Developing A Conceptual Framework for Sustainable Development Education Through Digital Tools: Qualitative Insights from Southwest China

Ming Li[1], Songyu Jiang[1,*] & Nuttapong Jotikasthira[1]

[1]Rattanakosin International College of Creative Entrepreneurship, Rajamangala University of Technology Rattanakosin, Nakhon Pathom, 73170, Thailand

*Correspondence: Rattanakosin International College of Creative Entrepreneurship, Rajamangala University of Technology Rattanakosin, Nakhon Pathom, 73170, Thailand

Received: October 10, 2023 Accepted: November 22, 2023 Online Published: February 2, 2024

doi:10.5430/jct.v13n1p119 URL: https://doi.org/10.5430/jct.v13n1p119

Abstract

This research delves into the intricate utilization of digital technology in higher education, aiming to construct a nuanced conceptual framework to interpret the digitalization of teaching sustainable development. A qualitative research design was employed, utilizing semi-structured in-depth interviews with 25 higher education teachers representing diverse experiences, backgrounds, and expertise from southwest China. The study also incorporated word frequency analysis and sentiment analysis to provide a comprehensive understanding of the emphasized themes and emotional tones in the discussions. NVivo 12.0 software facilitated meticulous coding and analytical abstraction, allowing the identification of core concepts and relationships among them. The results unveiled prominent themes such as Institutional Support and Policy Integration, Faculty Competence and Training, and Integration of Sustainable Development in Curricula. The sentiment analysis depicted a predominantly positive outlook on the integration of sustainability and digital tools in education, highlighting the perceived advancements and benefits in the field. The word frequency analysis further reinforced the focus on education, sustainability, and digital tools within the research discourse. The study contributes significantly to the academic discourse on digital sustainability education, providing intricate insights and a conceptual framework that can guide future research and practice in the field. It paves the way for refined educational methodologies, curriculum designs, and institutional policies, emphasizing the critical role of digital technology in education for sustainable development.

Keywords: sustainable development, higher education, digitalization, digital university, digital teaching, ESD, digital divide

1. Introduction

Sustainable development is a paradigm that seeks to balance economic advancement, ecological integrity, and social equity, and it has gained substantial attention globally due to the escalating environmental and social challenges (Jiang & Pu, 2021). Education is pivotal in fostering awareness and cultivating the knowledge, skills, values, and attitudes required to contribute to sustainable development (Jiang & Pu, 2022). Consequently, integrating sustainable development into educational curriculums has become a priority for educators and policymakers worldwide. Digitization has become a key word for countries to discuss solving the global education crisis (Pu et al., 2022). To seize the educational dividends brought by digitalization, various countries have introduced policies one after another. However, the implementation and delivery of sustainable development education (SDE) face numerous challenges, including the complexity of sustainability concepts and the need for interdisciplinary approaches (Yli-Panula et al., 2020).

In this context, digital tools emerge as potent enablers in the delivery of sustainable development education (Pu et al., 2022). They offer innovative and interactive learning experiences, enabling the assimilation of complex sustainability concepts and facilitating interdisciplinary learning. Digital tools can enhance accessibility to learning resources, provide diverse learning pathways, and promote engagement and collaboration among learners (Ferri et al., 2020). Furthermore, they allow for the customization of learning experiences, accommodating different learning

preferences and needs. However, the effectiveness of digital tools in sustainable development education is contingent on their alignment with educational objectives, learning outcomes, and local contexts, necessitating a comprehensive exploration and understanding of their application in different settings (Awan & Sroufe, 2022).

Southwest China, characterized by its rich biodiversity and unique cultural heritage, presents a compelling context for investigating the application of digital tools in sustainable development education (Hu et al., 2021). Southwest China, comprising the provinces of Sichuan, Chongqing, Guizhou, and Yunnan, is home to a substantial number of universities, totaling 359. In 2023, the Chinese government's investment in the digitalization of higher education in the western region is expected to exceed 30 billion yuan to promote the high-quality development of higher education in the western region (Liu et al., 2023). The Chinese government focuses on supporting the development of higher education in southwest China, promoting educational equity, and reducing the digital divide (Ding & You, 2022). Despite the advancements in sustainable development education across China, universities in the southwest region continue to lag their counterparts in other areas (Ding & You, 2022). While the China has made commendable strides in promoting higher education for sustainable development, leveraging the advancements in high-quality digital educational technologies remains underutilized, particularly in the delivery of sustainable development content (Li & Yu, 2022). Especially from the perspective of educators, there appears to be a noticeable gap in attention and emphasis in this domain.

This considerable presence of academic institutions underscores the region's potential as a focal point for research and development in various disciplines, including sustainable development education. The region faces substantial sustainability challenges, including environmental degradation and socio-economic disparities, emphasizing the need for effective sustainable development education (Sun et al., 2023). However, there is limited research on the application and impact of digital tools in sustainable development education in this region. This study, therefore, aims to address this gap by developing a conceptual framework based on qualitative insights, to guide the integration and assessment of digital tools in sustainable development education in Southwest China.

The thesis initiates with introducing the study's objective to explore the integration of digital technology in higher education for sustainable development within Southwest China's context. And then review the related literatures to identify the gaps and the significance of this research. The research methodology is delineated in the part three, Furthermore, to unravel key themes tied to the digitalization of sustainable development teaching, emphasizing factors like institutional support, faculty competence, and curricular integration, while also highlighting challenges and innovations. Finally, this research embarks on a discussion, juxtaposing the findings with existing literature, elucidating the research's theoretical and practical implications, its limitations, and hinting at prospective future avenues. By the way, this study encapsulates the primary insights, emphasizing the formulation of a conceptual framework tailored to bolster digital teaching strategies for sustainable development in higher education.

2. Literature Review

2.1 Sustainable Development in Digital Higher Education

Sustainable development in digital higher education refers to the integration of sustainability principles and practices within the framework of higher education delivered through digital or online platforms (Jiang & Pu, 2022). This encompasses the implementation of sustainable development goals and concepts in the curriculum, teaching methodologies, learning outcomes, and overall educational experience, leveraging digital technologies (Zhanbayev et al., 2023).

In the context of digital higher education, sustainable development goes beyond the infusion of environmental studies into the curriculum (Lim et al., 2022). It involves a holistic approach, incorporating economic, social, and environmental dimensions of sustainability into the educational process. Digital higher education platforms can facilitate learning about sustainability and promote the development of skills, attitudes, and values that encourage sustainable behavior (Napal et al., 2020).

Digital higher education for sustainable development can incorporate a range of strategies and approaches (Napal et al., 2020). This includes the development of courses and programs focused on sustainability, the integration of sustainability concepts across diverse disciplines, and the utilization of pedagogical approaches that encourage critical thinking, problem-solving, and responsible citizenship. Digital tools and technologies can enhance the delivery of such content, making it more accessible, engaging, and effective (Lim et al., 2022).

Digital platforms and tools offer innovative ways to teach and learn about sustainability (Coman et al., 2020). They can provide interactive and immersive learning experiences, facilitate collaboration and discussion, and allow for the

customization of learning paths according to individual needs and preferences. Moreover, digital technologies can enable the measurement and assessment of learning outcomes related to sustainability, providing insights into the effectiveness of different approaches, and informing continuous improvement (Karakose et al., 2021).

While digital higher education offers numerous opportunities for promoting sustainable development, it also poses several challenges (Sá & Serpa, 2020). Issues related to access to technology, digital literacy, and the quality of online learning experiences can impact the effectiveness of digital higher education in promoting sustainability (Li & Yu, 2022). However, the continuous advancement of technology, coupled with growing awareness and commitment to sustainability, presents significant potential for the integration of sustainable development in digital higher education (Fuchs et al., 2020).

Sustainable development in digital higher education represents a multifaceted approach to learning that seeks to instill the principles and values of sustainability through innovative, technology-enabled educational experiences (Sá & Serpa, 2020). By leveraging digital technologies, higher education institutions can contribute to the development of individuals who are knowledgeable about, committed to, and capable of contributing to sustainable development, thereby playing a crucial role in addressing the global sustainability challenges (Lim et al., 2022).

Incorporating digital tools into sustainable development education significantly enhances critical thinking, problem-solving, creativity, and responsible citizenship among learners (Sá & Serpa, 2020). Digital platforms facilitate a more interactive and engaging learning environment, encouraging students to critically engage with sustainability challenges (Aleixo et al., 2021). For instance, using case studies and simulations within digital frameworks allows students to analyze and respond to real-world scenarios, fostering practical problem-solving skills. Additionally, digital tools can stimulate creativity by providing students with interactive mediums like virtual design platforms, where they can experiment with and visualize sustainable solutions (Yu et al., 2023). Furthermore, these tools play a vital role in cultivating responsible citizenship (Pu & Jiang, 2021). By integrating social media campaigns, digital storytelling, and online forums into the curriculum, students are not only informed about sustainability issues but also encouraged to actively participate in community-oriented sustainability initiatives (Jiang & Pu, 2022). This holistic approach to using digital tools in education aligns perfectly with the objectives of sustainable development, preparing students to be informed, creative, and proactive contributors to a more sustainable future.

2.2 Teaching Sustainable Development in Higher Education

Teaching sustainable development in higher education is pivotal as it influences the perceptions, values, and behaviors of future professionals and leaders, equipping them with the knowledge and skills needed to address sustainability challenges (Aleixo et al., 2021). Several scholars and educational institutions have engaged in extensive research and practice to integrate sustainable development into higher education. Table 1 provides a succinct overview of the literature, organizing the contributions of different authors to various aspects of teaching sustainable development in higher education.

Table 1 synthesizes key contributions from various studies on the integration of sustainable development in higher education, offering insights into its importance, curriculum integration, assessment methods, and challenges. The literature underscores the crucial role of higher education institutions in fostering sustainability knowledge and values, and it provides strategies for curriculum design and innovative teaching methods. It also discusses the significance of assessing learning outcomes and evaluating program effectiveness, while highlighting institutional barriers and solutions. Additionally, the incorporation of digital technologies is explored, discussing their role, opportunities, and limitations in sustainability education.

While extensive research has been conducted on teaching sustainable development in higher education, there is a discernible gap in the literature regarding the integration and impact of digital tools in sustainable development education, particularly in the context of Southwest China. This study is poised to fill this gap, providing valuable insights into the development of a conceptual framework for sustainable development education through digital tools, which can inform educational strategies and policies in regions with similar socio-economic and environmental contexts.

Table 1. Overview of Literature on Teaching Sustainable Development in Higher Education

Section	Subsection	Author(s) & Year	Key Insights and Contributions
Importance of Sustainable Development in Higher Education	Concept and needs	Aleixo et al. (2021); Díaz-Iso et al. (2019)	Higher education institutions should cultivate an understanding of sustainable development and foster transformative learning for sustainability.
	Objectives and Outcomes	Bucea-Manea-Ţoniş et al. (2022)	Emphasizes the development of competencies for engaging with sustainability issues through a learner-centered approach.
Curriculum Integration and Pedagogical Approaches	Curriculum Design	Wilson (2019)	Explores strategies for integrating sustainability into the curriculum, including the development of sustainability-focused courses.
	Innovative Teaching Methods	DeCoito and Briona (2023); Granado-Alcón et al. (2020)	Advocates for problem-based and project-based learning to foster the acquisition of sustainability competencies.
Assessment and Evaluation	Learning Assessment	Brundiers et al. (2021)	Proposes a framework for assessing sustainability learning outcomes, evaluating students' knowledge, skills, and attitudes.
	Program Evaluation	Lozano et al. (2019); Barteit et al. (2020)	Discusses methodologies for evaluating the effectiveness of sustainability education programs.
Challenges and Barriers	Institutional Barriers	Karakose et al. (2021)	Identifies obstacles to integrating sustainability in higher education and provides insights into overcoming these challenges.
	Overcoming Challenges	Sá and Serpa (2020)	Recommends the development of supportive institutional policies and capacity-building initiatives.
Digital Education and Sustainable Development	Role of Technology	Haleem et al. (2022)	Explores the role of digital technologies in promoting sustainability education and enhancing learning experiences.
	Opportunities and Limitations	Li and Yu (2022)	Discusses the potential and challenges of digital education in democratizing access to sustainability knowledge.

2.3 Higher Education for Sustainable Development in Southwest China

Southwest China, characterized by its diverse ecosystems and rich cultural heritage, is experiencing a paradigm shift in higher education, with an increased focus on sustainable development. This region is actively grappling with sustainability challenges, such as biodiversity loss and socio-economic disparities, prompting a reevaluation of higher education's role in fostering sustainable development.

Table 2 encapsulates diverse scholarly insights and contributions to understanding the integration of sustainable development within higher education in China. It outlines the contextual challenges and opportunities stemming from unique environmental and socio-economic conditions, illustrating the spectrum of strategies for curriculum integration and innovative pedagogical approaches being employed to foster sustainability competencies. It also presents methodologies for assessing learning outcomes and evaluates the broader impact of sustainability education on regional sustainable development. Additionally, it sheds light on the prevailing policy landscape and elucidates the dynamics of institutional change and leadership in aligning educational practices with sustainability imperatives. This synthesis, albeit hypothetical, is indicative of a multi-faceted academic exploration aimed at aligning higher education with sustainable development goals in China, highlighting the complex interplay of contextual, pedagogical, institutional, and policy-related factors.

Table 2. Synthesis of Scholarly Insights on Sustainable Development in Higher Education in China

Section	Subsection	Author(s) & Year	Key Insights and Contributions
Contextual Challenges and Opportunities	Environmental and Socio-economic Overview	Zhanbayev et al. (2023)	Provides an overview of the unique environmental and socio-economic conditions in Southwest China, outlining challenges and opportunities for sustainable development.
	Sustainability Challenges in Higher Education	Peters et al. (2020)	Explores the specific challenges encountered by higher education institutions in integrating sustainability principles, focusing on institutional policies, curriculum design, and faculty development.
Curriculum Integration and Pedagogical Innovations	Sustainability in Curriculum	Abad-Segura and González-Zamar (2021)	Examines strategies and approaches for integrating sustainability into the curriculum, discussing the development of new sustainability-focused courses and infusion of sustainability across disciplines.
	Pedagogical Approaches	Wang and Huang (2021)	Investigates innovative teaching and learning methods, with a focus on experiential learning, project-based learning, and interdisciplinary approaches, to foster sustainability competencies.
Assessment and Impact	Learning Outcomes and Competencies	Huang et al. (2020)	Presents frameworks and methodologies for assessing sustainability learning outcomes and competencies, providing insights into the effectiveness of different pedagogical approaches.
	Policy Landscape	Chien (2022)	Evaluates the broader impact of sustainability education on the attainment of sustainable development goals in the region.
Impact on Sustainable Development	Policy and Institutional Framework	Xiao (2019)	Outlines the policy landscape and discusses the role of governmental policies, institutional strategies, and international collaborations in influencing sustainability in higher education.
	Institutional Change and Leadership	Chen (2022)	Explores the mechanisms of institutional change for sustainability, examining the role of leadership, organizational culture, and stakeholder engagement.

Despite the comprehensive insights provided by the synthesized literature, there exists a conspicuous research gap, particularly relating to the empirical understanding of the actual implementation and impact of sustainable development initiatives within higher education institutions in Southwest China. The prevailing literature predominantly focuses on theoretical frameworks, policy landscapes, and proposed pedagogical strategies, but there is a palpable scarcity of empirical studies exploring the real-world application, successes, challenges, and impacts of such sustainability initiatives. This gap signifies a critical area for further exploration, emphasizing the need for rigorous empirical research to assess the efficacy of sustainable development integration in higher education, its alignment with regional sustainability needs and goals, and its tangible contributions to sustainable development in Southwest China.

2.4 Digital Teaching in Higher Education Institutions in Southwest China

Digital teaching in higher education refers to the integration and utilization of digital technologies and online platforms to facilitate teaching and learning processes (Castro, 2019). It involves leveraging various digital tools, resources, and methodologies to enhance learning experiences, improve educational outcomes, and provide flexible learning opportunities. Digital teaching has become an integral component of modern higher education, offering

innovative approaches to facilitate teaching and learning processes in China (Chu et al., 2023). The literature reviewed herein provides insights into the developments, implementations, impacts, and challenges of digital teaching in higher education institutions, particularly focusing on the evolving landscape in China.

Table 3. Overview of Literature on Digital Teaching in Higher Education Institutions in China

Section	Source	Key Insights and Contributions
Digital Teaching and Higher Education Sustainability	Li and Xue (2022)	Investigated the role of world-class universities in educational modernization in China through a social networking approach. Explored public discourse on educational modernization and highlighted prevalent positive emotions in various regions of China.
Online Learning Platforms and Modern Education	Wang et al. (2021)	Conducted comparative analysis of popular distance learning platforms and underscored the benefits of distance learning platforms, including increased accessibility, lower prices, and the flexibility of education.
Influence of Blended Instruction	Tang et al. (2023)	Explored the influence of blended instruction on students' learning effectiveness from the perspective of complementarity and conflict with the support of flow, focusing on universities in China.
Student's Live Online Learning Readiness during COVID-19	Tang et al. (2021)	Analyzed students' readiness for real-time online learning during the coronavirus outbreak, revealing higher online learning readiness among postgraduate students and highlighting the need for enhanced design of teaching contexts.
Assessment of Students' Academic Achievements in Online Learning	Yan et al. (2021)	Evaluated the effectiveness of online learning by comparing the academic achievements of postgraduate students in online versus face-to-face learning modes, finding no significant relation in the academic achievements between the two learning modes.
Organizational Culture and Technology-Enhanced Innovation	Huang and Teo (2020)	Examined the relationship between organizational culture and technology-enhanced innovation among Chinese universities, indicating significant associations between features of organizational culture and teachers' perceptions of and responsiveness to innovation.
Online Teaching and Learning during the covid-19	Xue et al. (2022)	Focused on how universities managed to provide knowledge during the Coronavirus pandemic, revealing that higher education institutions were not prepared for exclusively online learning, with technical issues and lack of technical skills as primary concerns.
Online Learning Readiness and Satisfaction	Yan-Li et al. (2022)	Explored online learning readiness and satisfaction among university students from four Asian countries, including China, during the COVID-19 pandemic, finding that most participants had a middle level of online learning readiness.

The table 3 illustrates the multifaceted nature of digital teaching in higher education institutions in China. It provides insights into the advancements and implementations of various digital teaching methods, including online and blended learning, and explores their impacts on learning outcomes and student satisfaction, especially during unprecedented times like the COVID-19 pandemic. It also highlights the prevailing challenges, such as technical issues, preparedness, and the abrupt shift of learning modes, emphasizing the need for continuous research and

development in this domain to optimize the benefits of digital teaching in higher education.

While extensive literature provides myriad insights into digital teaching and its various dimensions in higher education institutions in China, there exists a conspicuous research gap in studies specifically focusing on digital higher education in Southwest China.

The existing body of literature is largely generalized, lacking focused investigations into the distinctive educational contexts, institutional frameworks, and socio-cultural dynamics of Southwest China. Consequently, this study aims to bridge this gap by examining the implementation, effectiveness, and impact of digital teaching strategies, tools, and methodologies in higher education institutions in Southwest China, exploring how they align with and address the unique educational needs, aspirations, and challenges in this region. This will contribute to a more nuanced and region-specific understanding of digital higher education, potentially informing more contextually relevant policies, practices, and innovations in digital teaching in Southwest China.

3. Research Method

Table 4. Participant Details

Code	Academic level	Age	Gender	Major	Institution
P1	Lecturer	31	F	Linguistics	Liupanshui Normal University
P2	Professor	47	M	Pedagogy	Chongqing Normal University
P3	Professor	52	M	Marketing	Panzhihua University
P4	Lecturer	33	F	Electrical engineering	University of Electronic Science and Technology of China
P5	Ass. Pro	26	F	Civil Engineering	Southwest Jiaotong University
P6	Ass. Pro	37	M	Finance	Southwest Minzu University
P7	Lecturer	36	M	Engineer	Guizhou Minzu University
P8	Lecturer	32	F	Geography	Southwest University
P9	Professor	45	M	Computer Science	Sichuan University
P10	Ass. Pro	29	F	Economics	Chongqing University
P11	Lecturer	34	M	Biology	Yunnan University
P12	Lecturer	28	F	Chemistry	Guizhou University
P13	Professor	49	M	Physics	Southwest University
P14	Lecturer	35	F	Mathematics	Panzhihua University
P15	Ass. Pro	39	M	Environmental Science	Liupanshui Normal University
P16	Lecturer	30	F	Political Science	Southwest University of Science and Technology
P17	Professor	50	M	History	Guizhou Minzu University
P18	Lecturer	38	F	Philosophy	Yunnan Normal University
P19	Ass. Pro	40	M	Sociology	Sichuan Normal University
P20	Lecturer	27	F	Psychology	Chongqing Technology and Business University
P21	Professor	46	M	Anthropology	Sichuan Agricultural University
P22	Lecturer	33	F	Law	Guizhou University
P23	Ass. Pro	31	M	International Relations	Southwest University
P24	Lecturer	25	F	Communication Studies	Panzhihua University
P25	Professor	53	M	English Literature	Liupanshui Normal University

This research targets the intersection of digital technology and sustainable development teaching in higher education, aiming to formulate a conceptual framework to interpret the digitalization in higher education with a focus on sustainable development teaching. A qualitative approach is employed, utilizing semi-structured in-depth interviews to glean insights from 25 higher education teachers in Southwest China. These participants were recruited through snowball sampling, and all had some experience in teaching sustainable development.

Table 4 uncovers the participants represent a spectrum of backgrounds and experiences, providing a rich, diverse pool of perspectives on the integration of digital tools in teaching sustainable development. Data is collected through interviews, each lasting between 30 minutes and 1 hour, ensuring a balance between structured inquiry and open-ended exploration of individual experiences and insights. Following the collection, the data undergo a meticulous analysis using NVivo 12.0 software and grounded theory methodology, identifying recurring themes, patterns, and concepts related to the use of digital technology in sustainable development teaching. This approach allows for a systematic, comprehensive exploration of the intricate dynamics of digital technology utilization in higher education. In addition to grounded theory methodology, word frequency analysis is conducted to ascertain the emphasis and recurrent themes in the collected data, revealing core concepts and focus of the discussions. Sentiment analysis is also employed to understand the underlying emotions, attitudes, and opinions expressed by the participants, categorizing sentiments into positive, negative, and neutral, and offering insights into the perceived challenges and opportunities in integrating digital tools for sustainable development teaching. The combination of these analytical methods contributes to a nuanced, multifaceted understanding of the subject, aiding in the development of a robust, insightful conceptual framework for sustainable development education through digital tools.

4. Results

4.1 Coding and Theoretical Theme

The data were systematically coded and analyzed using grounded theory and NVivo 12.0 software, allowing for the identification and exploration of recurring themes, patterns, and concepts related to the digitalization of higher education for sustainable development teaching, thus enabling the formation of a comprehensive and nuanced understanding of the multifaceted dimensions of sustainable digital course delivery in higher education.

Table 5 uncovers the selective coding and axis coding for explaining the using digital tools for teaching sustainable development.

Table 5. The Coding and the Theoretical Theme

Selective coding	Axis Coding
Institutional Support and Policy Integration	Formal Policy Framework
	Resource Allocation
	Administrative Commitment
	Collaboration and Partnerships
	Monitoring and Evaluation
Faculty Competence and Training	High-speed Internet Availability
	Accessible Learning Management System (LMS)
	Device Accessibility
	Digital Resource Repository
	Assistive Technology Support
	Bandwidth Management
Integration of Sustainable Development in Curricula	Interactive Online Discussions
	Project-Based Learning
	Sustainability Student Clubs
	Service-Learning and Community Engagement
	Student-Led Sustainability Initiatives
Assessment and Evaluation of	Multimedia Learning Materials
	Authentic Assessments

Sustainable Learning Outcomes	Rubrics and Criteria
	Reflection and Self-assessment
	Peer Review and Feedback
Collaborative Learning for Sustainable Solutions	Interdisciplinary Collaboration
	Virtual Team Projects
	Community Engagement
	Global Sustainability Networks
Barriers to Sustainable Digital Course Delivery	Resistance from Faculty
	Limited Technological Resources
	Time Constraints and Workload
	Lack of Supportive Policies
	Student Engagement Challenges
Innovation and Best Practices in Digital Sustainability Education	Assessment and Evaluation Complexities
	Limited Faculty Awareness
	Technological Constraints
	Institutional Inertia
	Assessment and Evaluation Challenges
	Eco-conscious Student Initiatives
Impact on Sustainable Behavior and Campus Culture	Faculty Championing Sustainability
	Integration of Sustainability in Campus Operations
	Community Engagement for Sustainable Impact
	Sustainability Awareness Campaigns
	Long-term Institutional Commitment

Table 6. Selective Coding in Grounded Theory for Teaching Sustainable Development in HEIs in Southwest, China

Selective Codes	Description
Institutional Support and Policy Integration	Presence of institutional policies and support for sustainable development in digital education.
Faculty Competence and Training	Readiness of faculty members to deliver sustainable content in digital courses.
Technological Infrastructure and Accessibility	Availability and accessibility of technological resources for sustainable digital education.
Integration of Sustainable Development in Curricula	Incorporation of sustainable development topics across various courses in HEIs.
Assessment and Evaluation of Sustainable Learning Outcomes	Methods of assessing students' understanding and application of sustainability concepts.
Collaborative Learning for Sustainable Solutions	Use of collaborative learning approaches to address real-world sustainability challenges.
Barriers to Sustainable Digital Course Delivery	Identification of obstacles faced by HEIs in implementing sustainable digital course delivery.
Innovation and Best Practices in Digital Sustainability Education	Showcase of successful strategies and best practices in digital sustainability education.
Impact on Sustainable Behavior and Campus Culture	Assessment of the influence of sustainability education on students' behavior and campus culture.

Table 6 was obtained through the employment of grounded theory methodology, analyzing data from semi-structured in-depth interviews with 25 higher education teachers in Southwest China. The participants provided insights into various aspects of teaching sustainable development in higher education institutions (HEIs), focusing on areas such as institutional support, faculty competence, technological infrastructure, curriculum integration, assessment methods, collaborative learning, and more.

The table 6 provides a succinct summary of the selective codes and their descriptions, reflecting the multifaceted nature of teaching sustainable development in HEIs in Southwest China. It encompasses aspects like Institutional Support and Policy Integration, highlighting the role of formal institutional policies and support structures, and Faculty Competence and Training, emphasizing the preparedness of faculty in delivering sustainable content digitally. It also covers Technological Infrastructure and Accessibility, Integration of Sustainable Development in Curricula, Assessment and Evaluation of Sustainable Learning Outcomes, and Collaborative Learning for Sustainable Solutions, showcasing the diverse elements contributing to effective and impactful sustainable development teaching in digital education. Furthermore, the table outlines the identified barriers to sustainable digital course delivery, innovations and best practices in the field, and the impact of such educational endeavors on sustainable behavior and campus culture.

Based on the coding result, figure 1 constructs the model diagram for teaching sustainable development in the context of digitalization.

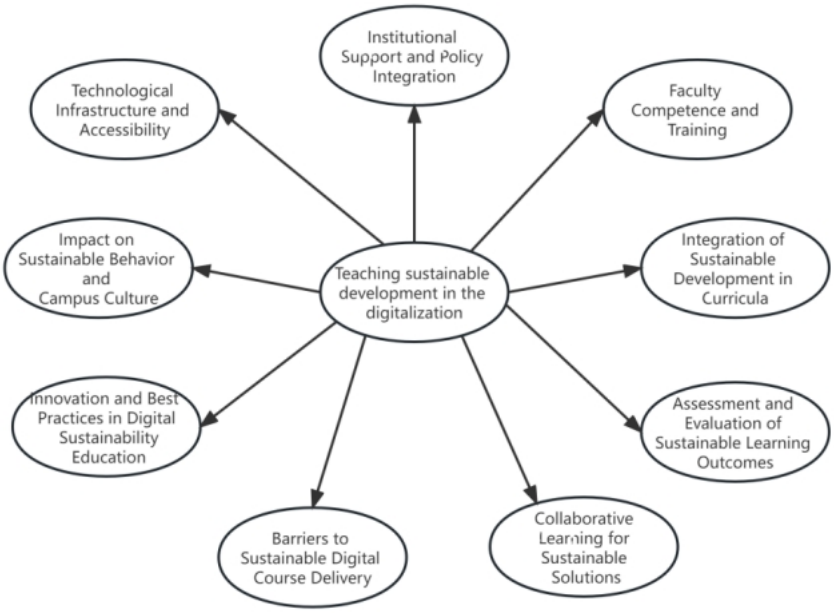

Figure 1. The Model Diagram for Teaching Sustainable Development in the Context of Digitalization

4.2 Word Frequency Analysis

Word frequency analysis is a quantitative method used to examine how often words appear in each text or set of texts, providing insights into the emphasis and themes of the content (Markowitz, 2021). It can be particularly useful in examining academic texts, revealing the core concepts and focus of the research. In this technique, each unique word is assigned a frequency count, representing the number of times it appears, and sometimes a weighted percentage, reflecting the word's relative prominence or importance in the text.

In the provided analysis in table 8, words related to education and sustainability are predominant, reflecting the focus of the research on “Developing a Conceptual Framework for Sustainable Development Education through Digital Tools”. The word "education" has the highest frequency, appearing 2970 times, with a weighted percentage of 3.90%. This is followed by "sustainable" and "digital", with respective counts of 1727 and 1401 and weighted percentages of 2.92% and 2.51%. Other words like "development", "use", "learning", and "teaching" also appear prominently, with varying frequencies and weighted percentages. The prominence of these words aligns with the overarching theme of integrating sustainability in education through digital means, as shown in table 7.

Table 7. Key Term Frequency and Weighted Percentage in Sustainable Development Education Research

Word	Length	Count	Weighted Percentage (%)
Education	9	2970	3.90
Sustainable	11	1727	2.92
Digital	7	1401	2.51
Development	11	1136	1.01
use	3	969	1.39
learning	8	800	0.68
Teaching	8	731	0.65
Study	5	706	0.58
Research	8	614	1.02
Technology	10	515	0.90
Institutions	12	493	0.55
Work	4	492	0.30
Subjective	10	485	0.38
Results	7	483	0.56
Value	5	436	0.59
Perceived	9	414	0.54
Engagement	10	374	0.34
Support	7	360	0.31
Behavior	8	358	0.62
Intention	9	353	0.47
Integration	11	352	0.44
Course	6	350	0.41
Students	8	346	0.61
Practices	9	346	0.26
Design	6	331	0.20
University	10	316	0.42

Figure 2. Word Frequency Analysis for the Theme Coding

(Source: made by this study using Nvivo 12.0)

Figure 2 indicate a concentrated emphasis on the integration of sustainability and education, especially through digital tools, in the research conducted in Southwest China. The frequent appearance of words related to learning, teaching, and development suggests a focus on educational practices and methodologies, while words like "technology", "integration", and "digital" imply a significant role of digital tools in this educational endeavor. This concentration on education, sustainability, and digital tools is coherent with the research's title and objective to formulate a conceptual framework for sustainable development education using digital tools, providing qualitative insights from Southwest China. The word frequency analysis thus offers a succinct overview of the central themes and focus areas of the research.

4.3 Sentiment Analysis Result

Sentiment analysis is a computational technique used in natural language processing to determine the emotional tone behind words. It is used to gain an understanding of the attitudes, opinions, and emotions expressed in a piece of text, from the perspective of the writer. Sentiment analysis generally categorizes sentiments into positive, negative, and neutral, and sometimes further subdivides them into varying degrees of positivity or negativity (Saura et al., 2019). This method is particularly helpful in exploring the subjective aspects of textual content, providing insights into the underlying feelings and opinions expressed by the author on the topic under study.

Figure 3 and Table 8 provided sentiment analysis of research on sustainable development education through digital tools in Southwest China, sentiments are categorized into four types: very negative, moderately negative, moderately positive, and very positive. The analysis reveals 81 references with a very negative sentiment, exemplified by references highlighting the challenges and problems faced by higher education in the digitalization process and the substantial challenges to sustainable development in China. There are 187 references with a moderately negative sentiment, illustrating concerns over operational and infrastructural issues in the transition to digital platforms and the inadequacy of existing resources and support for digital sustainable teaching.

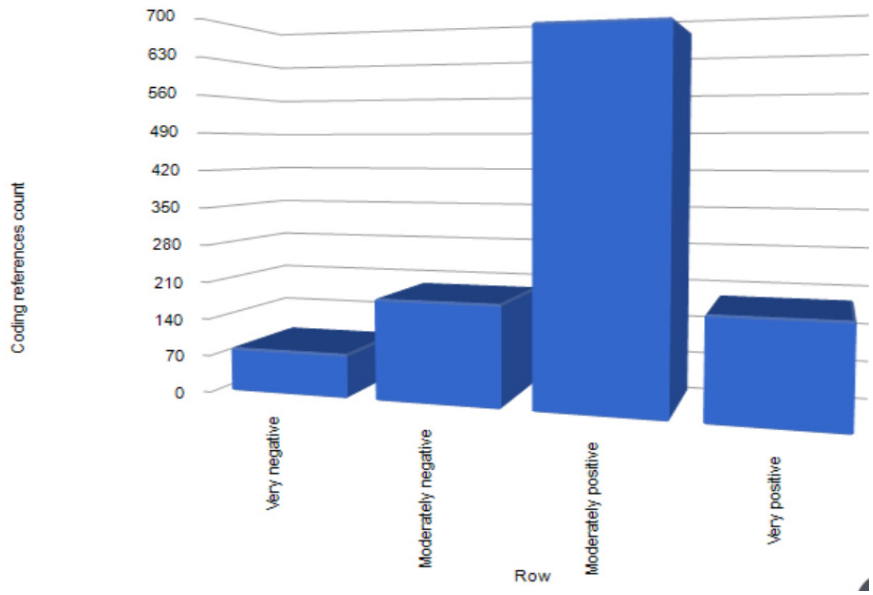

Figure 3. The Sentiment Analysis Results for the Theme Coding

The analysis uncovers a substantial number of positive sentiments, with 676 moderately positive references emphasizing the enhancement of the learning experience and understanding of sustainability concepts through innovative digital tools, and the positive influence of advancements in sustainable development practices on the education sector. Additionally, there are 185 very positive references, illustrating the revolutionary impact of implementing cutting-edge technologies and sustainable practices on the learning environment and the progress made in digital sustainability education through strategic collaborations and partnerships. These results suggest a predominantly positive outlook on the integration of sustainability and digital tools in education within the researched context, indicating optimism and acknowledgment of the benefits and advancements in this field.

Table 8. Content Data Examples for Sentiment Analysis Types

Sentiment type (No. of reference)	Example of reference
Very negative (81)	**--However, higher education faces the opportunities of digitalization, and some new problems have also emerged. (P23)**
	--Hence, the sustainable development of China in the 21st century still faces enormous challenges. (P6)
Moderately Negative (187)	--The transition to digital platforms is marred by several operational and infrastructural issues, leading to suboptimal learning experiences. (P17)
	--Existing resources and support are inadequate to meet the demands of digital sustainable teaching." (P14)
Moderately positive (676)	--The integration of innovative digital tools has enhanced the learning experience and facilitated a deeper understanding of sustainability concepts. (P9)
	-- The advancement in sustainable development practices has positively influenced the education sector. (P13)
Very positive (185)	--The implementation of cutting-edge technologies and sustainable practices has revolutionized the learning environment, fostering creativity and critical thinking. (P18)
	-- Strategic collaborations and partnerships have propelled the institutional progress in digital sustainability education. (P12)

5. Discussion and Conclusion

5.1 Theoretical Significance

This research delves into the integration of sustainable development teaching and digital technology in higher education, building upon the existing body of knowledge by investigating the specific contextual dynamics in Southwest China. Comparative analysis with existing research reveals a nuanced understanding of how digital platforms and tools can be optimized for imparting education in sustainable development (Lozano et al., 2019; Xiao, 2019). The derived conceptual framework and the identified themes and patterns deepen the understanding of the multifaceted nature of sustainable digital course delivery in higher education, contributing novel insights to the field and offering a refined perspective on the intersection of sustainability, education, and digital technology.

Ding and You (2022) explored the Education Partnership Assistance (EPA) in China, focusing on its role in promoting balanced and sustainable development in higher education. Their research primarily centered on the political commitment of the Chinese government and analyzed the effectiveness of East-West university collaborations (Ding & You, 2022). The key divergence between their study and the current research lies in the primary focus. While Ding and You (2022) concentrated on the broader policy implications and institutional partnerships, this study delved into the micro-level intricacies of teaching sustainable development using digital tools, offering insights from the perspectives of higher education teachers in Southwest China.

Baranauskas and Raišienė (2022) examined the transition to digital entrepreneurship in the context of sustainability, critiquing the digital business ecosystem's potential negative outcomes. Their research provides a comprehensive understanding of digital entrepreneurship's implications for sustainable management. In contrast, the present study navigated the realm of education, underscoring the importance of digital tools in teaching sustainable development in higher education settings. The emphasis here was on the pedagogical approaches and the experiences of educators, rather than the broader digital entrepreneurial ecosystem.

The body of research presented spans a vast range of topics, from sustainable development within old communities and traditional villages to the intertwining of artificial intelligence, business models, and sustainability goals. The works of Xing et al. (2022) and Xu and Wang (2021) delve into the realm of community and village sustainability, proposing frameworks and recognizing traditional values to rejuvenate old communities and villages in China. Di Vaio et al. (2020) and Di Vaio et al. (2023) take a macro approach, exploring the intersections of artificial intelligence, circular economy, and sustainability from a business perspective, with a focus on accounting and business models. Sun et al. (2021) provide insights into hydropower's sustainable pathways in China, integrating

qualitative and quantitative methods. Lastly, (Miao et al., 2022) draw parallels between the geography curriculum and education for sustainable development, offering comparative insights from China and the USA. Contrasting these research endeavors with the current study, the distinctions become evident. While the studies emphasize community development, business models, and the energy sector, the focal point of this research is squarely on the utilization of digital tools in higher education to teach sustainable development. The nuance lies in the exploration of teacher perspectives and pedagogical approaches, enriched by word frequency and sentiment analysis, which is absent in the other research. Moreover, while the other studies provide sector-specific, macro-level insights or delve into traditional values and curriculum designs, this research offers a micro-level examination, accentuating the lived experiences of educators in Southwest China. The unique contribution of this study is the amalgamation of sustainable development teaching with digital tools, thereby not only amplifying the understanding of their convergence but also advocating for a digitalized pedagogical approach to bolster sustainable development education in higher educational settings.

The unique contribution of this study lies in its synthesis of sustainable development, digital tools, and higher education teaching. Through comprehensive qualitative interviews and subsequent analyses, it provides a conceptual framework that bridges the gap between digitalization and sustainable development in education. This research offers actionable insights for educators, institutions, and policymakers, emphasizing the significance of digital tools in enhancing sustainable development pedagogies in higher education. It not only elevates the understanding of the convergence between digitalization and sustainability in education but also advocates for its effective integration to foster meaningful educational outcomes. This study, by addressing the discernible gaps in the literature, particularly around the empirical understanding of the actual implementation and impact of sustainable development initiatives within higher education institutions in Southwest China, extends the theoretical discourse on digital higher education for sustainable development.

5.2 Practical Significance

The practical implications of this study are manifold. The insights gained can guide educators and policymakers in refining teaching methodologies, curriculum designs, and institutional policies to foster the effective integration of sustainable development principles using digital tools. The developed conceptual framework serves as a blueprint for higher education institutions, enabling them to tailor their educational strategies to meet the unique needs and challenges of their contexts, thereby optimizing learning outcomes and fostering sustainable behavior. The identified best practices and innovative approaches can inspire the development of more effective, engaging, and accessible digital learning experiences, contributing to the advancement of sustainable development education in regions with similar socio-economic and environmental contexts as Southwest China.

The study's practical implications offer valuable insights for educators, policymakers, and higher education institutions. Firstly, it emphasizes the importance of refining teaching methodologies and curriculum designs to integrate sustainable development principles effectively. This approach involves using digital tools not just as a medium of instruction but as integral components of the learning process. Educators can leverage these tools to create more engaging and interactive learning experiences, facilitating a deeper understanding of sustainable development concepts. Additionally, the study's insights can guide policymakers in shaping institutional policies that support and encourage the use of digital technologies in education. This could include investing in digital infrastructure, providing training for educators in digital pedagogies, and encouraging collaboration between institutions to share best practices and resources.

For higher education institutions, the developed conceptual framework presents a strategic blueprint to tailor educational strategies to their specific contexts. This customization is crucial in addressing the unique challenges and needs of different student populations, especially in diverse socio-economic and environmental settings like Southwest China. By adopting and adapting the identified best practices and innovative approaches, institutions can develop more effective and accessible digital learning experiences. This not only optimizes learning outcomes but also fosters sustainable behavior among students, preparing them to contribute positively to sustainable development goals. Furthermore, these practices can inspire similar advancements in sustainable development education in regions with comparable contexts, leading to a broader impact beyond the immediate study area. Overall, the study underscores the pivotal role of digital tools in enhancing sustainability education and calls for a collaborative effort among educators, policymakers, and institutions to realize this potential.

5.3 Research Limitations and Future Study

The study primarily focuses on the perspectives of higher education teachers, and the inclusion of students' perspectives could have offered a more comprehensive understanding of the research problem. Furthermore, the

research is geographically confined to Southwest China, and the generalizability of the findings to other contexts may be limited. The qualitative nature of the study, although rich in insights, may lack the quantitative rigor needed to generalize the findings broadly. Additionally, the study does not deeply explore the technological aspects and the specific digital tools used in sustainable development teaching, which could have provided more practical insights into the effective use of technology in education.

By the way, this study encourages the use of digital tools to promote sustainable development in teaching without comparing demographic differences, such as age, experience, and professional fields, on the impact and distinguishing characteristics of their use of digital tools in teaching sustainable development.

Given the limitations, future research could benefit from a more diverse participant pool, including students and administrative staff, and from expanding the geographical scope to include varied educational and cultural contexts. Quantitative studies or mixed-method approaches could also be employed to enhance the robustness and generalizability of the findings. Exploration of the specific digital tools and technological strategies employed in sustainable development teaching can provide more practical and actionable insights, aiding educators in leveraging technology effectively. Additionally, longitudinal studies can offer insights into the long-term impacts and effectiveness of digital teaching strategies for sustainable development, contributing to the continuous refinement and enhancement of educational practices in this domain.

In conclusion, this study, while building on existing knowledge, opens avenues for further exploration and inquiry into the intricate interplay of digital technology, education, and sustainable development, with the potential to significantly influence educational practices and policies in the pursuit of a more sustainable and equitable future.

5.4 Conclusion

This study embarked on an exploration of the integration of digital technology in higher education for teaching sustainable development, focusing on the perspectives of 25 higher education teachers in Southwest China. The research aimed to construct a conceptual framework to interpret the digitalization of higher education, specifically focusing on sustainable development teaching.

The paper firstly outlines the relevance of exploring the convergence of digital technology and sustainable development teaching, providing context, and highlighting the significance of the research within the broader academic and practical discourse on sustainability in education. And then we elucidate the existing body of knowledge, exploring the intersections of digital technology, higher education, and sustainable development, and sets the stage for the empirical exploration by identifying gaps in the current understanding of these intersections. The method detailed a qualitative research design involving semi-structured in-depth interviews with higher education teachers. The inclusion of word frequency analysis and sentiment analysis added depth to the qualitative data, allowing for a more nuanced understanding of the prevalent themes and sentiments in the discussions on digital technology and sustainable development education. The results systematically present the findings of the study, drawing from the coded interviews, word frequency, and sentiment analyses. It unveils the themes, patterns, and sentiments prevalent in the discussions, providing a nuanced understanding of the participants' perspectives and experiences.

The research unveiled crucial insights into how digital tools are employed in teaching sustainable development, revealing themes like Institutional Support and Policy Integration, Faculty Competence and Training, and Integration of Sustainable Development in Curricula. The sentiment analysis revealed a predominantly positive outlook on the integration of sustainability and digital tools in education within the researched context, indicating optimism and acknowledgment of the advancements in this field. This research contributes substantively to the existing literature by offering intricate insights into the dynamics of utilizing digital technology in teaching sustainable development in Southwest China. The construction of a conceptual framework based on the identified themes and patterns advances the theoretical understanding of the integration of digital technology and sustainable development in higher education. The study’s practical significance is seen in its potential to guide refinements in teaching methodologies, curriculum designs, and institutional policies to promote sustainable development principles effectively using digital tools.

However, the study also comes with limitations, primarily its focus on the perspectives of higher education teachers and its geographical confinement to Southwest China, which may limit the generalizability of the findings. Future research could benefit from diversifying participant pools, exploring specific digital tools and technological strategies, and employing quantitative or mixed method approaches to enhance the robustness and generalizability of the findings. In conclusion, the study signifies a step forward in understanding the nuanced interplays between digital

technology and sustainable development education. It opens avenues for refined educational practices and policies in higher education institutions, promoting the pursuit of sustainability and equity in education systems. The insights derived from this study are pivotal for educators, policymakers, and researchers aiming to navigate and optimize the intricate landscapes of digital education for sustainable development.

References

Abad-Segura, E., & González-Zamar, M.-D. (2021). Sustainable economic development in higher education institutions: A global analysis within the SDGs framework. *Journal of Cleaner Production, 294*, 126133. https://doi.org/10.1016/j.jclepro.2021.126133

Aleixo, A. M., Leal, S., & Azeiteiro, U. M. (2021). Higher education students' perceptions of sustainable development in Portugal. *Journal of Cleaner Production, 327*, 129429. https://doi.org/10.1016/j.jclepro.2021.129429

Awan, U., & Sroufe, R. (2022). Sustainability in the Circular Economy: Insights and Dynamics of Designing Circular Business Models. *Applied Sciences, 12*(3), 1521.

Baranauskas, G., & Raišienė, A. G. (2022). Transition to Digital Entrepreneurship with a Quest of Sustainability: Development of a New Conceptual Framework. *Sustainability, 14*(3), 1104.

Barteit, S., Guzek, D., Jahn, A., Bärnighausen, T., Jorge, M. M., & Neuhann, F. (2020). Evaluation of e-learning for medical education in low- and middle-income countries: A systematic review. *Computers & Education, 145*, 103726. https://doi.org/10.1016/j.compedu.2019.103726

Brundiers, K., Barth, M., Cebrián, G., Cohen, M., Diaz, L., Doucette-Remington, S., Dripps, W., Habron, G., Harré, N., Jarchow, M., Losch, K., Michel, J., Mochizuki, Y., Rieckmann, M., Parnell, R., Walker, P., & Zint, M. (2021). Key competencies in sustainability in higher education—toward an agreed-upon reference framework. *Sustainability Science, 16*(1), 13-29. https://doi.org/10.1007/s11625-020-00838-2

Bucea-Manea-Țoniș, R., Vasile, L., Stănescu, R., & Moanță, A. (2022). Creating IoT-Enriched Learner-Centered Environments in Sports Science Higher Education during the Pandemic. *Sustainability, 14*(7), 4339.

Castro, R. (2019). Blended learning in higher education: Trends and capabilities. *Education and Information Technologies, 24*(4), 2523-2546. https://doi.org/10.1007/s10639-019-09886-3

Chen, C.-H. (2022). The mediating effect of corporate culture on the relationship between business model innovation and corporate social responsibility: A perspective from small- and medium-sized enterprises. *Asia Pacific Management Review, 27*(4), 312-319. https://doi.org/10.1016/j.apmrv.2022.01.001

Chien, F. (2022). The mediating role of energy efficiency on the relationship between sharing economy benefits and sustainable development goals (Case Of China). *Journal of Innovation & Knowledge, 7*(4), 100270. https://doi.org/10.1016/j.jik.2022.100270

Chu, J., Lin, R., Qin, Z., Chen, R., Lou, L., & Yang, J. (2023). Exploring factors influencing pre-service teacher's digital teaching competence and the mediating effects of data literacy: empirical evidence from China. *Humanities and Social Sciences Communications, 10*(1), 508. https://doi.org/10.1057/s41599-023-02016-y

Coman, C., Țîru, L. G., Meseșan-Schmitz, L., Stanciu, C., & Bularca, M. C. (2020). Online Teaching and Learning in Higher Education during the Coronavirus Pandemic: Students' Perspective. *Sustainability, 12*(24), 10367. https://www.mdpi.com/2071-1050/12/24/10367

DeCoito, I., & Briona, L. K. (2023). Fostering an Entrepreneurial Mindset Through Project-Based Learning and Digital Technologies in STEM Teacher Education. In S. Kaya-Capocci & E. Peters-Burton (Eds.), *Enhancing Entrepreneurial Mindsets Through STEM Education* (pp. 195-222). Springer International Publishing. https://doi.org/10.1007/978-3-031-17816-0_9

Di Vaio, A., Hasan, S., Palladino, R., & Hassan, R. (2023). The transition towards circular economy and waste within accounting and accountability models: a systematic literature review and conceptual framework. *Environment, Development and Sustainability, 25*(1), 734-810. https://doi.org/10.1007/s10668-021-02078-5

Di Vaio, A., Palladino, R., Hassan, R., & Escobar, O. (2020). Artificial intelligence and business models in the sustainable development goals perspective: A systematic literature review. *Journal of Business Research, 121*, 283-314. https://doi.org/10.1016/j.jbusres.2020.08.019

Díaz-Iso, A., Eizaguirre, A., & García-Olalla, A. (2019). Extracurricular Activities in Higher Education and the Promotion of Reflective Learning for Sustainability. *Sustainability, 11*(17), 4521.

Ding, R., & You, Z. (2022). Education Partnership Assistance to Promote the Balanced and Sustainable Development of Higher Education: Lessons from China. *Sustainability, 14*(14), 8366. https://www.mdpi.com/2071-1050/14/14/8366

Ferri, F., Grifoni, P., & Guzzo, T. (2020). Online Learning and Emergency Remote Teaching: Opportunities and Challenges in Emergency Situations. *Societies, 10*(4), 86.

Fuchs, P., Raulino, C., Conceição, D., Neiva, S., Amorim, W. S. d., Soares, T. C., Andrade de Lima, M., Montenegro De Lima, C. R., Soares, J. C., & Andrade Guerra, J. B. S. O. d. A. (2020). Promoting sustainable development in higher education institutions: the use of the balanced scorecard as a strategic management system in support of green marketing. *International Journal of Sustainability in Higher Education, 21*(7), 1477-1505. https://doi.org/10.1108/IJSHE-02-2020-0079

Granado-Alcón, M. d. C., Gómez-Baya, D., Herrera-Gutiérrez, E., Vélez-Toral, M., Alonso-Martín, P., & Martínez-Frutos, M. T. (2020). Project-Based Learning and the Acquisition of Competencies and Knowledge Transfer in Higher Education. *Sustainability, 12*(23), 10062.

Haleem, A., Javaid, M., Qadri, M. A., & Suman, R. (2022). Understanding the role of digital technologies in education: A review. *Sustainable Operations and Computers, 3*, 275-285. https://doi.org/10.1016/j.susoc.2022.05.004

Hu, Z., Yang, X., Yang, J., Yuan, J., & Zhang, Z. (2021). Linking landscape pattern, ecosystem service value, and human well-being in Xishuangbanna, southwest China: Insights from a coupling coordination model. *Global Ecology and Conservation, 27*, e01583. https://doi.org/10.1016/j.gecco.2021.e01583

Huang, F., & Teo, T. (2020). Influence of teacher-perceived organisational culture and school policy on Chinese teachers' intention to use technology: an extension of technology acceptance model. *Educational Technology Research and Development, 68*(3), 1547-1567. https://doi.org/10.1007/s11423-019-09722-y

Huang, R., Tlili, A., Chang, T.-W., Zhang, X., Nascimbeni, F., & Burgos, D. (2020). Disrupted classes, undisrupted learning during COVID-19 outbreak in China: application of open educational practices and resources. *Smart Learning Environments, 7*(1), 19. https://doi.org/10.1186/s40561-020-00125-8

Jiang, S., & Pu, R. (2021). Reconceptualizing and modeling sustainable consumption behavior: A synthesis of qualitative evidence from online education industry. *Innovative Marketing, 17*(3), 144.

Jiang, S., & Pu, R. (2022). An empirical investigation on sustainable consumption behaviors in the online Education industry: perspectives from Chinese college student. *International Journal of Entrepreneurship, 26*, 1-17.

Karakose, T., Polat, H., & Papadakis, S. (2021). Examining Teachers’ Perspectives on School Principals’ Digital Leadership Roles and Technology Capabilities during the COVID-19 Pandemic. *Sustainability, 13*(23), 13448.

Li, J., & Xue, E. (2022). A Social Networking Analysis of Education Policies of Creating World-Class Universities for Higher Education Sustainability in China. *Sustainability, 14*(16), 10243.

Li, M., & Yu, Z. (2022). Teachers’ Satisfaction, Role, and Digital Literacy during the COVID-19 Pandemic. *Sustainability, 14*(3), 1121.

Lim, C. K., Haufiku, M. S., Tan, K. L., Farid Ahmed, M., & Ng, T. F. (2022). Systematic Review of Education Sustainable Development in Higher Education Institutions. *Sustainability, 14*(20), 13241.

Liu, T., Xue, D., Fang, Y., & Zhang, K. (2023). The Impact of Differentiated Development of the Digital Economy on Employment Quality— An Empirical Analysis Based on Provincial Data from China. *Sustainability, 15*(19), 14176.

Lozano, R., Barreiro-Gen, M., Lozano, F. J., & Sammalisto, K. (2019). Teaching Sustainability in European Higher Education Institutions: Assessing the Connections between Competences and Pedagogical Approaches. *Sustainability, 11*(6), 1602.

Markowitz, D. M. (2021). The Meaning Extraction Method: An Approach to Evaluate Content Patterns From Large-Scale Language Data [Methods]. *Frontiers in Communication, 6*. https://doi.org/10.3389/fcomm.2021.588823

Miao, S., Meadows, M. E., Duan, Y., & Guo, F. (2022). How Does the Geography Curriculum Contribute to Education for Sustainable Development? Lessons from China and the USA. *Sustainability, 14*(17).

Napal, M., Mendióroz-Lacambra, A. M., & Peñalva, A. (2020). Sustainability Teaching Tools in the Digital Age. *Sustainability, 12*(8), 3366.

Peters, M. A., Wang, H., Ogunniran, M. O., Huang, Y., Green, B., Chunga, J. O., Quainoo, E. A., Ren, Z., Hollings, S., Mou, C., Khomera, S. W., Zhang, M., Zhou, S., Laimeche, A., Zheng, W., Xu, R., Jackson, L., & Hayes, S. (2020). China's Internationalized Higher Education During Covid-19: Collective Student Autoethnography. *Postdigital Science and Education, 2*(3), 968-988. https://doi.org/10.1007/s42438-020-00128-1

Pu, R., & Jiang, S. (2021). Understanding the consumption behaviors in online education towards promoting the sustainable development goals (SDGs). *Academy of Entrepreneurship Journal, 27*(6), 1-16.

Pu, R., Tanamee, D., & Jiang, S. (2022). Digitalization and higher education for sustainable development in the context of the Covid-19 pandemic: A content analysis approach. *Problems and Perspectives in Management*.

Sá, M. J., & Serpa, S. (2020). The COVID-19 Pandemic as an Opportunity to Foster the Sustainable Development of Teaching in Higher Education. *Sustainability, 12*(20), 8525.

Saura, J. R., Palos-Sanchez, P., & Grilo, A. (2019). Detecting Indicators for Startup Business Success: Sentiment Analysis Using Text Data Mining. *Sustainability, 11*(3), 917.

Sun, L., Niu, D., Wang, K., & Xu, X. (2021). Sustainable development pathways of hydropower in China: Interdisciplinary qualitative analysis and scenario-based system dynamics quantitative modeling. *Journal of Cleaner Production, 287*, 125528. https://doi.org/10.1016/j.jclepro.2020.125528

Sun, Y., Tian, W., Mehmood, U., Zhang, X., & Tariq, S. (2023). How do natural resources, urbanization, and institutional quality meet with ecological footprints in the presence of income inequality and human capital in the next eleven countries? *Resources Policy, 85*, 104007. https://doi.org/10.1016/j.resourpol.2023.104007

Tang, Q., Zhang, T., & Jiang, L. (2023). Influence of blended instruction on students' learning effectiveness: the role of Flow. *Education and Information Technologies, 28*(2), 1891-1909. https://doi.org/10.1007/s10639-022-11224-z

Tang, Y. M., Chen, P. C., Law, K. M. Y., Wu, C. H., Lau, Y.-y., Guan, J., He, D., & Ho, G. T. S. (2021). Comparative analysis of Student's live online learning readiness during the coronavirus (COVID-19) pandemic in the higher education sector. *Computers & Education, 168*, 104211. https://doi.org/10.1016/j.compedu.2021.104211

Wang, K., Zhang, L., & Ye, L. (2021). A nationwide survey of online teaching strategies in dental education in China. *Journal of dental education, 85*(2), 128-134.

Wang, Q., & Huang, R. (2021). The impact of COVID-19 pandemic on sustainable development goals – A survey. *Environmental Research, 202*, 111637. https://doi.org/10.1016/j.envres.2021.111637

Wilson, D. (2019). Exploring the Intersection between Engineering and Sustainability Education. *Sustainability, 11*(11), 3134.

Xiao, J. (2019). Digital transformation in higher education: critiquing the five-year development plans (2016-2020) of 75 Chinese universities. *Distance Education, 40*(4), 515-533. https://doi.org/10.1080/01587919.2019.1680272

Xing, Z., Guo, W., Liu, J., & Xu, S. (2022). Toward the Sustainable Development of the Old Community: Proposing a Conceptual Framework Based on Meaning Change for Space Redesign of Old Communities and Conducting Design Practices. *Sustainability, 14*(8), 4755.

Xu, Q., & Wang, J. (2021). Recognition of Values of Traditional Villages in Southwest China for Sustainable Development: A Case Study of Liufang Village. *Sustainability, 13*(14), 7569.

Xue, E., Li, J., & Xu, L. (2022). Online education action for defeating COVID-19 in China: An analysis of the system, mechanism and mode. *Educational Philosophy and Theory, 54*(6), 799-811. https://doi.org/10.1080/00131857.2020.1821188

Yan-Li, S., Jiang, N., Pamanee, K., & Sriyanto, J. (2022). Online learning readiness and satisfaction during covid-19 pandemic among university students in four Asian countries. *Journal of Nusantara Studies (JONUS), 7*(2), 245-269.

Yan, L., Whitelock-Wainwright, A., Guan, Q., Wen, G., Gašević, D., & Chen, G. (2021). Students' experience of

online learning during the COVID-19 pandemic: A province-wide survey study. *British journal of educational technology, 52*(5), 2038-2057.

Yli-Panula, E., Jeronen, E., & Lemmetty, P. (2020). Teaching and Learning Methods in Geography Promoting Sustainability. *Education Sciences, 10*(1), 5.

Yu, J., Jiang, S., Han, J., Li, L., & Ke, X. (2023). Promoting digital employment intention among students of Chinese higher education institutions. *Problems and Perspectives in Management, 21*(3), 22-39. https://doi.org/10.21511/ppm.21(3).2023.03

Zhanbayev, R. A., Irfan, M., Shutaleva, A. V., Maksimov, D. G., Abdykadyrkyzy, R., & Filiz, Ş. (2023). Demoethical Model of Sustainable Development of Society: A Roadmap towards Digital Transformation. *Sustainability, 15*(16), 12478.

Data Availability Statement

The datasets presented in this article are not readily available because they involve the interests of collaborators, as well as some privacy issues, and some data are confidential. However, further individual scholars or experts are welcome to request these datasets for academic references or other needs; requests to access these datasets should be directed to SJ, jiang.song@rmutr.ac.th.

Acknowledgments

We greatly appreciate the valuable contributions of our community advisory committee members. We would also like to thank the Dr. Ming Li and Dr. Songyu Jiang who took the time to participate in this study.

Authors contributions

Dr. Ming Li and Dr. Songyu Jiang were responsible for study design and revising. Dr. Ming Li and Dr. Songyu Jiang was responsible for data collection. Dr. Ming Li and Dr. Songyu Jiang drafted the manuscript and Dr. Nuttapong Jotikasthira1 revised it. All authors read and approved the final manuscript. In this paragraph, also explain any special agreements concerning authorship, such as if authors contributed equally to the study.

Funding

Not applicable.

Competing interests

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Informed consent

Obtained.

Ethics approval

The Publication Ethics Committee of the Sciedu Press.

The journal's policies adhere to the Core Practices established by the Committee on Publication Ethics (COPE).

Provenance and peer review

Not commissioned; externally double-blind peer reviewed.

Data availability statement

The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

Data sharing statement

No additional data are available.