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What Evidence Supports the Advancement of Language Learning Through Digital Innovation? Toward Achieving Sustainable Development Goals (SDGs) in the 21st Century Completed with Bibliometric Analysis

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ABSTRACT

This study aims to explore the role and contribution of digital technology in language learning and its connection to the achievement of Sustainable Development Goals (SDGs). A qualitative method was used through a Systematic Literature Review (SLR) to examine relevant articles from 2020 to 2025. To ensure transparency and rigor, the PRISMA protocol was adopted during the data identification, screening, and selection process. A quantitative bibliometric approach was applied to analyze keyword co-occurrence using VOSviewer, supporting the network visualization of the research landscape. The findings are presented: (i) a descriptive analysis covering publication trends by year, country, and subject area, and (ii) a keyword-based co-occurrence network visualization. The results reveal three major thematic clusters in technology-supported language education: sustainable digital pedagogy, the application of artificial intelligence, and the development of language and knowledge frameworks. Digital technology can broaden access to language education in underserved regions, support context-sensitive learning models, and improve the overall quality and equity of education. This study provides implementable recommendations for optimizing digital tools in inclusive, adaptive, and responsive ways to support the SDG 4 agenda for equitable and sustainable education.

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1. INTRODUCTION

The rapid advancement of digital technology has significantly transformed the global education landscape, opening up new opportunities to improve learning processes and outcomes more efficiently and innovatively. Digital technology itself refers to automated systems, generally computer-based, that are used to perform various tasks and process information quickly and accurately, reducing dependence on human manual labor [1–2]. Information processed through this technology is converted into a digital format in the form of a numeric representation (usually in the form of binary code 0 and 1), allowing the information to be processed, stored, and transmitted via electronic devices such as computers and other smart technologies [3–5].

In the context of language learning, the application of digital technologies such as artificial intelligence (AI), augmented reality (AR), virtual reality (VR), and various other digital innovations has presented an interactive, adaptive, and contextual learning approach. These technologies not only enable a more personal and dynamic learning process but also support various learning styles, expand access to education beyond the boundaries of the physical classroom, and encourage student independence in exploring learning materials independently [6–8]. However, behind the various potentials and pedagogical advantages offered, the use of digital technology in language learning still shows inequality in its implementation. In reality, the adoption of this technology generally only occurs in educational institutions that already have adequate technological infrastructure, high levels of digital literacy, and consistent policy support, resulting in gaps in access and use of technology between different regions or groups [9–11]. This situation shows the existence of structural barriers that still hinder the creation of inclusive and sustainable technology integration in the education sector.

This condition is further exacerbated by the limited alignment between the adoption of digital technologies in language teaching and the broader framework of global development, particularly the Sustainable Development Goals (SDGs). Many reports regarding SDGs have been well-documented (**Table 1**). Specifically, SDG 4 emphasizes the importance of providing inclusive, equitable, and quality education for all members of society, requiring educational strategies that are innovative, scalable, and long-term oriented [12–13]. Unfortunately, various digital initiatives in language education are often implemented in a fragmented manner and are not explicitly linked to these long-term sustainable development objectives.

Table 1. Previous studies on SDGs.

No	Title	Ref.
1	Safe food treatment technology: The key to realizing the Sustainable Development Goals (SDGs) zero hunger and optimal health	[14]
2	Analysis of student's awareness of sustainable diet in reducing carbon footprint to support Sustainable Development Goals (SDGs) 2030	[15]
3	Analysis of the application of Mediterranean diet patterns on sustainability to support the achievement of sustainable development goals (SDGs): Zero hunger, good health and well beings, responsible consumption, and production	[16]
4	Efforts to improve sustainable development goals (SDGs) through education on diversification of food using infographic: Animal and vegetable protein	[17]
5	Implementation of Sustainable Development Goal (SDGs) No. 12: Responsible production and consumption by optimizing lemon commodities and community empowerment to reduce household waste	[18]

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Table 1 (continue). Previous studies on SDGs.

No	Title	Ref.
6	The influence of environmentally friendly packaging on consumer interest in implementing zero waste in the food industry to meet sustainable development goals (SDGs) needs	[19]
7	The relationship of vocational education skills in agribusiness processing agricultural products in achieving sustainable development goals (SDGs)	[20]
8	Smart learning as transformative impact of technology: A paradigm for accomplishing sustainable development goals (SDGs) in education	[21]
9	Techno-economic analysis of production ecobrick from plastic waste to support sustainable development goals (SDGs)	[22]
10	Techno-economic analysis of sawdust-based trash cans and their contribution to Indonesia's green tourism policy and the sustainable development goals (SDGs)	[23]
11	Production of wet organic waste ecoenzymes as an alternative solution for environmental conservation supporting sustainable development goals (SDGs): A techno-economic and bibliometric analysis.	[24]
12	Hazard identification, risk assessment, and determining control (HIRADC) for workplace safety in manufacturing industry: A risk-control framework complete with bibliometric literature review analysis to support sustainable development goals (SDGs)	[25]
13	Sustainable packaging: Bioplastics as a low-carbon future step for the sustainable development goals (SDGs)	[26]
14	Contributing factors to greenhouse gas emissions in agriculture for supporting sustainable development goals (SDGs): Insights from a systematic literature review completed by computational bibliometric analysis	[27]
15	Characteristics of jengkol peel (Pithecellobium jiringa) biochar produced at various pyrolysis temperatures for enhanced agricultural waste management and supporting sustainable development goals (SDGs)	[28]
16	Effect of substrate and water on cultivation of Sumba seaworm (nyale) and experimental practicum design for improving critical and creative thinking skills of prospective science teacher in biology and supporting sustainable development goals (SDGs)	[29]
17	Innovative nanofluid encapsulation in solar stills: Boosting water yield and efficiency under extreme climate supporting sustainable development goals (SDGs)	[30]
18	Modernization of Submersible Pump Designs for Sustainable Irrigation: A Bibliometric and Experimental Contribution to Sustainable Development Goals (SDGs)	[31]
19	Integrating multi-stakeholder governance, engineering approaches, and bibliometric literature review insights for sustainable regional road maintenance: Contribution to sustainable development goals (SDGs) 9, 11, and 16	[32]
20	Computational engineering of malonate and tetrazole derivatives targeting SARS-CoV-2 main protease: Pharmacokinetics, docking, and molecular dynamics insights to support the sustainable development goals (SDGs), with a bibliometric analysis	[33]
21	A study on sustainable eggshell-derived hydroxyapatite/CMC membranes: Enhancing flexibility and thermal stability for sustainable development goals (SDGs)	[34]
22	Towards sustainable wind energy: A systematic review of airfoil and blade technologies over the past 25 years for supporting sustainable development goals (SDGs)	[35]
23	Assessment of student awareness and application of eco-friendly curriculum and technologies in Indonesian higher education for supporting sustainable development goals (SDGs): A case study on environmental challenges	[36]
24	Low-carbon food consumption for solving climate change mitigation: Literature review with bibliometric and simple calculation application for cultivating sustainability consciousness in facing sustainable development goals (SDGs)	[37]
25	Sustainable development goals (SDGs) in science education: Definition, literature review, and bibliometric analysis	[38]

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Although numerous studies have examined the effectiveness of specific technologies in improving various aspects of language learning, such as vocabulary acquisition [39–41], pronunciation [42–44], and reading comprehension [45]. Very few have comprehensively investigated how the integration of digital technologies can directly contribute to the achievement of Sustainable Development Goal 4 (SDG 4), which focuses on quality education. Most existing research remains limited to individual learning outcomes or specific linguistic skills, without linking them to broader macro-level issues such as access to education, equity, inclusivity, and long-term educational sustainability.

Several previous systematic literature reviews have explored the general relationship between education and the SDGs, such as the role of open and distance education[46], SDG integration in higher education institutions [47], the contribution of intellectual capital to sustainable development [48], the role of artificial intelligence in supporting SDG 4 [49], and self-directed learning approaches in mobile-assisted language learning [50]. However, these studies do not explicitly or holistically examine how digital technologies particularly within the context of language learning, contribute to the SDG 4 agenda in terms of strategic implementation, educational equity, and sustainable impact.

The urgency of this study lies in the growing demand for transformative educational models that not only integrate digital innovation but also ensure alignment with global development priorities, especially SDG 4 on quality education. In an era marked by technological acceleration and widening educational disparities, it is crucial to investigate how digital solutions in language education can bridge systemic gaps and foster inclusive, equitable, and lifelong learning opportunities.

This knowledge gap highlights the importance of conducting more strategic, integrative, and contextually grounded research to better understand the real contributions of digital technology in advancing sustainable education, especially in the field of language learning. Therefore, this study is both relevant and urgent, particularly in response to the global call for an inclusive, resilient, and digitally connected transformation of education.

This research aims to explore in depth how digital technologies are utilized in language teaching and the extent to which they support the achievement of SDG 4. A qualitative method was employed using a Systematic Literature Review (SLR) approach, focusing on critical review and synthesis of selected scholarly articles published between 2020 and 2025. In addition, this study integrates bibliometric analysis using VOSviewer software to visualize keyword co-occurrence and identify dominant terms and emerging research clusters within this field. The novelty of this study lies in its integrative perspective that frames digital technology not merely as a pedagogical tool but as a strategic enabler in building inclusive, high-quality, and sustainable language education systems aligned with the goals of SDG 4.

The research questions formulated in this study include:

(i) RQ1: What is the descriptive statistical distribution of the reviewed studies, including publication year, country of origin, and field of study?
(ii) RQ2: What categories of digital technology are utilized in the context of language learning?
(iii) RQ3: Which aspects of language learning are most frequently supported by digital technology?
(iv) RQ4: How is the implementation of digital technology linked to the achievement of Sustainable Development Goal 4 (SDG 4)?
(v) RQ5: What are the results of keyword co-occurrence visualization, and what thematic clusters are identified?

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(vi) RQ6: What research gaps are identified, and what are their strategic implications for the development of sustainable education?
(vii) RQ7: What optimization strategies can be proposed to effectively integrate digital technology into language teaching?

By addressing these questions, this study is expected to provide both theoretical and practical contributions in mapping policy directions, instructional design, and the development of language learning systems that support quality and sustainable education.

2. METHODS

This study employed a qualitative research method using a Systematic Literature Review (SLR) approach to explore the role and contribution of digital technology in language teaching and its connection to the achievement of Sustainable Development Goal 4 (Quality Education). The SLR approach was chosen because it provides a comprehensive and structured framework for identifying, evaluating, and synthesizing evidence from previous research. This is particularly important given that most existing studies tend to be fragmented, focusing only on the effectiveness of specific digital tools in enhancing linguistic components such as vocabulary, pronunciation, or reading comprehension, without explicitly linking them to sustainable education outcomes.

To strengthen the findings, this study incorporated a quantitative bibliometric analysis using VOSviewer software. Detailed information regarding this method is explained elsewhere [51-53]. This tool facilitates the creation of network visualizations based on keyword co-occurrence, enabling the identification of dominant themes, term relationships, and cluster structures across the selected articles. The integration of SLR and bibliometric analysis allows for a broader understanding of how digital technologies contribute to the development of equitable and quality language education aligned with SDG 4.

2.1. Identification

Studies were identified through the Scopus database. Data retrieval was conducted on 23 June 2025 using a combination of relevant keywords, namely technology, language, and Sustainable Development Goals. These keywords were applied to the title, abstract, and keywords of the article with the Boolean operator “AND” to direct the search only to articles that specifically discuss the three topics. The search query used was: TITLE-ABS-KEY("technology") AND TITLE-ABS-KEY("language") AND TITLE-ABS-KEY("Sustainable Development Goals"). This strategy was used to ensure that the articles retrieved were directly related to the integration of technology in language learning that contributes to the achievement of the Sustainable Development Goals (SDGs). From the search results, 189 articles were obtained that met the initial criteria before further screening and selection processes were carried out.

2.2. Screening

The studies were collected using predetermined keywords in the Scopus database, followed by a systematic screening process. Screening was conducted to ensure that only relevant and high-quality articles meeting the inclusion criteria were retained for further analysis. Eligible articles were required to contain information closely aligned with the research focus, as reflected in the keywords identified in their titles and abstracts.

The screening criteria included several key aspects:
(i) Publication year between 2020 and 2025,

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(ii) Written in English,
(iii) Categorized as scientific journal articles (excluding conference proceedings, book chapters, theses, or technical reports),
(iv) Fully published (not in-press),
(v) Freely available as open-access articles,
(vi) Published in journals indexed in Scopus.

The purpose of applying these criteria was to improve the accuracy of study selection and ensure the consistency and quality of the sources used. Literature that did not meet the criteria, such as non-English documents or non-journal formats, was excluded due to limitations in accessibility and academic reliability.

This entire screening process was systematically documented and is presented in **Table 2**. Based on **Table 2**, out of the initial 189 articles retrieved from Scopus, 159 were excluded for not meeting one or more of the criteria. Consequently, 30 articles were retained and deemed suitable for in-depth analysis. This process ensured that only articles meeting methodological standards were included in the final dataset for further examination.

Table 2. Screening Process of Articles.

Criteria	Inclusion	Exclusion
Publication Year	2020–2025	Outside the 2020–2025 range
Document Type	Scientific journal article	Conference paper, book chapter, thesis, technical report
Language	English	Not written in English
Publication Status	Fully published	In-press or unpublished articles
Accessibility	Open access	Not available as open access
Journal Indexing	Indexed in Scopus (Q1–Q4)	Not indexed in Scopus

2.3. Included

The initial data analysis involved a total of 189 articles retrieved during the identification phase. After the preliminary screening process, 30 articles were considered to meet the basic inclusion criteria and were eligible for further analysis. Subsequently, a comprehensive quality assessment was conducted to ensure that the selected articles demonstrated strong scientific validity and were relevant to the research focus.

The evaluation process considered four main aspects: the context of the study, the clarity of research objectives, the methodology employed, and the quality of research findings and analysis. These evaluation criteria were designed to ensure that only high-quality scholarly articles were included in the final analysis. The detailed criteria are summarized in **Table 3**.

Each article was scored based on these four aspects using a 1-to-4 scale, as outlined in **Table 4**.

Table 3. Quality Assessment Criteria of Articles.

No	Criteria	Description
1	Study Context	Does the article clearly explain the research plan, implementation, and development?
2	Research Objectives	Are the research aims described in a detailed and focused manner?
3	Methodology	Does the article elaborate on research design, sample, data collection, and data analysis?
4	Research Findings	Are the data and results presented and analyzed thoroughly?

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Table 4. Article Quality Scoring Scale.

Criteria	Score 4 (Excellent)	Score 3 (Good)	Score 2 (Fair)	Score 1 (Poor)
Study Context	The research framework and theoretical basis are fully explained	The theoretical framework is presented	General explanation with limited detail	Not explained
Research Objectives	Objectives are detailed and focused	Objectives are clearly stated	Objectives are presented in general terms without specificity	Objectives are not clearly stated
Methodology	Research design, sample, data collection, analysis, and validation are fully explained.	Most aspects are covered, but lack detail on validation	Design and data collection are explained with limited detail, and no analysis	The methodology is inadequately explained
Research Findings	Data and results are analyzed and comprehensively explained	Data and results are presented	Data is presented generally, lacking detailed interpretation	Data and results are not fully presented

Each article could receive a maximum score of 16 if all criteria were rated with the highest score or a minimum score of 4 if none were met. Articles scoring below 8 were excluded from further analysis. The quality assessment results showed that 30 articles met the evaluation standards and were deemed suitable for in-depth analysis.

This selection process was conducted systematically to minimize potential bias and ensure the credibility of the research. All stages of the article identification and selection followed the PRISMA protocol, which is illustrated in **Figure 1**.

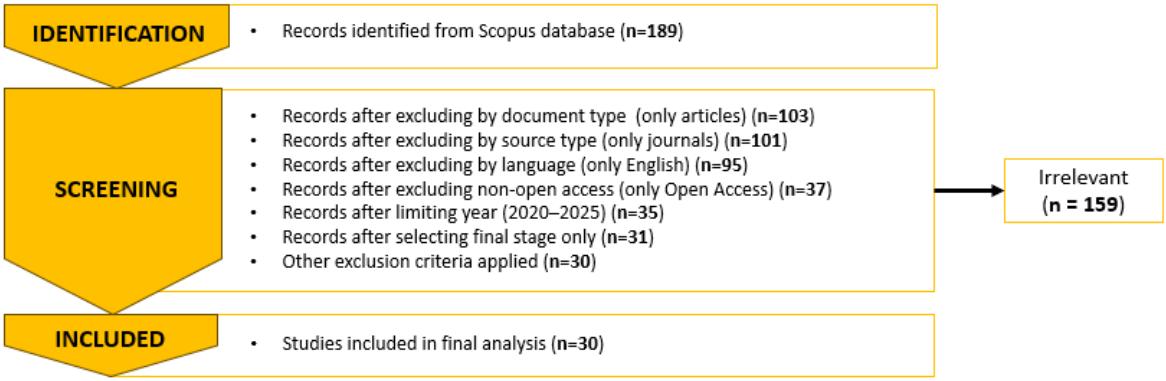

Figure 1. SLR process flow following the PRISMA protocol.

3. THEORETICAL FRAMEWORK

3.1. Development of Digital Technology

The development of digital technology is the result of a long technological evolution, beginning with the agricultural era, continuing through the industrial era, and progressing into the information and communication era [54,55]. Each of these phases has brought significant changes in the way people live, work, and interact socially. The peak of this transformation is marked by the digital revolution, which integrates computers, the internet, and global communication into an intelligent system that enables efficiency and automation across various sectors of life [56].

The invention of the computer was a key milestone in the advancement of digital technology. Since the emergence of first-generation computers after World War II, computing

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technology has continuously evolved culminating in the microprocessor and the internet era, which enabled global connectivity [57]. The integration of computers and communication technologies gave rise to the internet as a global information infrastructure that facilitates unlimited data exchange across time and space.

Furthermore, the advancement of digital technology has been driven by the rise of smart applications and mobile devices, such as smartphones, that support daily activities through features like digital communication, e-commerce, social media, and productivity tools [58]. Intelligent systems such as ATMs, mobile banking, and artificial intelligence (AI) have replaced many manual roles, creating greater efficiency in business and public services.

The turn of the millennium is often referred to as the digital era, as almost every aspect of human activity is now intertwined with digital technology. Concepts such as the Industrial Revolution 4.0, Japan's Society 5.0, Smart Cities in Asia, the Industrial Internet in North America, and China's "Made in China 2025" demonstrate how digital transformation has become a core pillar of national development strategies. The adoption of technologies like the Internet of Things (IoT), AI, and big data has created a digital ecosystem that bridges the physical and virtual worlds in an adaptive and intelligent manner.

In the field of education, this transformation has led to the emergence of digital systems that are replacing traditional ones, including digital transactions, e-learning, e-libraries, and various other online services [59]. These changes reflect a paradigm shift toward a connected society, where digitalization is not merely a supporting tool, but a foundational element in building equitable, inclusive, and sustainable access to education.

Understanding the trajectory of digital technology development provides a solid theoretical foundation for examining how these technologies are integrated into language education and how they contribute to the achievement of the Sustainable Development Goals, particularly SDG 4 on quality education.

3.2. Definition of Digital Technology

Digital technology is a form of information technology that focuses on the use of computerized systems to carry out various activities, replacing human labor with automated systems based on digital devices [60]. This technology operates on the principle of processing information in numerical data form, particularly through binary systems (0 and 1) that can be read, processed, and stored by computers [61]. Essentially, digital technology is not merely a technical aid, but a high-speed calculation system capable of managing various types of information such as text, images, audio, and video efficiently and accurately [62].

The emergence and development of digital technology have had a significant impact on the quality and efficiency of data management. Images become sharper, storage capacity becomes more efficient, and data transmission processes become faster and more stable. This technology has also driven the emergence of various innovations in the fields of communication and information, including the development of data communication networks ranging from HSDPA, 2G, 3 G, and 4G to the current 5G technology [63]. These advancements not only support personal communication but also accelerate the transformation of public services and business information systems.

Furthermore, digital technology evolves around three main pillars: digital transition, network convergence, and digital infrastructure [64]. Digital transition refers to the shift from manual or analog systems to digital systems across various aspects of life [65]. Network convergence refers to the integration of multiple communication functions, such as telephony, video, and data, into a unified and efficient system, both in households and industries. Meanwhile, digital infrastructure refers to the systems and devices that support

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the digital ecosystem, including internet networks, hardware, and software applications that are interconnected [66].

Digital technology is also adaptive to changes in lifestyle. For instance, the increasing need for flexibility between work and leisure (work-life blend) has encouraged the digital industry to offer relevant technological solutions, ranging from mobile devices and digital entertainment services to online learning (e-learning) systems. The convergence of work, leisure, and mobility presents both a challenge and an opportunity for technology producers to develop products that align with modern lifestyle trends.

Therefore, digital technology functions not only as a technical tool but also as a transformative force that reshapes patterns of communication, learning, work, and interaction across various sectors. Its rapid development serves as a key foundation for driving innovation, service efficiency, and the advancement of a knowledge-based society in the era of the Fourth Industrial Revolution.

3.3. Definition of Language Learning

Language learning refers to the process through which individuals acquire or develop proficiency in one or more languages, encompassing skills such as listening, speaking, reading, and writing. In the digital era, language learning is increasingly mediated by technology, as seen in Computer-Assisted Language Learning (CALL), which emphasizes learner autonomy, interactivity, and multimedia engagement [67]. CALL highlights the role of computers not merely as tools, but as interactive environments that facilitate individualized, communicative, and integrative language learning experiences.

Moreover, language learning is not only a cognitive-linguistic activity but also a socially situated process. Language learning plays a central role in language learning, as learners invest in language practices that are shaped by power relations, access to resources, and imagined communities. Language learning thus involves both the acquisition of linguistic competence and the negotiation of social identity within specific cultural and communicative contexts [68].

In sum, language learning in contemporary contexts integrates technological tools and socio-cultural dynamics, making it a multifaceted process that combines skill development, identity formation, and digital engagement.

3.4. Definition of Sustainable Development Goals (SDGs)

The Sustainable Development Goals (SDGs) are a global agenda initiated by the United Nations in 2015, comprising 17 interlinked goals designed to serve as a blueprint for achieving a better and more sustainable future for all by 2030 (see **Figure 2**). Fundamentally, the SDGs aim to balance economic growth, social inclusion, and environmental protection through an integrated and universal approach to development [69]. This systems-based perspective emphasizes the interconnectedness of global challenges and the need for coordinated solutions that address the complexity of sustainable progress.

From a theoretical standpoint, SDGs embody both normative aspirations and strategic frameworks for nations to align their policies with long-term sustainability targets. The SDGs offer not only a theoretical foundation for sustainable development but also a holistic structure for empirical assessment and policy integration across sectors, particularly in addressing inequality, environmental degradation, and economic resilience [70].

In the field of education and technology, the integration of SDGs has become increasingly relevant. Ragadhita *et al*. [71] highlight that in engineering education, for instance, the SDGs serve as a foundation for developing interdisciplinary, socially responsible, and future-ready

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curricula. Similarly, Regona *et al*. [72] reveal that advancements in digital technologies, particularly artificial intelligence, have significant potential to accelerate progress toward multiple SDGs, especially when applied in strategic sectors like construction, urban planning, and education.

As the world reaches the mid-term point of SDG implementation, critical reflections on their progress and effectiveness have emerged. Sorooshian [73] notes that while global efforts have generated momentum, many goals remain off track, thereby requiring enhanced cross-sector collaboration, data-driven policymaking, and stronger stakeholder engagement. Collectively, these insights reaffirm the SDGs as not only aspirational benchmarks but also operational frameworks that call for systemic change, digital transformation, and inclusive development at all levels.

Figure 2. 17 Pillars of Sustainable Development Goals (SDGs).

4. RESULTS AND DISCUSSION

4.1. Descriptive Statistics of the Reviewed Studies

Figure 3 illustrates the distribution of selected articles based on their year of publication from 2020 to 2025. The trend shows a noticeable increase in scholarly interest over the years, particularly in the last three years of the observed period. In 2020, there were 5 relevant articles, followed by a slight drop to 3 in 2021, and reaching the lowest point in 2022 with only 2 articles. However, the trend significantly improved in the following years, with 4 articles in 2023, 6 in 2024, and peaking in 2025 with 11 articles.

The dotted trend line in the figure indicates a positive linear trajectory, reflecting growing academic engagement with the topic of digital technology in language learning and its intersection with the Sustainable Development Goals (SDGs). This growth suggests not only increased research activity but also greater recognition of the importance of integrating educational technology in support of global development agendas, particularly SDG 4 (Quality Education).

The spike in publications in 2025 can be attributed to several contextual factors:

(i) The post-pandemic acceleration of digital transformation in education has prompted deeper exploration of tech-based pedagogies.

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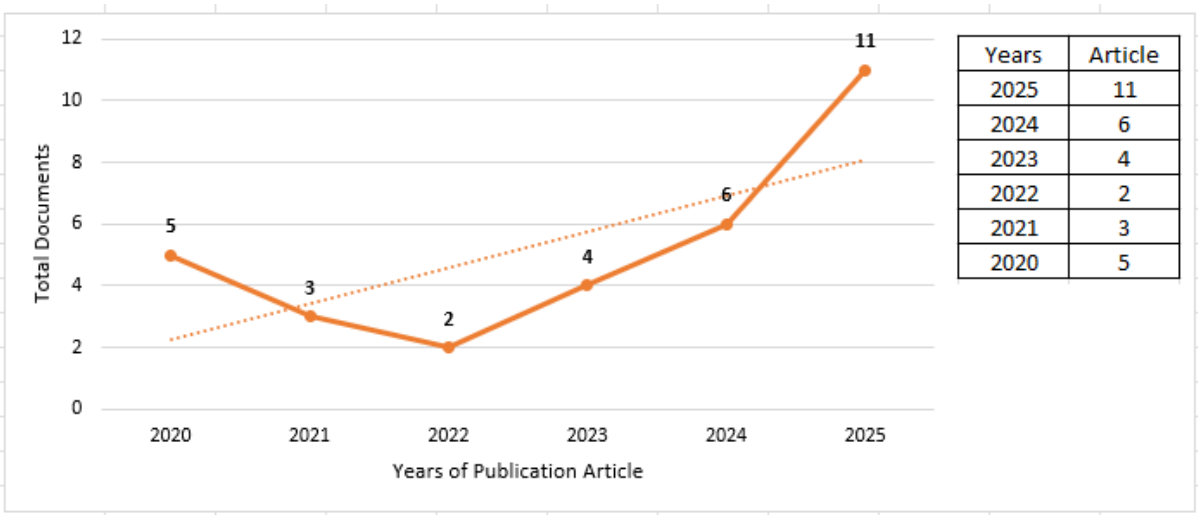
(ii) Strengthened alignment of educational policies and research agendas with the 2030 Sustainable Development Goals, particularly in areas of inclusive and equitable education.
(iii) The proliferation of open-access publishing platforms and international collaboration has broadened the visibility and dissemination of educational research.



Years	Article
2025	11
2024	6
2023	4
2022	2
2021	3
2020	5

Figure 3. The distribution of the reviewed documents across publication years from 2020 to 2025 shows an increasing trend in research output over time.

This trend is consistent with the findings of Ugalingan *et al*. [74], who showed that incorporating SDG-related themes into language learning, especially in digital or online settings, can enhance not only linguistic competence but also learners' awareness of global issues. Such integration supports a dual function of technology in education: as a pedagogical tool and a driver of global citizenship.

Additionally, Zahir *et al*. [75] emphasize the importance of inclusive design in technology-mediated language instruction, such as the provision of speech therapy programs in the Maldives, which align with both SDG 4 and SDG 10 (Reduced Inequalities). Their research reinforces the notion that digital tools should be embedded within frameworks that prioritize accessibility, equity, and culturally responsive teaching.

Taken together, the data in **Figure 3** reflect an upward momentum in the research community toward leveraging digital technology for sustainable language education. This trend may continue beyond 2025 as institutions, researchers, and policymakers increasingly adopt SDG-aligned strategies and digital pedagogies to address both local and global educational challenges.

Figure 4 illustrates the distribution of publications based on the country or region of origin of the authors. The visualization shows that China leads with a total of seven publications, followed by India and the United States with six publications each. Spain ranks next with five publications, while Australia, France, Malaysia, and the Netherlands each contributed four publications. Brazil and Germany follow with three publications respectively.

This distribution highlights the global interest in the integration of digital technology into language education and its relation to Sustainable Development Goals (SDG 4). However, the dominance of countries with strong research capacity and digital infrastructure (e.g., China, India, USA) is apparent. These countries are not only active in educational research but also in broader digital transformation efforts across sectors.

The high number of publications from China and India aligns with the global trend of digitalization, where both countries are investing heavily in educational technologies and

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innovation. According to Del Giudice *et al*. [76], nations that prioritize digital transformation tend to become centers of knowledge creation, particularly in contexts linked to sustainability. Similarly, Similarly, Naik *et al*. [13] emphasize that India's national policies on education and technology integration, despite facing structural challenges, have led to increased scholarly outputs on digital learning frameworks. Rehman Khan *et al*. [77] highlight, too, the importance of policy support, infrastructure readiness, and cross-sectoral synergy in advancing the implementation of technology-driven sustainability initiatives.

This trend is also supported by findings from Wang *et al*. [1] and Cheng *et al*. [2], who explain that the successful adoption of digital technology across disciplines is often driven by a combination of policy support, industry academia collaboration, and technological readiness. In the context of language education, these conditions enable researchers to explore not only instructional design but also how digital learning tools can promote inclusivity, equity, and sustainability.

Beyond technological capability, cultural and pedagogical priorities also shape the research output in different regions. For example, the prominence of studies from the United States and Spain may reflect long-standing academic interests in educational innovation, multicultural classrooms, and technology-enhanced language instruction, as also noted by Lu *et al*. [11] in their study on pre-service language teachers' technology adoption.

Interestingly, contributions from countries such as Malaysia and Brazil, though numerically fewer, signal the emerging role of developing economies in shaping the global discourse on educational technology. These countries are increasingly leveraging digital tools to address local learning gaps while also participating in broader conversations about the SDGs. The study by Purmayanti [9], for example, highlights challenges and opportunities in implementing digital literacy among Indonesian EFL learners, reflecting the regional relevance of this research.

Moreover, the global distribution observed in **Figure 4** affirms that interest in the SDG-aligned integration of digital technology in language education is not geographically limited. Rather, it reflects a shared educational imperative that cuts across continents, languages, and economic conditions.

In light of this, future research should explore not only technological tools but also the policy ecosystems, teacher readiness, and learner agency that enable meaningful integration of technology in line with the 2030 education agenda. As noted by Snyder [78], literature reviews and systematic mappings like this play a critical role in synthesizing cross-country developments to inform evidence-based educational policy and innovation.

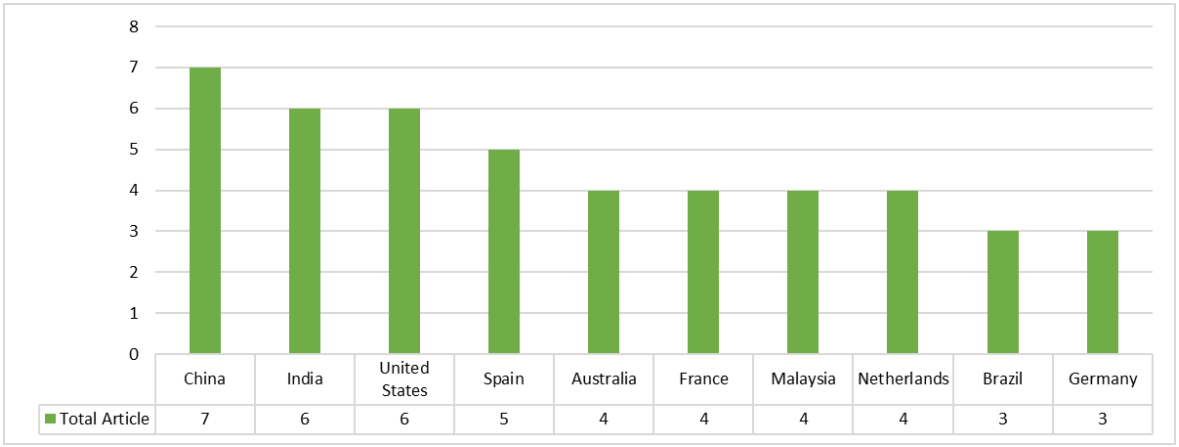

Figure 4. Distribution of documents by country of origin, based on the top 15 countries with the highest number of publications.

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Figure 5 presents the distribution of subject areas represented by the 30 articles analyzed in this study. The majority of articles fall under the field of Social Sciences (23.6%), followed by Computer Science and Other (each 12.5%), and Environmental Science (11.1%). Other contributing disciplines include Business, Management & Accounting (8.3%), Agricultural and Biological Sciences (6.9%), Engineering (6.9%), Energy (6.9%), Arts and Humanities (5.6%), Chemical Engineering (2.8%), and Earth and Planetary Sciences (2.8%).

The dominance of articles from the Social Sciences highlights that the study of digital technology in language education and its relevance to SDG 4 is not merely viewed as a technical matter but rather as a broader social, policy, and educational issue. This aligns with the findings of Rehman Khan *et al*. [77], who argue that the implementation of sustainable technology in certain sectors, such as tourism, requires an interdisciplinary approach that considers social and cultural contexts in order to develop adaptive and inclusive recommendation systems. Meanwhile, Herrera-Franco *et al*. [79] emphasize the importance of disciplinary diversity in generating a comprehensive understanding of the complex phenomena associated with sustainable development.

Therefore, this multidisciplinary distribution suggests that the integration of digital technology in education, particularly in language teaching, requires contributions from multiple fields to ensure that the solutions developed are holistic and applicable across various social contexts.

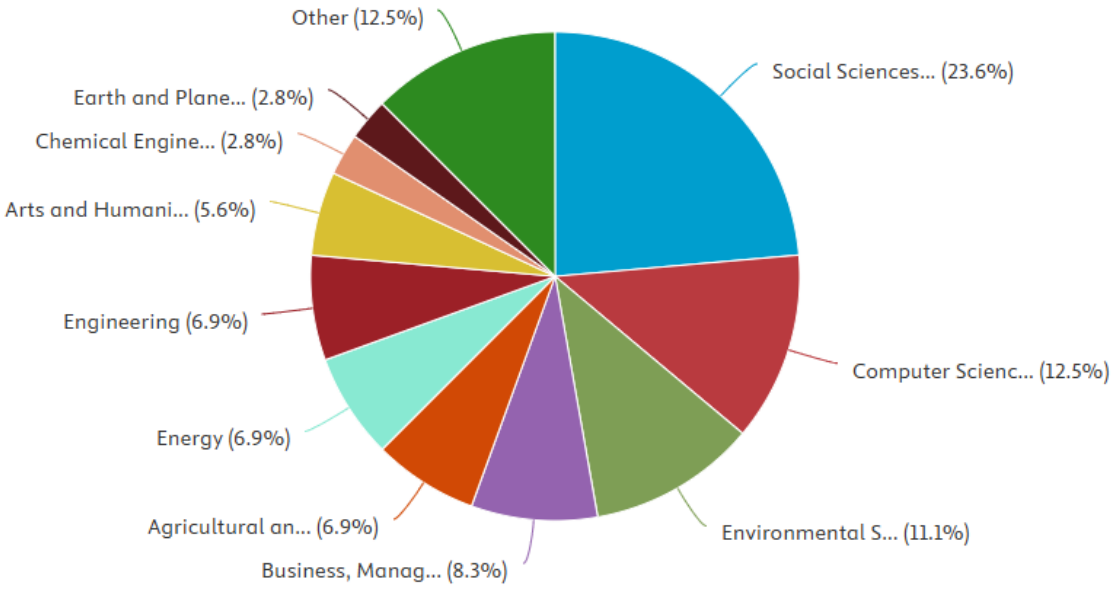

Figure 5. Distribution of subject areas in the reviewed articles.

Table 5 presents the ten most highly cited documents among the 30 articles analyzed in this study. The article by Chan *et al*. [80], titled "Levers and leverage points for pathways to sustainability", ranks first with 214 citations, indicating its substantial influence in academic discourse on sustainability. The second position is occupied by Del Giudice *et al*. [76] with 132 citations, discussing digitalization and sustainable business models in the maritime sector through a bibliometric approach. Next, the article by Radovanovic *et al*. [81], which develops digital literacy performance indicators for sustainable development, has received 91 citations, highlighting the critical role of digital literacy in the context of the SDGs.

Other significantly cited documents include those by Rehman Khan *et al*. [77] and Herrera-Franco *et al*. [79], with 42 and 34 citations, respectively. These studies address

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recommendation systems for sustainable e-tourism and a bibliometric analysis of scientific research in Ecuador. The remaining articles in the list cover diverse topics such as the use of language in community-based tourism, socially relevant microbiology education concepts, rural spatial data infrastructure, and the circular economy through the Airbnb platform.

The high number of citations for certain articles reflects two key aspects: first, a concentrated scholarly interest in interdisciplinary and practical themes; and second, the growing global academic attention toward sustainability, digitalization, and educational technology. These highly cited articles serve as critical foundations that shape the direction and focus of subsequent research, including those that explore language education in support of achieving SDG 4.

Table 5. The top ten most cited documents among the articles analyzed in this study.

No.	Author	Title	Year	Citation	Ref
1.	Del Giudice *et al*.	Digitalization and new technologies for sustainable business models at the ship–port interface: a bibliometric analysis	2022	132	[76]
2.	Rehman Khan *et al*.	Systematic review of contextual suggestion and recommendation systems for sustainable e-tourism	2021	42	[77]
3.	Herrera-Franco *et al*.	Scientific research in Ecuador: A bibliometric analysis	2021	34	[79]
4.	Chan *et al*.	Levers and leverage points for pathways to sustainability	2020	214	[80]
5.	Radivanovic *et al*.	Digital literacy key performance indicators for sustainable development	2020	91	[81]
6.	Agarwal & Ojha	Prioritizing implications of Industry-4.0 on the sustainable development goals: A perspective from the analytic hierarchy process in manufacturing operations	2024	25	[82]
7.	Nomnian *et al*.	Language and community-based tourism: Use, needs, dependency, and limitations	2020	24	[83]
8.	Timmis *et al*.	A concept for international societally relevant microbiology education and microbiology knowledge promulgation in society	2024	15	[84]
9.	Iban & Aksu	A model for big spatial rural data infrastructure in Turkey: Sensor-driven and integrative approach	2020	15	[85]
10.	He & Mai	The circular economy: A study on the use of Airbnb for sustainable coastal development in the Vietnam Mekong Delta	2021	13	[86]

4.2. Category Digital Technology in Language Teaching

Based on the literature analysis conducted, various types of digital technologies used in the context of language teaching were found, which were categorized into five main groups, namely: Artificial Intelligence (AI), Mobile-Assisted Language Learning (MALL), Augmented & Virtual Reality (AR/VR), Learning Management Systems (LMS), and Digital Game-Based Learning. Each category reflects the focus of use and specific contributions of technology in supporting language learning and the achievement of SDG 4 (see **Table 6**).

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Table 6. Summary of Digital Technology Categories in Language Teaching.

No	Technology Category	Description of Use	Ref.
1	Artificial Intelligence (AI)	ChatGPT, NLP, and LLMs are used to enhance reflection, grammar adaptation, and conceptual understanding	[87-89]
2	Mobile-Assisted Language Learning (MALL)	Mobile application with location-based contextual information	[90]
3	Augmented and Virtual Reality (AR/VR)	VR integrated with IoT and NLP for immersive learning experiences	[91]
4	Learning Management Systems (LMS)	Digital platforms with deep learning-based data analysis	[92]
5	Digital Game-Based Learning	Game-based collaborative activities and experimental tasks	[93]

Based on **Table 5**, the first category is Artificial Intelligence (AI), including the use of natural language processing (NLP), machine learning, and large language models (LLMs)-based technologies such as ChatGPT. Xiaoyu *et al*. [87] evaluated the effectiveness of ChatGPT in environmental education and found that AI can enhance conceptual understanding through a conversational interface that supports self-reflection and exploration. Yu [88] added that NLP-based systems can be used to develop automatic and adaptive grammar question search methods in English e-learning platforms. Mao *et al*. [89] also stated that the use of LLMs in the medical context shows the broad potential of AI for other educational applications, including in the field of language teaching.

Furthermore, the Mobile-Assisted Language Learning (MALL) category includes the use of mobile applications to support flexible and personalized language learning access. Gallegos *et al*. [90] developed a smartphone application that integrates location-based information, demonstrating how mobile devices can present content contextually and adaptively to user needs. Although the study focused on land security, the implications for location-based learning can also be applied in the context of language learning.

The third category is Augmented & Virtual Reality (AR/VR), which is used to create immersive and interactive learning environments. Bhuyan *et al*. [91] explored the use of a combination of VR technology with cloud and IoT-based NLP, which can create a language learning experience that is close to reality and allows active engagement of learners. This technology supports multimodal integration in learning that is in line with the principles of sustainable education.

The next category, Learning Management Systems (LMS), refers to digital platforms that systematically manage and deliver learning content. Rangasamy *et al*. [92] showed that the use of deep learning for ESG data analysis in LMS can be transformed into a language learning system that leverages big data to customize materials and assessments. LMS also enables cross-disciplinary integration relevant to the sustainability context.

Finally, Digital Game-Based Learning was introduced through the study of Kim *et al*. [93], who used an online global experiment-based activity (water testing) to enhance the STEM competencies of community college students. Although this study was in the field of chemistry, its collaborative, game-based learning design can be applied in language learning to build communication and problem-solving skills in real contexts.

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4.3. Focus on Technology-Supported Language Learning

The use of digital technology in language learning has encouraged exploration of various aspects of language (see **Table 7**). Based on **Table 7**, there are five main areas of focus of the research, namely vocabulary mastery, speaking and pronunciation skills, reading comprehension, writing skills, and written language representation. Each aspect has a different approach to technology integration. The following is a more detailed explanation of the focus of language learning supported by technology.

(i) Vocabulary and Grammar Acquisition. Yu [88] highlighted the role of Natural Language Processing (NLP) technology in helping language learners understand and master grammatical structures, especially in the context of online questions. The NLP-based approach enables the system to generate grammatical questions that are contextual and adaptive to the learner's abilities, which indirectly also supports vocabulary acquisition through contextual exposure. This is in line with the trend of increasing efficiency in technology-assisted grammar teaching.

(ii) Speaking and Pronunciation Skills. Zahir *et al*. [75] emphasized the importance of designing inclusive technology-based speech therapy services to support speaking skills in a region like the Maldives. This study highlights the role of technology in providing speech-based services that are adaptive to local needs. Technology is also utilized to create learning environments that are sensitive to cultural and linguistic contexts, especially for vulnerable groups.

(iii) Reading Comprehension and Critical Literacy. Research by Bhat *et al*. [94] shows how a gender-based linguistic approach is used to examine digital fiction literature in language learning. This study reflects the use of digital literature to shape critical reading comprehension skills, not only linguistically, but also by considering the social and ideological contexts in the text.

(iv) Writing and Language Representation Skills. Alshraah *et al*. [95] underline the importance of digital literacy in supporting language representation skills, including writing, as part of sustainable educational empowerment. Technology integration helps expand access to collaborative writing platforms and more inclusive narrative development, especially for women and marginalized communities.

(v) Reinforcement Through Generative Language Models. Koteczki *et al*. [96] showed that Large Language Models (LLMs) can be integrated into the language learning modeling process to improve the efficiency of assignments and assessments, especially in aspects of text production such as writing. This system not only helps in providing automatic feedback but also in the formation of better sentence structures and ideas.

Table 7. Focus on Language Aspects in Technology-Based Learning.

Language Aspect	Research Focus	Ref.
Vocabulary and Grammar	Online grammar questions based on NLP	[88]
Speaking and Pronunciation	Digital and adaptive speech therapy services	[76]
Reading Comprehension	Critical analysis of digital literary texts based on gender	[94]
Writing Skills	Digital literacy and inclusive writing based on gender	[95]
Written Language Representation	Task modeling assisted by LLM for efficiency and sustainability	[96]

4.4. Linkage Digital Technology with Sustainable Development Goals (SDG 4)

The analysis of 30 selected articles shows that the integration of digital technologies in language teaching has a significant contribution to several key indicators in the Sustainable

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Development Goals, especially SDG 4 (Quality Education) (see **Table 8**). Based on **Table 8**, the focus of these contributions can be categorized into four main aspects: inclusiveness of education, improving the quality of language learning, scalability and access to educational technology, and equalizing learning opportunities in limited areas.

(i) Educational Inclusivity. Many studies have highlighted the role of technology in enhancing educational inclusion for vulnerable groups and marginalized communities. Rehman Khan *et al*. [77], for example, in their systematic review found that contextual recommendation systems in e-learning were able to increase the participation of users from diverse social and cultural backgrounds. Alshraah *et al*. [95] also asserted that digital initiatives that consider gender equality in language education can narrow the access gap between boys and girls.

(ii) Quality of Language Learning. Technology not only expands access but also improves the quality of learning. Studies by Yu [88] and Kim *et al*. [93] showed that the integration of NLP (Natural Language Processing) and digitally assisted global project-based learning was able to improve student engagement, grammatical comprehension, and cross-cultural communication competence. This reflects a more interactive and contextual quality of language learning.

(iii) Scalability and Access to Technology-Based Education. The use of technologies such as artificial intelligence, recommendation systems, and cloud-based applications has proven to be able to reach a wider population of learners. For example, studies by Bhuyan *et al*. [91] and Rangasamy *et al*. [92] show how IoT and deep learning models can support sustainable learning infrastructure in various sectors, including languages. This allows for efficient distribution of learning resources and personalization of content based on learner needs.

(iv) Equalizing Learning Opportunities in Limited Areas. Several studies also underline the importance of developing location-based applications and open resources to reach underserved areas. Iban & Aksu [85] emphasize the need for a spatial data infrastructure that supports information dissemination in remote areas. Similar things are also seen in the educational application developed by Gallegos *et al*. [90], which presents land and agriculture-based content to support contextual education in rural areas.

Table 8. Research Contribution to SDG Pillar 4.

No	Contribution Aspect	Description	Ref.
1	Inclusivity of Education	Technology improves access for vulnerable groups and gender equality.	[77], [79], [95]
2	Quality of Language Learning	NLP and collaborative approaches improve language skills.	[88], [93], [95]
3	Scalability and Technology Access	Cloud, AI, and deep learning support large-scale and personalized learning.	[91], [92], [82], [87]
4	Equalizing Learning Opportunities in Limited Areas	Location-based applications and community models support learning in remote areas.	[85], [90], [83]

These findings as a whole confirm that digital technology plays a key role (leverage point) in the transformation of education to be more inclusive, equitable, and quality. As stated by Chan *et al*. [80], the use of technology needs to be placed within a sustainability framework so that the results are not only effective in the short term but also reach the long-term goals of human development.

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4.5. Visual Analysis: Keyword Co-occurrence Results

Figure 6 shows a visualization of the keyword co-occurrence network of the 30 articles analyzed, generated using the VOSviewer software. This network illustrates how the main keywords are related to each other in a literature corpus. Each node represents a keyword, while the lines between nodes indicate the strength of the co-occurrence based on the frequency of their co-occurrence in the same document. The larger the node, the higher the frequency of its occurrence, while the thickness of the lines indicates the strength of the relationship between words [97-101].

Based on **Figure 6**, three main clusters are identified, marked with different colors: red, green, and blue clusters. The red cluster is dominated by keywords such as sustainable development goal, technology, study, and SDGs, indicating a focus on the conceptual dimension and goals of sustainable development. The green cluster contains words such as language, application, information, and artificial intelligence, indicating a focus on the application of technology in language learning. Meanwhile, the blue cluster, with keywords such as development, knowledge, and natural language processing, represents issues related to system development and natural language processing in a digital context.

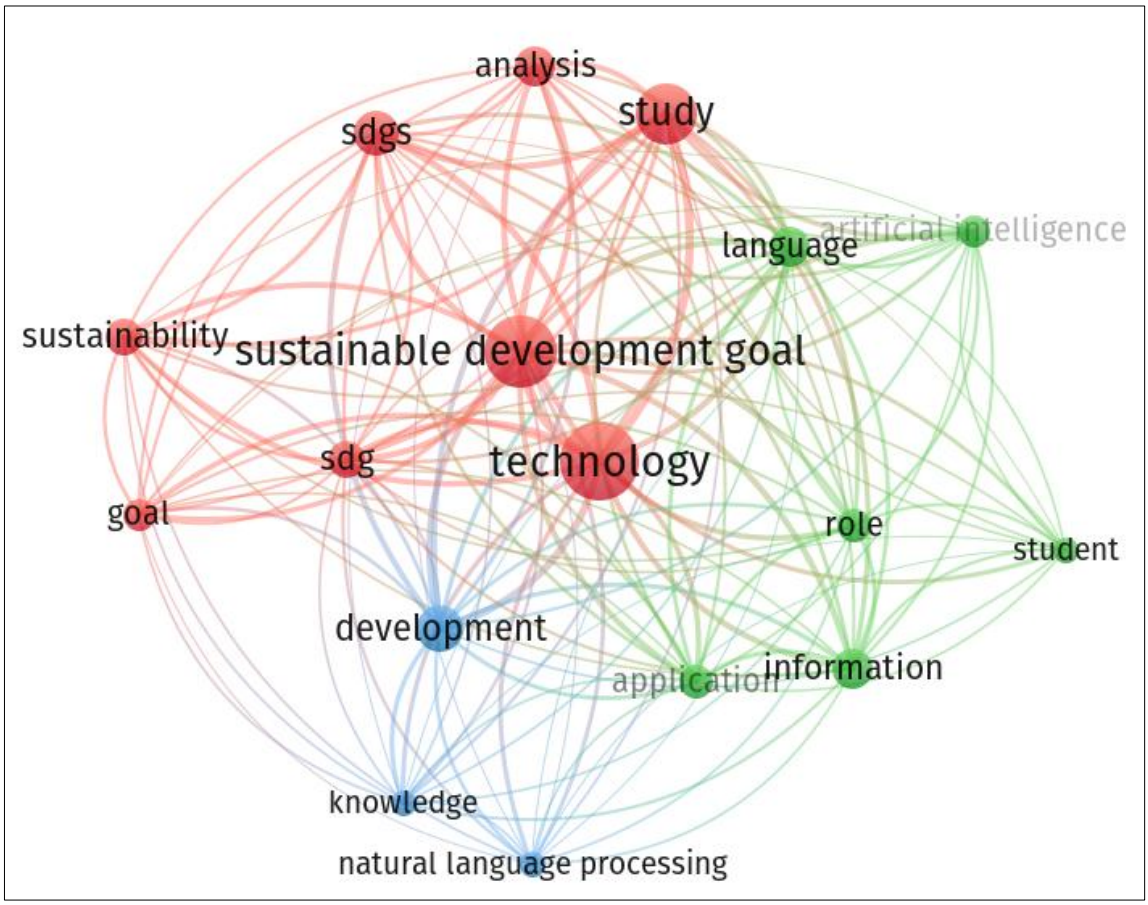

Figure 6. Keyword co-occurrence network visualization.

Table 9 presents the distribution of keywords based on clusters formed through keyword co-occurrence network analysis using VOSviewer software. As previously explained, overall, there are three main clusters formed, each marked with a different color: red (Cluster 1), green (Cluster 2), and blue (Cluster 3). Cluster 1 (red) is the most dominant, consisting of keywords such as technology, sustainable development goal, study, SDGs, and sustainability. The word technology is recorded as having the highest number of occurrences, namely 28

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times, with the highest relationship strength (total link strength) of 164, indicating that the issue of technology is central to the discourse on SDG integration in language teaching. Meanwhile, the word sustainable development goal appears 25 times with a relationship strength of 147, strengthening the position of this topic as a conceptual foundation in the publications analyzed. This cluster represents the conceptual and reflective realm, where studies focus on the urgency, approach, and strategy for achieving SDGs through digital transformation.

Different from Cluster 1, Cluster 2 (green) highlights more practical and implementable aspects. Keywords such as application, artificial intelligence, information, language, role, and student reflect the close relationship between the use of cutting-edge technology, especially artificial intelligence, and the language learning process. The strength of the relationship between the words language and information, which both reached 74, and the frequency of occurrence was 11 times, indicating the importance of the role of technology in managing information and supporting more efficient language teaching. This cluster also suggests attention to the role of students in a sustainable digital learning environment.

Meanwhile, Cluster 3 (blue) emphasizes the dimensions of knowledge and technological innovation based on language processing. Keywords such as development, knowledge, and natural language processing (NLP) dominate this cluster. The word development itself appears 14 times with a total link strength of 94, indicating that the topic of developing digital systems or competencies is an important concern in studies included in this cluster. The presence of the term NLP indicates that the automation approach based on language technology is starting to be integrated in the context of education and digital literacy, especially in order to support the agenda of sustainable education.

These three clusters show differentiation but complementarity in the research landscape. The red cluster reflects the conceptual and macro dimensions of technology and SDGs integration, the green cluster highlights the context of real applications in educational practice, while the blue cluster shows technical and innovative depth based on information processing. This finding confirms that future research developments can be directed at uniting these three dimensions, for example, by designing an AI-based language teaching system that is not only technologically efficient but also in line with sustainability principles.

Table 9. Distribution of keywords based on network visualization clusters.

Cluster	Color	Term	Link	Total Link Strength	Occurrences
1	Red	Analysis	16	66	11
		Goal	15	48	8
		Sdg	16	67	10
		Sdgs	16	88	13
		Study	16	113	20
		Sustainability	15	61	10
		Sustainable development goal	16	147	25
		Technology	16	164	28
2	Green	Application	16	65	9
		Artificial intelligence	16	51	8
		Information	16	74	11
		Language	16	74	11
		Role	16	60	9
		student	14	34	6
3	Blue	Development	16	94	14
		Knowledge	16	40	6
		Natural Language Processing	16	36	6

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4.6. Research Gaps and Strategic Implications

Based on the analysis of the 30 selected articles, several significant contributions have been made by previous studies in supporting the achievement of the Sustainable Development Goals (SDGs), particularly SDG 4. However, there are also research gaps that require strategic follow-up in future investigations, as outlined in **Table 10**.

Table 10. Research Gaps and Strategic Implications of Technology-Based Language Learning in Relation to SDG 4.

SDG 4 Aspect	Findings and Contributions of Previous Studies	Research Gaps.	Strategic Implications	Ref.
Educational Inclusivity	Recommendation systems and bibliometric mapping to expand access to learning	Approaches remain focused on higher education and tourism, limited focus on basic education and marginalized regions.	Digital inclusion needs to be integrated into basic language curricula and community-based programs.	[77,79]
Quality of Language Learning	Integration of local contexts and interdisciplinary approaches enhances material relevance.	Few studies comprehensively evaluate language learning outcomes supported by digital technology	Evaluation of learning quality should assess the holistic impact of AI, NLP, and language learning applications	[81,83, 84]
Scalability and Technology Access	Use of VR, NLP, and mobile apps for sustainable education across sectors	Limited large-scale implementation in language education, particularly in areas with insufficient infrastructure	Scalable and adaptive edtech models and policies are needed, responsive to local infrastructure	[90,91]
Equitable Learning Opportunities	Global learning and digital literacy promote participation of vulnerable groups, including women and minorities.	Limited cross-cultural studies and long-term impact assessments of technology on educational equity	Technology-based curricula must consider gender, cultural sensitivity, and global accessibility fairly.	[93,95]

In terms of language learning quality, studies such as those by Nomnian *et al*. [83] and Timmis *et al*. [84] show that integrating local contexts and interdisciplinary approaches can enrich language learning materials and enhance students' language competencies. Nonetheless, most existing research remains focused on supportive technologies such as applications or AI-based content without thoroughly examining the relationship between such technologies and holistic language learning outcomes. Some researchers [81] emphasize that digital literacy is a key indicator for achieving the SDGs; yet, few studies have comprehensively evaluated the role of digital literacy in the success of technology-supported language education.

Regarding scalability and access to educational technologies, several studies have explored the potential of technologies such as Natural Language Processing (NLP), mobile applications, and artificial intelligence models to extend educational outreach across sectors. For instance, Bhuyan *et al*. [91] developed a VR- and NLP-based approach to support sustainable education

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innovation, while Gallegos *et al*. [90] demonstrated how spatial data-based applications can improve connectivity in agricultural regions. Although these technologies are promising, they still face challenges in large-scale implementation, particularly in the context of language education in areas with limited infrastructure and inadequate policy support.

In the dimension of equitable learning opportunities, studies such as those by Kim *et al*. [93] and Alshraah *et al*. [95] underscore the importance of empowering students from marginalized communities, including those marginalized by gender and social status. Global learning activities and digital literacy programs have been shown to increase learning motivation, equitable access, and mastery of 21st-century competencies. However, other studies, such as those in the literature [80], emphasize that achieving transformative change requires a systemic approach that integrates social, cultural, and ecological dimensions not merely relying on technological interventions.

4.7. Strategies for Optimizing Digital Technology in Language Learning

Based on the literature analysis presented in the previous subsections, the optimization of digital technology in language learning to support the Sustainable Development Goals (SDG 4) should be guided by three core principles: contextualization, adaptive technological diversity, and integration with inclusive and evidence-based approaches.

Findings by Rehman Khan *et al*. [77] reveal that contextual suggestion systems in the e-tourism sector can enhance the efficiency and relevance of learning based on user needs. In the context of language learning, a similar approach can be adapted by designing learning systems that consider students' preferences, language needs, and diverse backgrounds, particularly for learners from underserved communities.

Furthermore, Herrera-Franco *et al*. [79] emphasize the importance of equitable knowledge access through open-access platforms. An effective strategy is the utilization of Open Educational Resources (OER), which allow for the wide and cost-free distribution of language learning materials. This directly supports the principle of educational inclusivity as outlined in SDG 4.

From a leverage perspective, Chan *et al*. [80] propose a levers and leverage points framework, emphasizing the need for systemic interventions to achieve sustainability. In language education, leverage can be realized through the integration of curricula based on digital literacy, not only focusing on language skills but also incorporating digital competencies and global awareness. As noted by Radovanović *et al*. [81], Digital Literacy Key Performance Indicators (KPIs) should be used as a reference for designing language learning content and tools that support sustainable development.

The implementation of cutting-edge technologies such as Artificial Intelligence (AI), Natural Language Processing (NLP), and Virtual Reality (VR) also plays a critical role. Agarwal and Ojha [82] point out that Industry 4.0 approaches can be leveraged to design adaptive learning solutions tailored to individual needs. For example, platforms combining NLP and cloud-based systems [91] can automatically generate personalized questions or learning materials according to the learner's proficiency level. This aligns with the strategy of adaptive and sustainable personalized learning through digital means.

On the other hand, Nomnian *et al*. [83] and Timmis *et al*. [84] underline the importance of integrating language learning with local sociocultural contexts, including community involvement and socially relevant education. Therefore, optimizing digital technology for language learning should also account for localization aspects, such as incorporating regional dialects or cultural themes in the materials and involving communities in the learning process.

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Moreover, the study by He & Mai [86] on the use of digital platforms in coastal area development shows that successful technological implementation depends greatly on contextual appropriateness and infrastructure support. This is especially relevant for underdeveloped regions (known as 3T: frontier, outermost, and disadvantaged areas), where technology-based solutions must be lightweight and accessible, for example, mobile applications with offline capabilities [90].

Finally, strategic approaches must be supported by continuous, data-driven evaluation. Xiaoyu *et al*. [87] recommend heuristic evaluation and usability assessments to ensure the effectiveness of digital platforms in education. Thus, optimization strategies should not only focus on technological development but also include processes of validation, educator training, and the active engagement of educational stakeholders through collaborative and participatory approaches.

5. CONCLUSION

This study concludes that the integration of digital technology in language teaching contributes significantly to the achievement of the Sustainable Development Goals (SDGs), particularly SDG 4 (Quality Education). Through a Systematic Literature Review (SLR) using the PRISMA protocol and keyword-based bibliometric analysis, the study found that technologies such as Artificial Intelligence (AI), online learning, and Natural Language Processing (NLP) have been employed to expand access, improve quality, and promote inclusivity in language education. The analysis of 30 selected articles revealed that the use of digital technologies in language instruction not only enhances linguistic competencies such as vocabulary acquisition and reading comprehension but also helps overcome geographical, economic, and social barriers to education. These findings align with the core mission of SDG 4, which emphasizes equitable access to quality education for all. Identified optimization strategies include the selection of contextual and locally responsive technologies, the strengthening of digital literacy, and the active involvement of stakeholders in the design and implementation of learning systems. To maximize impact, there is a need for educational policies that strategically integrate digital innovation into both curricula and assessment systems.

However, this study has several limitations. First, the literature analyzed is limited to publications indexed in the Scopus database from 2020 to 2025, which may exclude relevant studies from other databases or earlier periods. Second, the analysis focuses more on thematic and bibliometric patterns without delving into the practical outcomes or empirical effectiveness of the technologies reviewed. As a recommendation, future research should further explore the effectiveness of technology-based blended learning approaches across diverse cultural and social contexts. In addition, it is essential to develop clear indicators to measure the success of digital technology integration in supporting SDG 4. A cross-disciplinary approach and collaboration among researchers, educators, technology developers, and policymakers are strongly recommended to ensure that digital transformation in language learning truly becomes a key driver of sustainable education.

6. AUTHORS' NOTE

The authors declare that there is no conflict of interest regarding the publication of this article. The authors confirmed that the paper was free of plagiarism.

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