclusions remained based on researcher evaluation. The flow diagram of the SLR research method used in this study is shown in Figure 1.

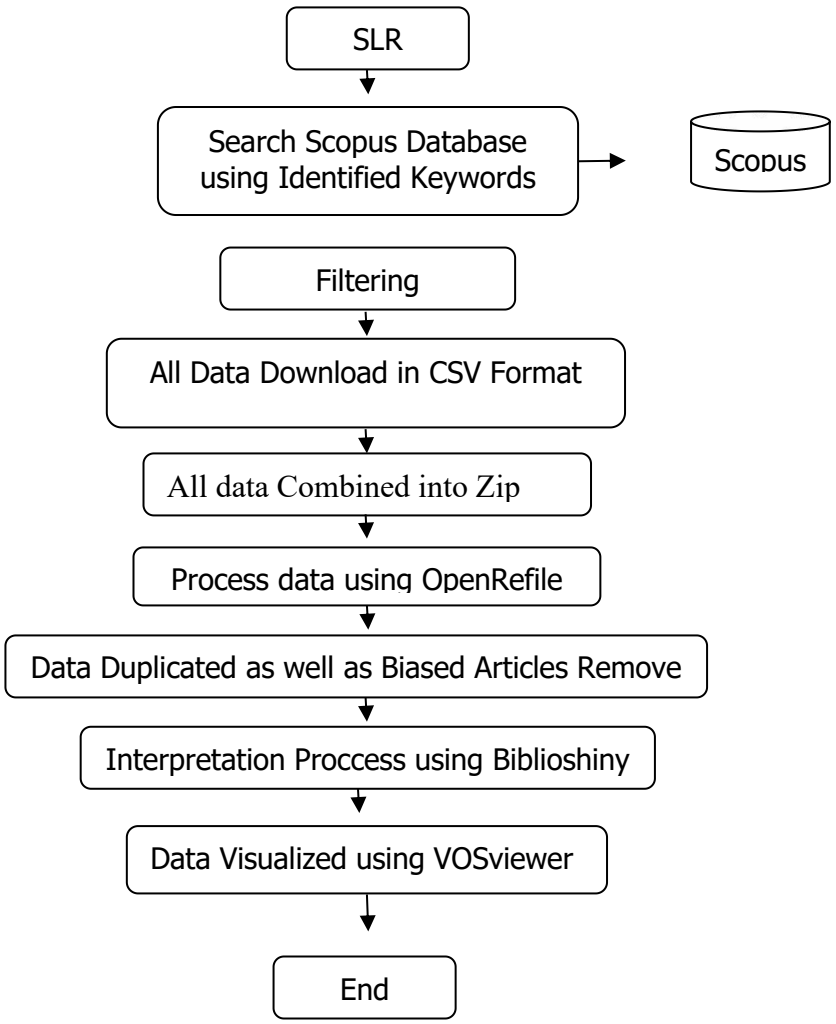

Figure 1. Flow DiagramResearch Methods

Prism Method

This study also uses the PRISMA (*Preferred Reporting Items for Systematic Reviews and Meta-Analyses*) method which is designed to present the article selection process in a systematic, clear, and structured manner. This process includes several stages, namely identification, filtering, and inclusion of relevant articles. The PRISMA diagram is used to ensure that the literature search and selection process is carried out validly, avoiding duplication, and making it easier for readers to understand the selection flow carried out in the preparation of a literature review. The steps taken based on the PRISMA method are shown in Figure 2.

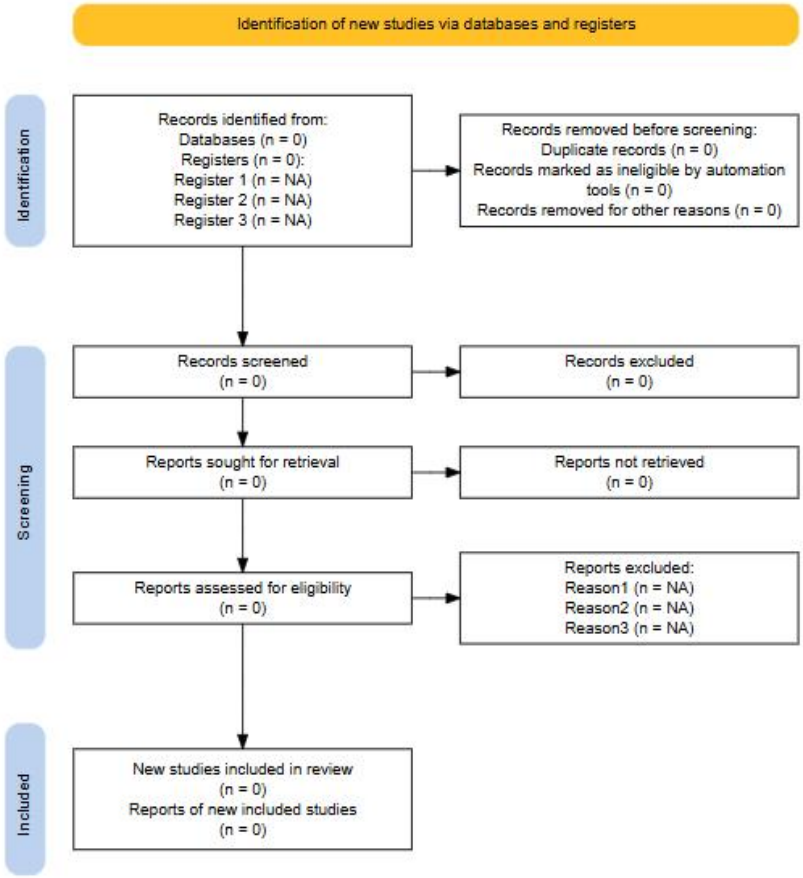

Figure 2. Prism Method Diagram

RESULTS AND DISCUSSION

Bibiometric Studies

At the bibliometric study stage, the researcher conducted a literature search in Scopus using the keywords *("human-computer interaction" OR HCI) AND ("online learning" OR "e-learning")* and obtained 285 documents after the screening process. A second search using keywords *("sustainable media" OR "digital sustainability")* yielded 71 documents with the same criteria. All data is then combined in a single ZIP file using *files2zip.com* site and processed using OpenRefine for data cleanup processes, such as removing duplication and aligning metadata.

Reduce duplicate data

Using the keys *("human-computer interaction" OR HCI) AND ("online learning" OR "e-learning") ("sustainable media" OR "digital sustainability")* which are exported and then decompressed to a zip and then inserted into the open refine. This application is used to filter data, especially to see whether or not there is data obtained from search results. In addition, this application can also be used to eliminate keyword bias contained in the data obtained where initially the data was obtained as many as 356 articles, when entered into open refine to 353 articles.

Metadata	Description	Missing Counts	Missing %	Status
AB	Abstract	0	0.00	Excellent
C1	Affiliation	0	0.00	Excellent
AU	Author	0	0.00	Excellent
DT	Document Type	0	0.00	Excellent
SO	Journal	0	0.00	Excellent
PY	Publication Year	0	0.00	Excellent
TI	Title	0	0.00	Excellent
TC	Total Citation	0	0.00	Excellent
CR	Cited References	1	0.28	Good
DI	DOI	1	0.28	Good
DE	Keywords	11	3.12	Good
ID	Keywords Plus	59	16.71	Acceptable
RP	Corresponding Author	353	100.00	Completely missing
LA	Language	353	100.00	Completely missing
WC	Science Categories	353	100.00	Completely missing

Figure 3. Meta data on DE/Keword is good.

Furthermore, the process of interpreting bilometric data can be carried out using the Bibliosiny application as follows. The main information data as a whole is obtained as shown in table 1.

Table 1. Key Information on the data sheet.

Description	Results
MAIN INFORMATION ABOUT DATA	
Timespan	2016:2026
Sources (Journals, Books, etc.)	148
Documents	353
Annual Growth Rate %	20.35
Document Average Age	2.92
Average citations per doc	14.9
References	46341
DOCUMENT CONTENTS	

Description	Results
Keywords Plus (EN)	2613
Author's Keywords (DE)	1428
AUTHORS	
Authors	1209
Authors of single-authored docs	28
AUTHORS COLLABORATION	
Single-authored docs	30
Co-Authors per Doc	3.59
International co-authorships %	25.21
DOCUMENT TYPES	
Article	353

Table 1 presents the bibliometric characteristics of 353 scientific articles published between 2016 and 2026 from 148 different sources. The annual publication growth rate of 20.35% indicates a substantial increase in research on sustainable digital learning media, Human–Computer Interaction (HCI), and online learning. This trend reflects the growing global interest in digital education, accelerated by digital transformation and the increasing integration of sustainability and HCI perspectives in educational technology research (Walker & Voce, 2023; Laufer et al., 2021). The average document age of 2.92 years and an average of 14.9 citations per article indicate that the literature is both recent and has gained reasonable academic attention. This suggests that the topic has become an active interdisciplinary research area involving education, computer science, and information systems (Williamson, 2021). The dataset contains 46,341 references, 2,613 Keywords Plus, and 1,428 Author Keywords, indicating broad thematic diversity. The variety of keywords reflects the evolution of research from conventional e-learning toward emerging topics such as sustainability, artificial intelligence, accessibility, usability, and user experience. A total of 1,209 authors contributed to the publications, with an average of 3.59 authors per article and 25.21% involving international collaboration. This finding indicates that collaborative research has become the dominant pattern, although international collaboration remains moderate, suggesting opportunities to strengthen global research networks in sustainable digital education (Walker & Voce, 2023; Laufer et al., 2021). Overall, these findings demonstrate that sustainability and HCI in online learning have developed into a rapidly growing and increasingly interdisciplinary research field.

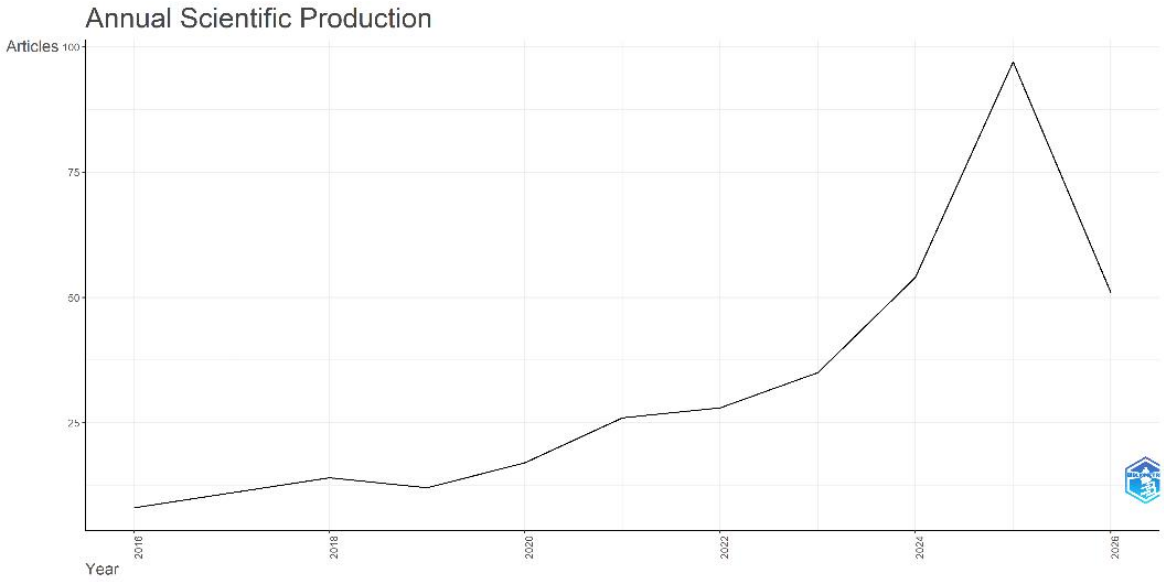

Figure 4. Growth Chart Annually.

It can be shown by the distribution of the data table as below.

Table 2. Annual growth.

Year	Articles
2016	8
2017	11
2018	14
2019	12
2020	17
2021	26
2022	28
2023	35
2024	54
2025	97
2026	51
Total	In total

Based on Figure 4 and Table 2 on Annual Scientific Production, we can see a fairly consistent trend of increasing the number of articles from year to year, although there is a slight fluctuation during the observation period. At the beginning of the 2016 period, the number of articles published was recorded at 8 articles. This number gradually increased until 2018 reached 14 articles, before finally decreasing slightly to 12 articles in 2019. Entering 2020, the number of publications again increased to 17 articles and continued to grow significantly in the following years. A very sharp increase was seen starting in 2023 with 35 articles, until finally reaching its peak in 2025 with the highest number of publications, which was 97 articles. This number represents the highest annual scientific production during the eleven-year observation period. The increasing publication trend indicates the growing global research interest in sustainable media, Human–Computer Interaction (HCI), and online learning, particularly following the rapid digital transformation in education and the widespread adoption of online learning technologies (Walker & Voce, 2023). In 2026, the number of publications decreased to 51 articles. This decline is most likely because the current year (2026) was still ongoing during data collection, meaning that not all publications had been indexed in the Scopus database. Overall, these findings demonstrate a rapid increase in scientific publication productivity, especially between 2020 and 2025. Despite the temporary decline in 2026, the overall trend continues to indicate the expanding development of research in this field. The following analysis is presented in Figure 5.

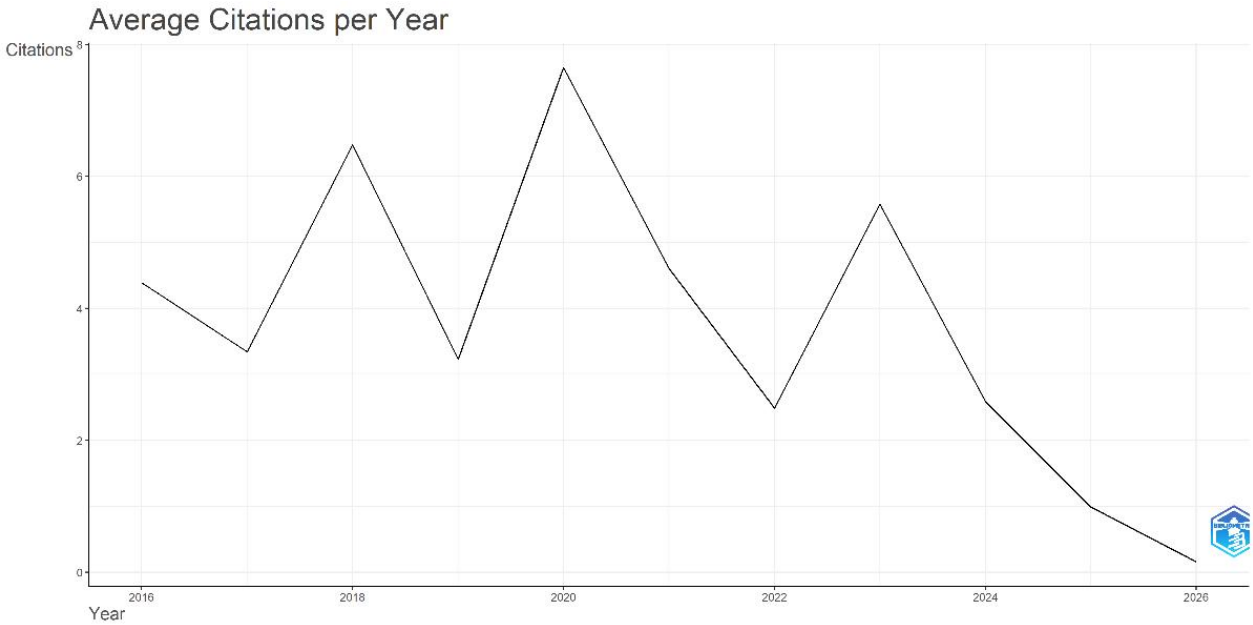

Figure 5. Graph of Citations per Year.

It can be explained in the form of a table distribution as below.

Table 3. Citations per year.

Year	MeanTCperArt	N	MeanTCperYear	CitableYears
2016	48.25	8	4.39	11
2017	33.36	11	3.34	10
2018	58.36	14	6.48	9
2019	25.83	12	3.23	8

Year	MeanTCperArt	N	MeanTCperYear	CitableYears
2020	53.53	17	7.65	7
2021	27.65	26	4.61	6
2022	12.46	28	2.49	5
2023	22.31	35	5.58	4
2024	7.78	54	2.59	3
2025	1.98	97	0.99	2
2026	0.16	51	0.16	1

Based on Figure 5 and Table 3, although the number of publications (N) increased significantly, particularly from 2023 to 2025, the average citations per article (Mean TC per Art) showed a declining trend. In 2018 and 2020, each article received an average of 58.36 and 53.53 citations, respectively, indicating that publications during those years had a stronger scientific impact. However, the average citations gradually decreased to 1.98 in 2025 and 0.16 in 2026. This decline does not necessarily indicate lower research quality but is mainly influenced by the shorter citation window of recently published articles, which require more time to accumulate citations. A similar pattern is observed in the Mean TC per Year, which peaked at 7.65 citations in 2020 before declining to 0.99 in 2025 and 0.16 in 2026. The low citation count in 2026 should also be interpreted cautiously because data collection was conducted while the publication year was still ongoing. Furthermore, articles published in earlier years have had more opportunities to receive citations than recent publications. Overall, these findings indicate that the rapid growth in publication output is not always accompanied by an immediate increase in citation impact, reflecting the continuing development of research in sustainable media, Human Computer Interaction (HCI), and online learning, where publication productivity has expanded rapidly following the digital transformation in education (Williamson, 2021). The following analysis is presented in Figure 6.

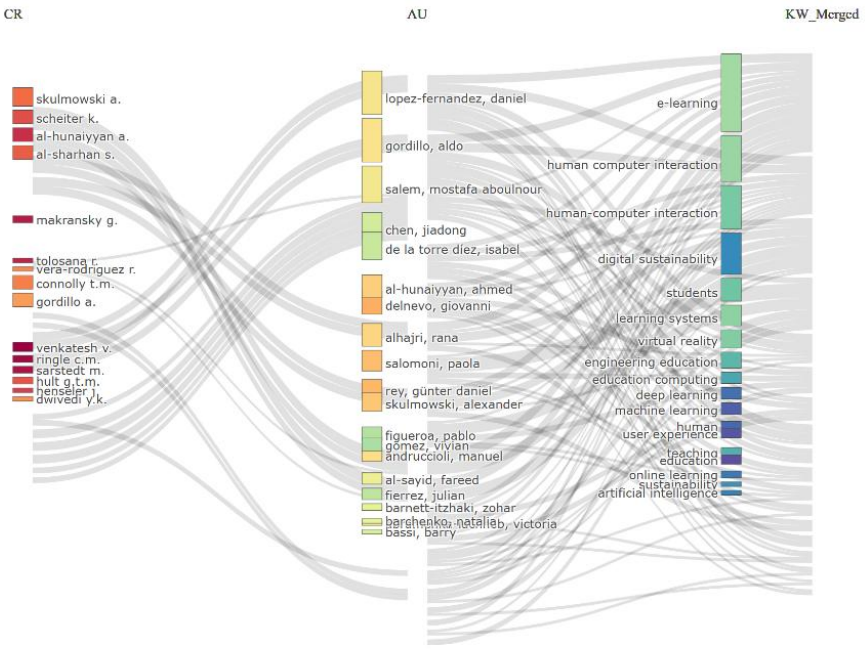

Figure 6. Three-Field Plot diagram

Figure 6 illustrates the relationship among the most frequently cited references (CR), authors (AU), and keywords (KW_Merged) using a Sankey diagram. The visualization shows that influential references by authors such as Skulmowski, Al-Hunaityan, and Venkatesh are strongly connected to productive researchers, including Gordillo, Aldo, Lopez-Fernandez, Daniel, and Salem, Mostafa Abounour, indicating their important role in bridging established theoretical foundations with emerging research topics. The dominant keywords, including *e-learning*, *human–computer interaction*, *digital sustainability*, and *learning systems*, demonstrate that research has increasingly focused on developing sustainable digital learning environments. Furthermore, the emergence of keywords such as *artificial intelligence*, *machine learning*, and *virtual reality* reflects the thematic evolution of this field toward intelligent and immersive learning technologies, driven by the rapid digital transformation of education and the growing demand for user-centered learning systems (Qin et al., 2025; Rithiely et al., 2025). Overall, the diagram highlights the integration of influential references, active researchers, and emerging technologies, indicating that research on sustainable media and Human–Computer Interaction (HCI) is becoming increasingly interdisciplinary and continuously evolving. The most relevant sources are presented in Figure 7 below.

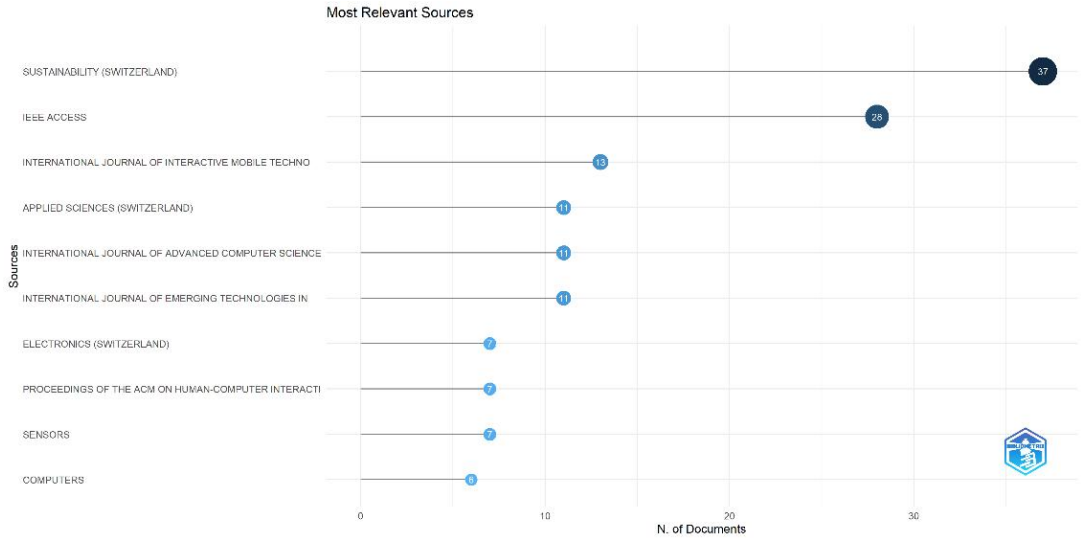

Figure 7. Most Relevant Source

Figure 7 presents the most relevant sources in the analyzed literature using a horizontal bar chart. The results show that *Sustainability* (Switzerland) is the leading publication source with 37 articles, followed by *IEEE Access* with 28 articles, indicating that both journals have become major publication platforms for research on sustainable media, Human–Computer Interaction (HCI), and online learning. The dominance of *Sustainability* reflects the increasing integration of sustainability principles with digital education and technological innovation, particularly in response to the growing emphasis on sustainable development and digital transformation in education , (Laufer et al., 2021). Meanwhile, the strong contribution of *IEEE Access* demonstrates the important role of engineering and information technology research in advancing intelligent learning systems and HCI applications. Other journals, including the *International Journal of Interactive Mobile Technologies*, *Applied Sciences*, and the *International Journal of Emerging Technologies in Learning*, also contribute substantially, highlighting the interdisciplinary nature of this research area. Overall, these findings indicate that research on sustainable digital learning is increasingly supported by journals that combine sustainability, educational technology, and computer science, reflecting the growing convergence of these disciplines (Qin et al., 2025). The Sources' Local Impact analysis based on the top ten journals is presented in the following section.

Table 4. Sources' Local Impact

Source	h_index	g_index	m_index	TC	NP	PY_start
IEEE ACCESS	11	27	1.222	740	28	2018
INTERNATIONAL JOURNAL OF EMERGING TECHNOLOGIES IN LEARNING	8	11	0.800	188	11	2017
SUSTAINABILITY (SWITZERLAND)	6	9	0.667	131	37	2018
COMPUTERS AND EDUCATION	5	6	0.556	846	6	2018
COMPUTERS IN HUMAN BEHAVIOR	5	5	0.455	471	5	2016
APPLIED SCIENCES (SWITZERLAND)	4	7	0.571	50	11	2020

Source	h_index	g_index	m_index	TC	NP	PY_start
HUMAN BEHAVIOR AND EMERGING TECHNOLOGIES	4	4	0.571	272	4	2020
INTERNATIONAL JOURNAL OF ADVANCED COMPUTER SCIENCE AND APPLICATIONS	4	8	0.667	74	11	2021
PROCEEDINGS OF THE ACM ON HUMAN-COMPUTER INTERACTION	4	6	0.667	46	7	2021
SENSORS	4	7	0.667	101	7	2021

Based on Table 4, the Sources' Local Impact analysis demonstrates that the influence of scientific journals is determined not only by publication output but also by citation performance. *IEEE Access* ranks first with the highest h-index (11), g-index (27), and 740 total citations from 28 publications, indicating its strong and consistent contribution to research on Human–Computer Interaction (HCI), intelligent systems, and digital learning technologies. Although *Computers & Education* and *Computers in Human Behavior* published relatively fewer articles, they achieved remarkably high citation counts, suggesting that their publications provide substantial theoretical and practical contributions that are widely recognized by the research community. Meanwhile, *Sustainability* (Switzerland) recorded the highest number of publications, reflecting the increasing integration of sustainability concepts with digital education and technological innovation in response to the rapid digital transformation of education , (Laufer et al., 2021). The presence of journals such as *Applied Sciences*, *Sensors*, and the *Proceedings of the ACM on Human–Computer Interaction* further demonstrates the interdisciplinary nature of this research field, which combines education, computer science, engineering, and sustainability (Qin et al., 2025; Wang et al., 2025). Overall, these findings indicate that journal influence is shaped by both research quality and long-term scientific impact rather than publication quantity alone.Next is Core Sources by Bradford's Law data. This data is taken from the top 10 data.

Figure 8. Core Sources by Bradford'd Law.

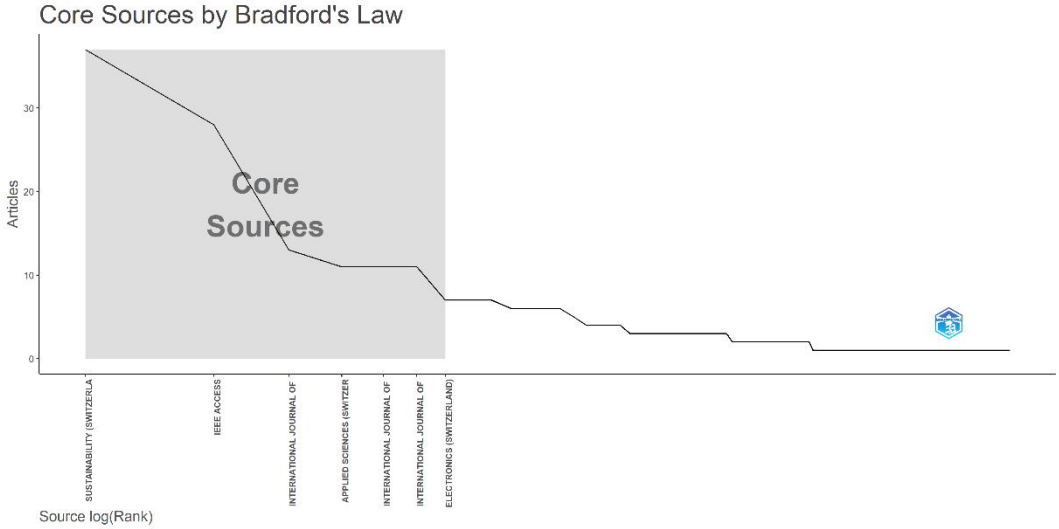

Figure 8 presents the core sources identified using Bradford's Law, which indicates that a relatively small number of journals account for the majority of publications within a research field,

while a much larger number of journals contribute fewer articles. The results show that *Sustainability* (Switzerland) and *IEEE Access* form the core sources, followed by the *International Journal of Interactive Mobile Technologies*, *Applied Sciences* (Switzerland), the *International Journal of Advanced Computer Science*, and the *International Journal of Emerging Technologies in Learning*. The dominance of these journals reflects their central role in disseminating research on sustainable media, Human Computer Interaction (HCI), and online learning, particularly as digital transformation has accelerated the integration of sustainability, educational technology, and intelligent (Sari & Tyaningsih, 2024). In contrast, the large number of journals outside the core zone illustrates the interdisciplinary expansion of this research area, where contributions originate from diverse fields such as computer science, engineering, education, and sustainability (Kurniawati & Hadi, 2024). Overall, the Bradford distribution confirms that although research is increasingly distributed across many publication outlets, a limited number of core journals continue to play a dominant role in shaping knowledge and guiding future research in this field. The cumulative occurrence of publication sources is presented in Figure 9.

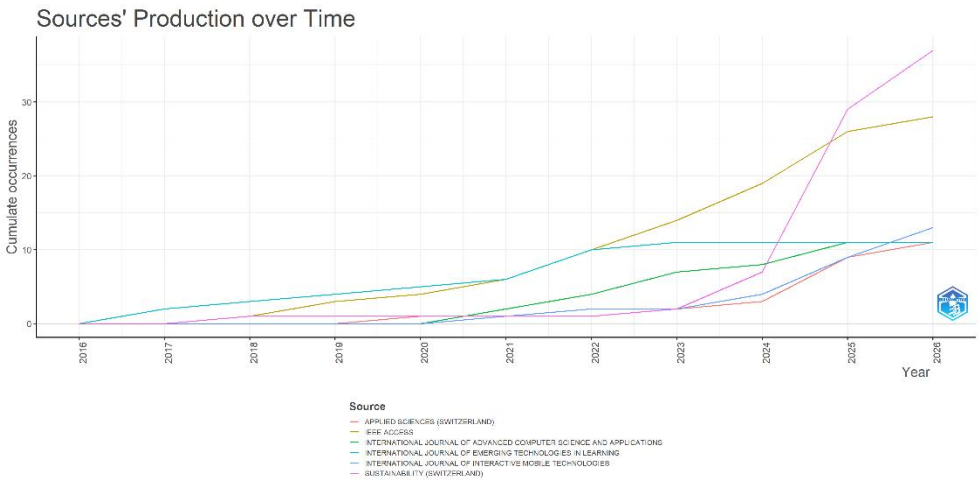

Figure 9. Cumulate Occurrences Graph

Figure 9 illustrates the cumulative occurrence of publications across major scientific journals from 2016 to 2026. The results show that publication growth remained relatively low until 2020, followed by a substantial increase after 2021, with *Sustainability* (Switzerland) exhibiting the most rapid cumulative growth and becoming the leading publication source by 2026. This trend reflects the growing emphasis on integrating sustainability principles with digital education, Human–Computer Interaction (HCI), and technological innovation, particularly following the acceleration of digital transformation in education (Nucifera et al., 2022). *IEEE Access* also demonstrates consistent growth throughout the observation period, highlighting its important role as a leading platform for publishing research on intelligent systems, artificial intelligence, and digital learning technologies. Meanwhile, other journals, such as the *International Journal of Emerging Technologies in Learning*, *International Journal of Interactive Mobile Technologies*, and *Applied Sciences*, show moderate but steady growth, indicating the expanding interdisciplinary nature of this research area. Overall, the cumulative publication trends suggest that research on sustainable digital learning is increasingly concentrated in journals that integrate sustainability, educational technology, and computer science, reflecting the continuous evolution of this field (Silvester et al., 2023) The most relevant authors are presented in Table 5.

Table 5. Most Relevant Authors

Author	Articles	Articles Fractionalized
DELNEVO, GIOVANNI	5	1.25

Author	Articles	Articles Fractionalized
KING, GÜNTER DANIEL	4	2.00
SOLOMON, PAOLA	4	1.00
SKULMOWSKI, ALEXANDER	4	2.00
AL-HUNAIYYAN, AHMED	3	0.75
ALHAJRI, RANA	3	0.75
ANDRUCCIOLI, MANUEL	3	0.75
GORDILLO, ALDO	3	0.83
LOPEZ-FERNANDEZ, DANIEL	3	0.83
SALEM, MOSTAFA ABOULNOUR	3	3.00

Table 5 presents the most relevant authors based on the total number of publications and fractionalized authorship, highlighting both research productivity and individual contributions. Delnevo, Giovanni recorded the highest number of publications with five articles, while Rey, Günter Daniel and Skulmowski, Alexander achieved higher fractionalized scores, indicating a more substantial contribution to their publications. Although Salem, Mostafa Abounour published only three articles, he obtained the highest fractionalized contribution, suggesting a leading role in the research process. These findings indicate that research development in sustainable media, Human–Computer Interaction (HCI), and online learning is driven not only by publication productivity but also by strong individual and collaborative contributions. The emergence of these productive authors reflects the rapid expansion of interdisciplinary research integrating educational technology, digital learning, and intelligent systems, which has accelerated following the digital transformation of education (Wahyuni et al., 2023). Overall, the distribution of author productivity suggests that both collaborative research networks and significant individual contributions play important roles in advancing knowledge and innovation within this field. The authors' production over time is presented in Figure 10.

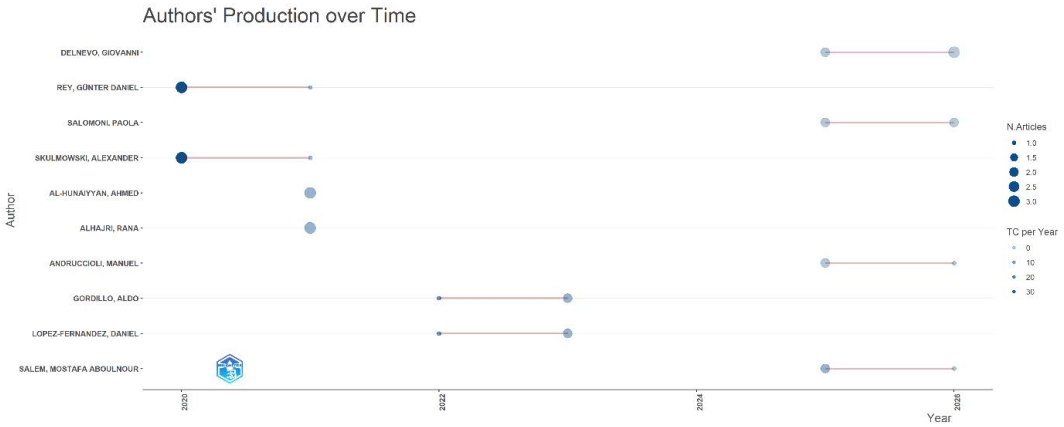

Figure 10. Authors Production over Time.

Figure 10 illustrates the publication productivity of the most relevant authors between 2020 and 2026. Rey, Günter Daniel and Skulmowski, Alexander made significant contributions during the early period, as indicated by the higher citation impact of their publications in 2020. In contrast, publication activity increased markedly after 2023, with authors such as Delnevo, Giovanni, Salomoni, Paola, and Salem, Mostafa Abounour becoming the most productive contributors and maintaining consistent publication output through 2026. This shift suggests the emergence of new leading researchers alongside established authors, reflecting the rapid expansion of research on sustainable media, Human–Computer Interaction (HCI), and online learning following the accelerated digital transformation in education. The growing involvement of new authors also indicates that this field has attracted broader interdisciplinary collaboration, particularly with the increasing adoption of artificial intelligence and other digital learning technologies (Fadlan et al., 2022).

Overall, the figure demonstrates the continuous evolution of the research community, where both experienced and emerging researchers contribute to advancing knowledge and innovation in this field. The countries' scientific production is presented in Table 6.

Table 6. Countries' Scientific Production.

Country	Freq
CHINA	104
USA	71
SPAIN	50
UK	40
GERMANY	39
INDIA	35
SAUDI ARABIA	29
ITALY	28

Country	Freq
MALAYSIA	26
NETHERLANDS	22

Table 6 presents the scientific production by country, showing that China leads with 104 publications, followed by the United States (71), Spain (50), the United Kingdom (40), and Germany (39). The dominance of China reflects the country's substantial investment in digital technologies, artificial intelligence, and educational innovation, which has significantly accelerated research on sustainable media, Human–Computer Interaction (HCI), and online learning. Similarly, the strong publication output of the United States and several European countries demonstrates their long-standing research capacity and active contributions to digital education and HCI. The increasing presence of Asian countries, including India, Saudi Arabia, and Malaysia, indicates a broader geographical expansion of research driven by the rapid adoption of digital learning technologies and the growing emphasis on sustainable education following the global digital transformation (Fadlan et al., 2022). Overall, these findings suggest that scientific productivity in this field is becoming increasingly global, reflecting the growing international commitment to advancing technology-enhanced learning and sustainable educational development (B. Wijayanto et al., 2022; Sutoyo & Rahayu, 2022).

The countries' production over time is presented in the following figure.

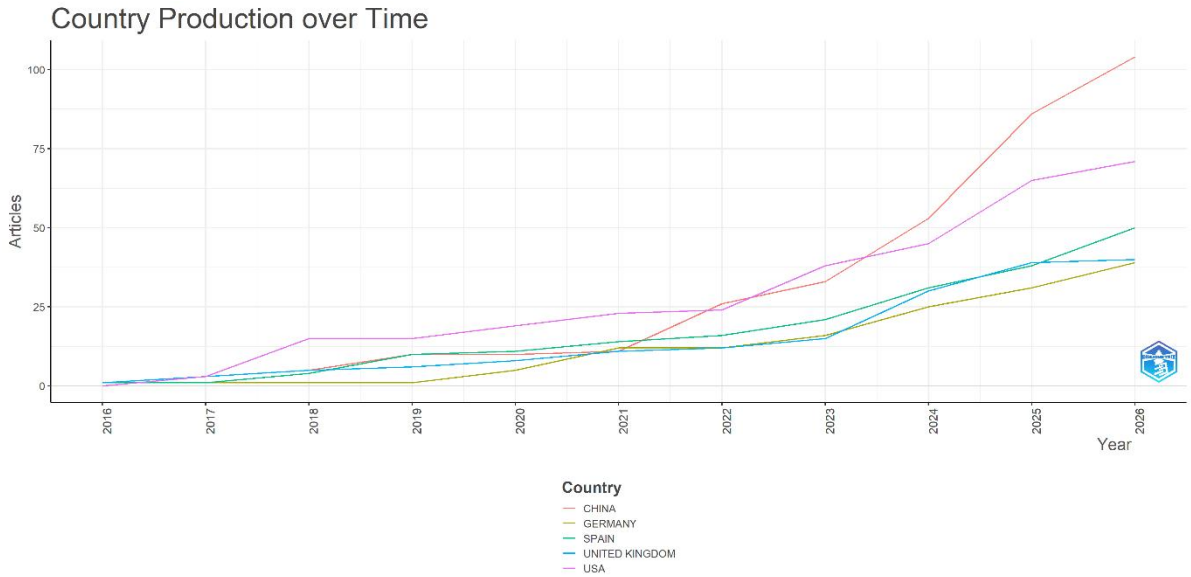

Figure 11. Graph of Countries' Production over Time.

Figure 11 illustrates the growth of scientific publications by the most productive countries from 2016 to 2026. During the 2016–2019 period, publication output remained relatively low across all countries, but a substantial increase occurred after 2020, with China showing the most significant growth, followed by the United States, Spain, the United Kingdom, and Germany. This sharp increase is closely associated with the accelerated digital transformation in education following the COVID-19 pandemic, which stimulated research on sustainable media, Human Computer Interaction (HCI), online learning, and emerging technologies. China's dominant growth also reflects its strong investment in digital innovation and artificial intelligence, while the consistent productivity of the United States and European countries demonstrates their continued leadership in educational technology and HCI research (Ahmad & Abdullah, 2021). Overall, the

findings indicate that research productivity has expanded globally since 2020, with Asian countries playing an increasingly important role in advancing technology-enhanced and sustainable learning, reflecting the evolving international research landscape (Sobaih et al., 2021). The most cited countries are presented in Figure 12.

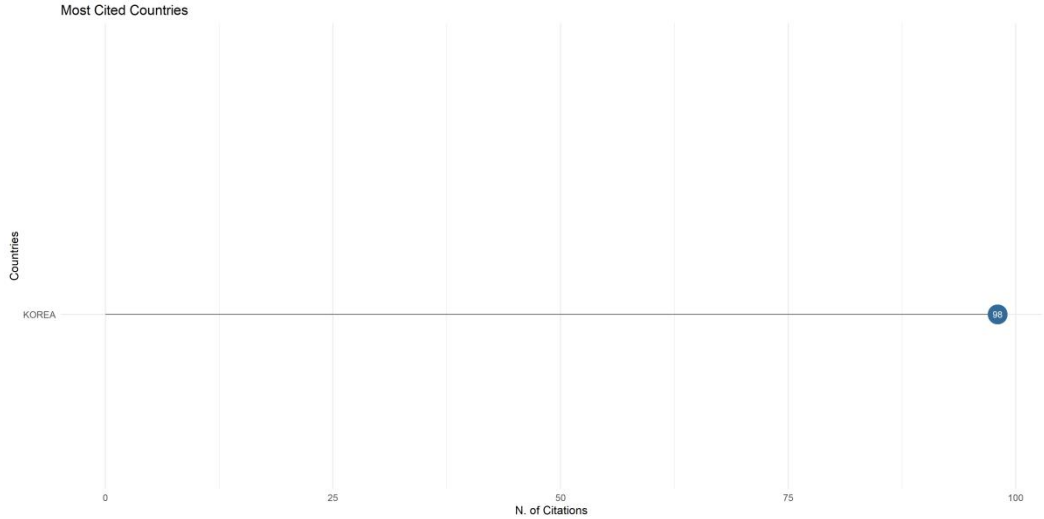

Figure 12 Most Cited Countries.

Figure 12 presents the most cited countries, illustrating the scientific influence of publications based on the total number of citations they have received. Korea recorded the highest citation count with 98 citations, indicating that publications from this country have made a substantial contribution to the development of research on sustainable media, Human–Computer Interaction (HCI), and online learning. High citation counts generally reflect that published studies provide significant theoretical or practical contributions and are widely recognized by the global scientific community. This finding is consistent with the rapid advancement of digital learning technologies and intelligent educational systems, which have increased the visibility and impact of research in this field (Sobaih et al., 2021). Overall, the results suggest that scientific influence is determined not only by publication productivity but also by the quality, relevance, and long-term impact of research, highlighting the growing international collaboration and continuous development of technology-enhanced learning (Rizqiyana et al., 2022).

Overlay visualization.

The following can be seen in Figure 13 below which displays *overlay visualization*, which is a visualization that shows the relationship between topics as well as the development of research trends based on color differences.

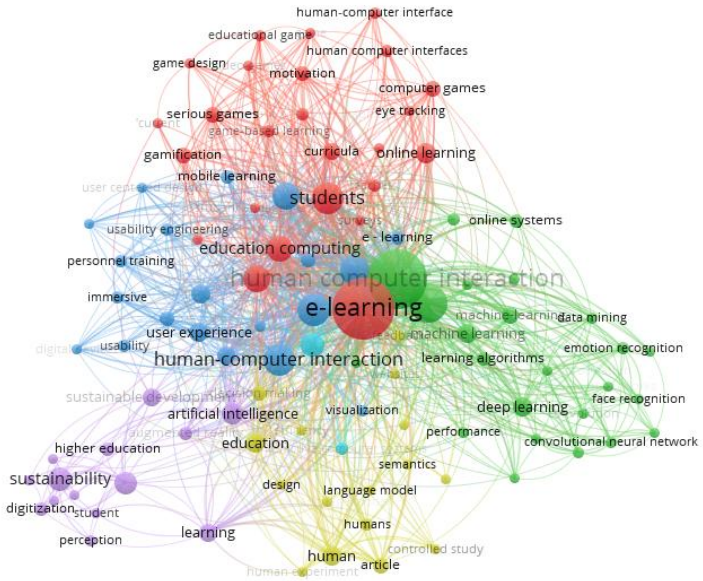

Figure 13 Overlay visualization.

Figure 13 presents the keyword co-occurrence network generated using VOSviewer, illustrating the thematic relationships among research topics in sustainable media, Human–Computer Interaction (HCI), and online learning. The largest nodes, *e-learning* and *human–computer interaction*, indicate that these remain the core themes of the field, while their strong connections with keywords such as *artificial intelligence*, *machine learning*, *students*, and *education computing* demonstrate the increasing integration of intelligent technologies into digital learning environments. The emergence of *artificial intelligence*, *deep learning*, and *virtual reality* as prominent keywords reflects the thematic evolution of the field from conventional e-learning systems toward more adaptive, intelligent, and immersive learning technologies. In addition, the close relationship between *sustainability*, *higher education*, and digital transformation indicates that sustainability has become an essential component of educational technology research rather than a separate topic. This evolution is consistent with recent studies reporting that advances in artificial intelligence, digital transformation, and sustainable education have reshaped research priorities in HCI and online learning (Sobaih et al., 2021). Overall, the network demonstrates that the field has evolved into an interdisciplinary research domain integrating education, sustainability, and intelligent digital technologies.

Network Visualization.

The following can be seen in Figure 14 below which shows *the network visualization*,

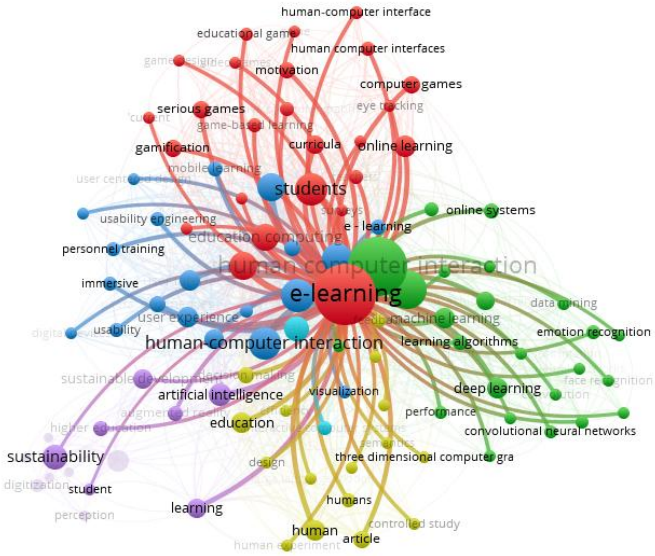

Figure 14 Network Visualization.

Figure 14 presents the keyword network visualization, showing that e-learning and human–computer interaction are the central nodes connecting multiple research themes. The close relationship between the AI cluster (machine learning, deep learning, convolutional neural networks) and the HCI cluster (user experience, usability engineering, human computer interfaces) indicates that recent research increasingly integrates intelligent technologies with user-centered design to create more adaptive and effective digital learning environments. At the same time, the strong connection between the sustainability cluster and educational technology keywords shows that sustainability has evolved from a supporting issue into a core component of online learning research, particularly in the context of digital transformation and long-term educational implementation (Hakimi et al., 2025). The network also links pedagogical themes such as gamification, serious games, and student engagement with AI and HCI, demonstrating that the field has become highly interdisciplinary and is moving toward the integration of intelligent technology, user experience, and sustainable education (Gonzalez & Ledo, 2025). Overall, the visualization suggests that future research will increasingly focus on combining AI-driven learning systems with HCI principles and sustainability perspectives.

Of the 353 data obtained, 153 will be focused on article types.

SLR Review

Table 7. SLR Review

Yes	Type	Quantity
1	Article	153
2	Conference Paper	73
3	Review	45
4	Book	82
Total		353

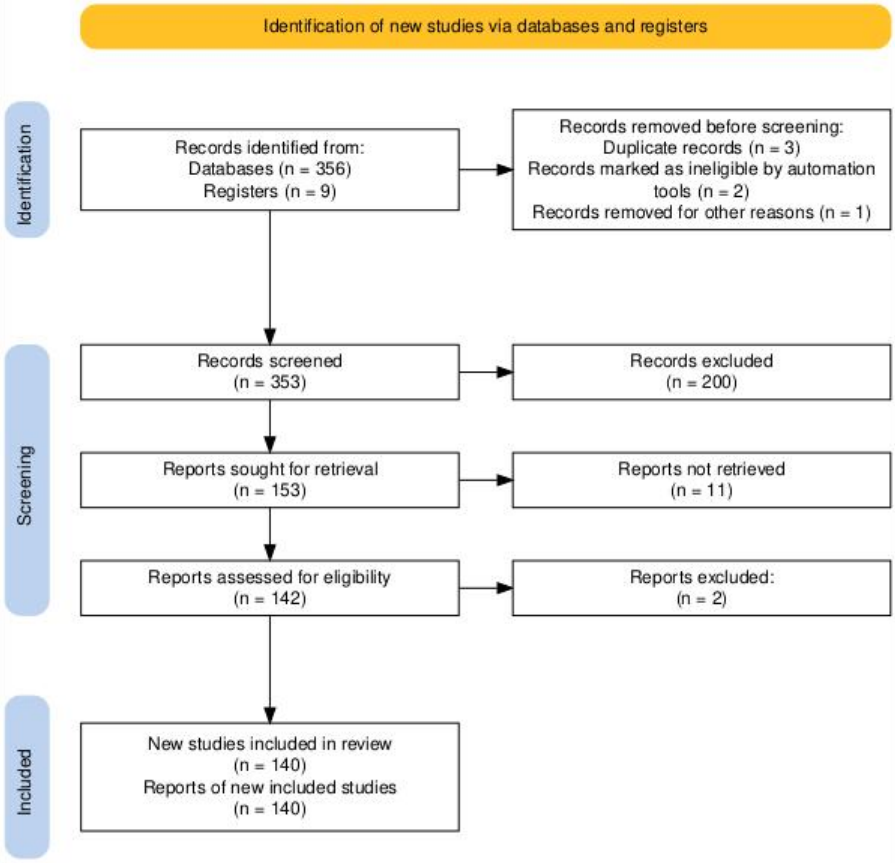

Figure 15 Prism Method Result Diagram

Figure 15 presents the PRISMA flow diagram describing the systematic article selection process used in this Systematic Literature Review (SLR). The identification stage yielded 365 records, consisting of 356 articles from the primary database and 9 records from the register. Prior to screening, metadata standardization and cleaning were performed using OpenRefine, resulting in the removal of six records, including duplicate entries and records that did not meet the predefined criteria. After data cleaning, 353 articles were screened based on their titles and abstracts, leading to the exclusion of 200 irrelevant studies. Subsequently, 153 full-text articles were sought for retrieval, of which 11 could not be accessed. The remaining 142 articles underwent full-text eligibility assessment, and two additional articles were excluded because they did not satisfy the inclusion criteria or contained corrupted files. Consequently, 140 studies were included in the final review. This rigorous selection process follows the PRISMA 2020 guidelines and ensures that only relevant, reliable, and high-quality studies are included, thereby improving the validity and transparency of the evidence synthesis used in this research.

The selected studies were classified into six research methodology categories, namely experimental, pre-experimental, survey/questionnaire, machine learning/computational, design-based research, and literature review. This classification provides an overview of the methodological approaches used to investigate sustainable media, Human–Computer Interaction (HCI), and online learning, reflecting the interdisciplinary nature of this research field and the increasing adoption of digital technologies and artificial intelligence in educational research (Corrales et al., 2025).

The distribution of these research methodologies is presented in Table 8.

Table 8. Key Classifications in the Ecilit AI Methodology Table

Methodology Categories	Number of Papers	Introduce yourself	Example Method	Description
Experimental	40	28.6%	Pre-test & Post-test, Control Group	Direct-treatment research to test the influence of a variable on learning outcomes or behavior
Pre-Experimental	15	10.7%	One Group Pretest-Posttest	Simple experiment with no control group, only looking at changes before and after treatment
Survey or Questionnaire	30	21.4%	SUS (System Usability Scale), Likert Questionnaire	Collect data from respondents to measure user satisfaction, perception, or experience
Machine Learning or Computing	20	14.3%	SVM, Logistic Regression, SMOTE	Using computational algorithms for data classification, prediction, or analysis
Design-Based Research	10	7.1%	Iterative Design, Prototyping, Evaluation	Product development methods (media/applications) with design, test, and improvement cycles
Reviews / Workshops / Literature Studies	25	17.9%	Literature Review, Systematic Review, Workshop	Review existing research to find trends, challenges, and research opportunities
Total	140	100%	—	—

The analysis of 140 selected studies shows that experimental (28.6%) and survey (21.4%) approaches are the most frequently employed research methodologies, indicating that previous studies have primarily focused on evaluating the effectiveness of digital learning technologies and understanding user experiences in Human–Computer Interaction (HCI). Literature review (17.9%) and machine learning/computational methods (14.3%) also contribute substantially, reflecting the growing use of artificial intelligence and data-driven approaches in educational research. In contrast, pre-experimental (10.7%) and design-based research (7.1%) remain less common, suggesting that the development and iterative evaluation of innovative learning systems are still relatively limited. Overall, the findings demonstrate that quantitative methods dominate this research field, while more comprehensive approaches are needed to support the design, implementation, and long-term evaluation of sustainable digital learning environments (Kartimi et

al., 2023; Sabila et al., 2024). The classification of the main research findings is presented in the following table.

Table 9. Main Classifications in the Table Main findings of Ecilit AI

Key Findings Categories	Number of Papers	Key Examples
Improved Learning Outcomes	35	Post-test scores improve, concept comprehension is better
Increased Motivation & Engagement	30	Users are more interested, active, and engaged in learning
System/Media Effectiveness	25	Applications/games have proven to be effective as a learning medium
Usability & User Experience (UX)	20	Easy-to-use system, high user satisfaction (SUS)
Influence of Technology (AI/VR/AR)	15	Technology enhances interactivity and personalization
Limitations & Constraints	10	Difficulty of use, requires user adaptation
Scalability & Implementation	5	The system can be widely used (MOOC, online platform)
Total	140	—

Based on the 140 selected studies, the most common findings were improved learning outcomes (35 articles) and increased motivation and engagement (30 articles), indicating that digital learning technologies generally have a positive impact on educational performance and learner participation. System or media effectiveness (25 articles) and usability or user experience (20 articles) were also widely investigated, highlighting the importance of developing user-centered learning systems that are both effective and easy to use. Furthermore, studies focusing on artificial intelligence (AI), virtual reality (VR), and augmented reality (AR) (15 articles) demonstrate the growing adoption of intelligent and immersive technologies to enhance learning experiences. In contrast, relatively few studies addressed system limitations, implementation challenges, and scalability, suggesting that these issues remain underexplored despite their importance for the long-term adoption of sustainable digital learning systems (Kartimi et al., 2023) Overall, these findings indicate that future research should place greater emphasis on implementation strategies, scalability, and sustainable deployment alongside technological innovation. The summary category classification is presented in the following table.

Table 10. Key Classifications in the Elicit AI Summary Table

Category Summary	Number of Papers	Percentage	Examples of Keywords
Learning Media Development	38	27.1%	Educational games, apps, interactive media, learning platforms
Evaluation of Learning Effectiveness	32	22.9%	Improvement of learning outcomes, post-test post-test, effectiveness
User Experience (UX) Analysis	22	15.7%	usability, SUS, user satisfaction, user experience
Technology Utilization (AI/VR/AR)	18	12.9%	Virtual reality, augmented reality, machine learning
Online Learning / E-learning	15	10.7%	LMS, MOOC, online learning, COVID-19
Development of Learning Models/Methods	10	7.1%	inquiry-based learning, learning model
Literature Studies/Reviews	5	3.6%	Literature Review, Systematic Review
Total	140	100%	—

Based on the 140 selected studies, the summary categories were dominated by learning media development (27.1%) and learning effectiveness evaluation (22.9%), indicating that recent research has primarily focused on designing innovative digital learning platforms and assessing their educational impact. User experience (UX) analysis (15.7%) also received considerable attention, reflecting the growing importance of usability and learner satisfaction in Human–Computer Interaction (HCI). Furthermore, the increasing application of artificial intelligence (AI), virtual reality (VR), and augmented reality (AR) (12.9%) demonstrates the integration of intelligent and immersive technologies into digital learning environments. Although online learning (10.7%) has expanded rapidly following the digital transformation of education, fewer studies have addressed the development of learning models (7.1%) and literature reviews (3.6%), suggesting opportunities to strengthen theoretical frameworks and long-term pedagogical innovation (Rithiely et al., 2025). Overall, these findings indicate that future research should balance technological innovation with the development of robust learning models and comprehensive theoretical perspectives. The classification of study designs is presented in the following table.

Table 11. Key Classifications in the Elicit AI Design Study Table

Study Design	Number of Papers	Percentage	Unique Characteristics
Experimental Design	40	28.6%	Using variable, pre-test & post-test controls to measure the effect of treatment
Pre-Experimental Design	15	10.7%	Without a control group, only one test group before & after
Survey Research	30	21.4%	Data collection via questionnaires (e.g. SUS, Likert) for perceptual analysis
Quasi-Experimental	10	7.1%	Similar to an experiment but without full randomization
Design-Based Research	10	7.1%	Iterative: design → test → evaluation → system improvement
Case Study	8	5.7%	In-depth study on a specific case/group
Research & Development (R&D)	12	8.6%	Focus on creating and validating learning products/media
Literature Review	10	7.1%	Analysis and synthesis of previous research
Mixed Methods	5	3.6%	Combination of quantitative and qualitative data
Total	140	100%	—

Based on the 140 selected studies, experimental design was the most widely adopted research approach (28.6%), indicating that researchers primarily focused on empirically evaluating the effectiveness of digital learning technologies and Human–Computer Interaction (HCI) applications through controlled interventions. Survey research (21.4%) was also frequently employed to examine user perceptions, satisfaction, and technology acceptance, while research and development (8.6%) emphasized the design and validation of innovative learning media. Other approaches, including quasi-experimental, design-based research, case studies, and literature reviews, demonstrate the growing diversity of research methodologies; however, mixed methods (3.6%) remain relatively limited, suggesting that the integration of quantitative and qualitative evidence has not been widely explored. This distribution reflects the current emphasis on effectiveness evaluation and technology validation, while highlighting the need for more comprehensive methodological approaches to better understand the long-term implementation and sustainability of digital learning innovations (Facciotti et al., 2025).The classification of future research categories is presented in the following table.

Table 12. Key Classifications in the Future Research Table Elicit AI

Categories	Frequency	Urgency Levels	Representative Examples
Improved Learning Outcomes	35	Height	Improved post-test scores, significantly improved concept understanding
User Motivation & Engagement	30	Height	Users are more active, interested in using learning media
Effectiveness of Learning Media	25	Height	Games/apps have proven to be effective as learning aids
Usability & User Experience (UX)	20	Medium	SUS evaluation, ease of use, user satisfaction
Technology Utilization (AI/VR/AR)	15	Medium	The use of VR/AI improves learning interactivity
System Constraints & Limitations	10	Height	Difficulty of use, limitations of features, user adaptation
Scalability & Implementation	5	Low	Large-scale use (MOOCs, online platforms)
Total	140	—	—

Based on the 140 selected studies, the highest-priority research topics were improving learning outcomes (35 articles), enhancing user motivation and engagement (30 articles), and evaluating the effectiveness of learning media (25 articles), indicating that current research primarily aims to maximize the educational benefits of digital technologies. These findings reflect the growing emphasis on developing learner-centered systems that improve academic performance while maintaining active user engagement. Studies addressing system limitations and constraints (10 articles) also represent an important research priority, as overcoming technical and usability challenges is essential for the successful implementation of digital learning systems. In contrast, scalability and implementation (5 articles) remain relatively underexplored despite their critical role in supporting the long-term adoption of educational technologies. These results suggest that future research should move beyond evaluating learning effectiveness by placing greater emphasis on scalable, sustainable, and practically implementable digital learning solutions integrated with emerging technologies such as artificial (Rizqiyana et al., 2022).

CONCLUSION

This study contributes a conceptual understanding of how digital learning media design, Human-Computer Interaction (HCI), and sustainability dimensions are interconnected in supporting long-term online learning implementation. The proposed framework highlights that sustainable educational technology adoption requires not only effective learning content but also user-centered design, usability, accessibility, and institutional readiness. Practically, the findings provide guidance for educators, technology developers, and educational institutions in designing digital learning environments that are adaptive, inclusive, and sustainable. However, this study has several limitations, including the reliance on literature indexed in the Scopus database, the selected publication period, and the limited availability of studies explicitly addressing environmental sustainability aspects of digital learning. Future research should validate the proposed framework through empirical studies across diverse educational contexts and further investigate strategies for

integrating technological, pedagogical, and environmental sustainability dimensions in digital learning ecosystems.

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In addition, the author appreciates the contributions of researchers and academics whose works are the main sources in this literature review. The support, input, and resources provided by various parties have made an important contribution to the completion of the research entitled *"Integrating Sustainable Media and Human-Computer Interaction (HCI) in Online Learning: Evidence from a Systematic Literature Review."*

AUTHOR CONTRIBUTION STATEMENT

SA and WH contributed to the conceptualization of research, methodology, literature search and analysis, data collection and curation, bibliometric analysis, implementation of Systematic Literature Review (SLR), interpretation of research results, preparation and revision of manuscripts, and final approval of published manuscript versions.

CONFLICTS OF INTEREST

The authors state that there is no conflict of interest in this study. The authors have no financial, professional, or personal interests that could affect the results, interpretation, or presentation of this research. This research is conducted independently without any influence from the sponsor in the selection of research topics, research design, data collection, data analysis, interpretation of results, manuscript writing, or decisions to publish research results.

INFORMED CONSENT STATEMENT

Not applicable. This research is a Systematic Literature Review (SLR) that uses secondary data in the form of scientific articles obtained from the Scopus database. This study did not involve human or animal participants directly so did not require informed consent.

USE OF ARTIFICIAL INTELLIGENCE (AI)-ASSISTED TECHNOLOGY

During the preparation of this study, the authors used Elicit AI and Scite AI to assist in the search, selection, and synthesis of literature in the *Systematic Literature Review* (SLR) process. The author also uses ChatGPT (OpenAI) to help with language editing and the preparation of academic manuscripts. All resulting results have been reviewed, verified, and re-edited by the authors, who are solely responsible for the final content of the publication.

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