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Review

# Innovations in higher education in the pursuit of SDG 4: A bibliometric analysis of research on quality education

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**Abstract:** This study maps and analyzes the intellectual landscape of research on innovations in higher education aligned with Sustainable Development Goal 4 (SDG 4: Quality Education), aiming to identify key trends and inform institutional strategies. Utilizing a bibliometric analysis of 1259 Scopus articles (2020–2024) and employing VOSviewer software, the research identified six emergent thematic clusters: digital transformation, AI integration, pedagogical innovation, employability, sustainability, and cross-sector collaboration. Key findings highlight the influence of highly cited works discussing sustainable digital transformation, generative AI, and flexible learning models accelerated by COVID-19, reflecting higher education's rapid adaptation to technological and societal changes. These results offer practical guidance for institutional leaders and policymakers on enhancing technology-enhanced learning, labor market-aligned curricula, and educational resilience, underscoring the value of frameworks like the Triple Helix. Ultimately, this study provides a comprehensive, data-driven synthesis and actionable insights toward advancing inclusive, future-ready, and sustainable educational systems.

**Keywords:** innovations in higher education; educational technology; bibliometric analysis; co-citation analysis; sustainable development goals (SDG 4); teaching and learning innovation

## 1. Introduction

In recent years, the landscape of higher education has undergone significant transformation driven by the accelerating pace of innovation and the urgent need to adapt to societal, technological, and economic changes. Higher education institutions worldwide are increasingly challenged to redefine their roles as providers of knowledge as well as engines of innovation and catalysts for socioeconomic development [1]. The growing pressures of globalization, digitalization, and the Fourth Industrial Revolution have compelled universities to adopt innovative approaches to teaching, research, and community engagement [2]. Furthermore, the unexpected disruptions caused by the COVID-19 pandemic have highlighted both vulnerabilities and opportunities within higher education systems, forcing a rapid transition to online and hybrid delivery [3]. These developments underscore the necessity of exploring the patterns, trends, and intellectual structures of innovations in higher education to inform future policies and practices.

A growing body of literature examines the multifaceted nature of innovation in higher education. For instance, Marshall et al. [4] emphasized that innovation in this sector is not limited to technological advancement, but also encompasses pedagogical shifts, curriculum reforms, and institutional strategies that aim to enhance student learning outcomes and institutional performance. The integration of emerging

technologies such as artificial intelligence (AI), virtual reality (VR), and learning analytics has opened new avenues for personalized and data-driven learning experiences [5]. Moreover, studies such as [6] demonstrated how pedagogical innovations such as the flipped classroom model enhance student engagement and autonomy. Similarly, Kolb's [7] theory of experiential learning continues to inspire the design of learner-centered environments that foster critical thinking and real-world problem-solving.

In parallel, scholars have paid increasing attention to the role of higher education in advancing the United Nations' Sustainable Development Goals (SDGs), particularly SDG 4: Quality Education. Baena-Morales and Merma-Molina [8] proposed that universities are uniquely positioned to equip students with the competencies needed for sustainable development, such as systems thinking, anticipatory skills, and strategic problem-solving. Thus, the global agenda for sustainability has become a driving force for curricular and institutional innovation, fostering interdisciplinary approaches that link academic inquiry with societal needs [9].

The rapid evolution of educational technologies has also been well-documented. Studies have explored how the integration of online learning platforms, mobile learning, and open educational resources (OER) expands access to and flexibility in higher education [5]. In particular, the COVID-19 pandemic has intensified scholarly interest in emergency remote teaching, highlighting the resilience and adaptability of higher education institutions [10]. Furthermore, research by Rogers [11] on the diffusion of innovation has provided valuable insights into how new technologies and practices are adopted and scaled within educational ecosystems.

Despite this growing body of research, several gaps remain in the literature. Although numerous studies have examined specific aspects of innovation in higher education, such as pedagogical strategies, technological tools, and policy frameworks, there remains a lack of comprehensive mapping of the intellectual landscape of this field. Much of the existing research tends to be fragmented, focusing on isolated case studies or limited geographical contexts, thus failing to capture the global trends and collaborative networks that drive innovation [1,12]. Moreover, there is a limited understanding of how research output on higher education innovation has evolved over time, the themes that have dominated scholarly discussions, and which authors and institutions have been the most influential.

Additionally, although thematic reviews and narrative syntheses provide valuable insights, they are often constrained by subjective biases and a limited scope [13]. Few studies have employed rigorous bibliometric approaches to systematically analyze large volumes of academic publications in this field. Bibliometric analysis offers an objective and quantitative method to uncover patterns in scholarly communication, such as co-authorship networks, keyword co-occurrences, citation trends, and thematic clusters [14]. By leveraging bibliometric techniques, researchers can identify influential publications, emerging research frontiers, and evolving intellectual structures, thereby offering a more comprehensive and data-driven understanding of innovation in higher education.

The urgency to bridge these gaps has become even more pressing in the light of recent global disruptions and the accelerated pace of digital transformation. Higher

education institutions are under increasing pressure to innovate not only in their pedagogical models, but also in their organizational structures, research agendas, and community engagement strategies [2,4]. Without a clear, data-informed understanding of the research landscape, policymakers, academic leaders, and educators may struggle to make strategic decisions that align with institutional goals and broader societal imperatives.

Given this context, this study aims to conduct a comprehensive bibliometric analysis of research on innovation in higher education. By systematically analyzing publications indexed in the Scopus database, this study sought to map the intellectual structure, identify key themes and trends, and uncover influential authors, journals, and institutions contributing to this dynamic field. Specifically, this study utilizes co-citation analysis, keyword co-occurrence analysis, and co-word clustering techniques to provide a holistic view of how innovation in higher education has been conceptualized and developed over time.

The objectives of this study are threefold: first, to analyze the growth trajectory and publication patterns related to innovations in higher education; second, to identify the main research themes, intellectual foundations, and emerging areas of interest within the field; and third, to highlight influential scholarly contributions and collaborative networks that shape the discourse on educational innovation. Through these objectives, this study aims to fill existing gaps in the literature by providing a macro-level perspective on evolution and the current state of research on innovation in higher education.

Ultimately, this bibliometric study will offer valuable insights for academics, policymakers, and institutional leaders seeking to understand the direction of educational innovation and position their strategies in alignment with global research trends. By shedding light on the interconnectedness of ideas, disciplines, and research actors, this study aims to inform evidence-based decision-making and promote the continuous transformation of higher education in response to the challenges and opportunities of the 21st century.

## 2. Methods

This study adopted a quantitative bibliometric approach to examine the intellectual structure and research trends surrounding innovation in higher education. Bibliometric analysis systematically evaluates extensive bodies of academic literature to identify publication patterns, thematic relationships, and influential contributions [14]. Using VOSviewer software (version [insert version]), the study conducted co-citation, keyword co-occurrence, and network visualization analyses to map the knowledge base and research dynamics within the field.

The data were sourced from the Scopus database, known for its comprehensive coverage of peer-reviewed publications. The search strategy utilized the Boolean string “Innovation” AND “higher education” AND “education”, ensuring that the retrieved records directly reflected the study’s scope. To refine results, the following parameters were applied: publication years 2020–2024, subject area: Social Sciences, document type: article, and language: English. These filters were designed to capture the most recent developments and relevant discussions on educational innovation.

After refinement, 1259 documents were included for analysis, representing a robust dataset for identifying key research trends and thematic concentrations.

During the data-processing phase in VOSviewer, specific inclusion thresholds were implemented to ensure analytical rigor and focus on influential literature. For co-citation analysis, only documents with a minimum of 20 citations were considered, enabling the identification of highly influential studies shaping the intellectual structure of the field. In analyzing cited references, a threshold of 10 citations per reference was applied to isolate foundational works that inform ongoing research in educational innovation.

In the keyword co-occurrence analysis, a minimum threshold of 14 occurrences per keyword was set to capture dominant research concepts and thematic foci. For visualization clarity, this threshold was further refined to 15 occurrences when constructing final network maps. These procedures facilitated the identification of major clusters representing distinct yet interconnected areas of inquiry, such as pedagogical innovation, digital transformation, and sustainable education.

VOSviewer's visualization capabilities allowed for the creation of network maps illustrating relationships among keywords, authors, and cited references. These visual representations revealed interconnected research communities, emerging trends, and core conceptual frameworks driving innovation in higher education. Cluster analysis was subsequently employed to synthesize related themes, enabling a structured interpretation of the research landscape.

Overall, this methodological framework ensured objectivity, transparency, and replicability, providing a comprehensive overview of how innovation in higher education has evolved between 2020 and 2024. By combining bibliometric techniques with advanced visualization tools, the study offers an integrated understanding of the field's intellectual structure, revealing how educational innovation is advancing in response to contemporary academic and societal challenges.

## 2.1. Search strategy and data collection

**Table 1** presents the search string used in the study and its justification. The keywords "Innovation" AND "higher education" AND "education" were selected to retrieve relevant studies focusing on transformative practices, technologies, instructional strategies, and developments within higher education institutions. The use of Boolean operators ensured a more precise and focused database search by identifying literature that simultaneously addressed innovation and higher education. Overall, the search strategy provided a comprehensive and systematic approach for gathering relevant studies aligned with the objectives of the review.

**Table 1.** Database search strategy used.

| Keyword | Justification |
|---|---|
| "Innovation" AND "higher education" AND "education" | The keywords "Innovation" AND "higher education" AND "education" were selected to comprehensively capture research focusing on transformative practices within educational institutions. This combination ensures the retrieval of studies addressing technological, pedagogical, and policy innovations, specifically within the context of higher education, aligning with the study's thematic focus. |

## 3. Results and discussion

This section outlines the key insights obtained from the bibliometric analysis of 1259 documents that focus on innovation in higher education. The analysis revealed the expanding trajectory and publication trends within the field, pinpointed the most influential and frequently cited works shaping scholarly discourse, and mapped the intellectual landscape through co-citation and keyword co-occurrence analyses. Collectively, these findings demonstrate that innovation in higher education is developing into a comprehensive and dynamic area of research, characterized by the integration of technological advancements, social responsibility, pedagogical enhancement, and adaptability to global challenges.

**Figure 1** presents the annual publication trends from 2020 to 2024, based on data retrieved from the Scopus database, using the keywords "Innovation" AND "Higher Education" AND "Education," filtered by subject area (Social Sciences), document type (Article), and language (English). The data reflect a steady and accelerating increase in scholarly output over the five year period. In 2020, approximately 360 documents were published, which gradually rose to around 400 in 2021, followed by continued growth to about 450 in 2022. The upward trend became more pronounced in 2023, with the number of publications rising sharply to over 550, peaking in 2024, with approximately 780 articles.

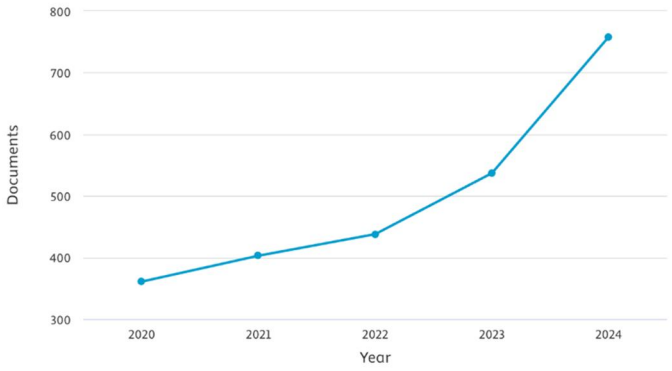


**Figure 1.** Number of publications based on scopus database.

This progression indicates growing academic engagement with the intersection of innovation and higher education, particularly within the social sciences domain. The continuous rise in publications suggests an increasing recognition of the importance of educational innovation, driven by global shifts, such as digital transformation, evolving pedagogical models, and the integration of sustainable development goals in higher education. The significant leaps in 2023 and 2024 likely reflect intensified efforts to reimagine education systems in the post-pandemic era as institutions worldwide continue to adapt to new learning environments and societal expectations.

Overall, the graph illustrates that research interest in innovation in higher education is not only sustained, but also accelerating. This suggests a vibrant and expanding field of inquiry where scholars actively contribute to discussions on how innovation can transform educational practices, policies, and outcomes in response to contemporary global challenges.

### 3.1. Citation analysis

Through document citation analysis, **Table 2** highlights the most highly cited publications in the dataset. The list is Abad-Segura et al. [15] with 306 citations, Michel-Villarreal [16] with 276 citations, and Oke and Fernandes [17] with 249 citations. These citation figures reflect the significant impact and scholarly relevance of these studies within the academic community.

**Table 2.** Top 10 highest-cited documents.

| No | Authors | Title | Citations |
|---|---|---|---|
| 1 | Abad-Segura et al. [15] | Sustainable management of digital transformation in higher education: Global research trends | 306 |
| 2 | Michel-Villarreal [16] | Challenges and Opportunities of Generative AI for Higher Education as Explained by ChatGPT | 276 |
| 3 | Oke and Fernandes [17] | Innovations in teaching and learning: Exploring the perceptions of the education sector on the 4th industrial revolution (4IR) | 249 |
| 4 | Liu et al. [18] | Understanding academics' adoption of learning technologies: A systematic review | 198 |
| 5 | Abelha et al. [19] | Graduate employability and competence development in higher education-A systematic literature review using PRISMA | 189 |
| 6 | Southworth et al. [20] | Developing a model for AI Across the curriculum: Transforming the higher education landscape via innovation in AI literacy | 187 |
| 7 | Marks and Thomas [21] | Adoption of virtual reality technology in higher education: An evaluation of five teaching semesters in a purpose-designed laboratory | 174 |
| 8 | Butler-Henderson and Crawford [22] | A systematic review of online examinations: A pedagogical innovation for scalable authentication and integrity | 167 |
| 9 | Bokolo et al. [23] | Blended Learning Adoption and Implementation in Higher Education: A Theoretical and Systematic Review | 161 |
| 10 | Zawacki-Richter [24] | The current state and impact of Covid-19 on digital higher education in Germany | 148 |

#### 3.1.1. Trends and emerging themes in innovations in higher education

The analysis of the top ten most-cited documents reveals significant trends shaping innovations in higher education. Abad-Segura et al. [15], with the highest citations, emphasize the sustainable management of digital transformation, highlighting universities' commitment to integrating technology while aligning with sustainability goals. Michel-Villarreal [16] reflects growing scholarly attention to generative AI, particularly ChatGPT, recognizing both its opportunities and challenges in reshaping teaching, assessment, and curriculum design. Similarly, Oke and Fernandes [17] explored the perceptions of the Fourth Industrial Revolution, underlining the urgency for education to align with emerging digital economies.

Liu et al. [18] complement this by examining faculty adoption of learning technologies and affirming that institutional support is vital for successful innovation. Graduate employability has emerged as a recurring theme, with Abelha et al. [19] focusing on competency development to meet labor market needs. Southworth et al [20] further expanded this by proposing models for AI literacy across curricula and preparing students for future work environments shaped by automation and AI technologies.

The adoption of immersive learning technologies is also evident, as Marks and Thomas [21] assessed the integration of virtual reality to enhance engagement and

experiential learning. Meanwhile, Butler-Henderson and Crawford [22] addressed the shift to online examinations, ensuring integrity in remote learning contexts. Anthony et al. [23] and Zawacki-Richter [24] capture the widespread adoption of blended learning and accelerated digitalization driven by the COVID-19 pandemic.

Collectively, these works demonstrate a rapidly evolving field toward technologically enriched, sustainable, and flexible educational models, with a clear focus on employability, innovation adoption, and the future readiness of higher education institutions.

## 3.2. Citation distribution and implications for innovations in higher education

The citation distribution of the top ten most-cited documents in this study reflects a dynamic and rapidly evolving research landscape in innovations in higher education. The most-cited work by Abad-Segura et al. [15], with 306 citations, underscores the urgency of sustainably managing digital transformation in higher education, signaling a foundational concern for aligning technological adoption with long-term institutional sustainability. Michel-Villarreal [16], with 276 citations, emphasizes the emerging discourse around generative AI, particularly ChatGPT, highlighting both the promise and complexities of AI integration in higher education. The prominence of this work demonstrates the rapidly growing academic interest in AI's transformative impact on pedagogy and assessment.

The next tier of highly cited studies, such as Oke and Fernandes [17] with 249 citations and Liu et al. [18] with 198 citations, illustrates the sector's preoccupation with the Fourth Industrial Revolution and faculty's adoption of learning technologies. These studies collectively suggest that understanding educators' perceptions and preparedness is crucial for successful technology adoption. Mid-range citations, such as Abelha et al. [19] and Southworth et al. [20], both around 180 citations, point to an increasing focus on graduate employability and AI literacy, indicating a shift towards aligning educational outcomes with future workforce demands.

Lower in citation counts but still significant, Marks and Thomas [21], Butler-Henderson and Crawford [22], Bokolo et al. [23], and Zawacki-Richter [24] contributed to essential themes of immersive learning, academic integrity in online assessments, blended learning models, and the acceleration of digitalization during the pandemic. This distribution reflects a balanced mix of theoretical exploration and practical application, highlighting how scholarly attention is spread across emerging technologies, institutional strategies, and learner-centered outcomes.

The implications of this distribution are significant. The concentration of citations on digital transformation, AI, and employability-focused innovations reveals an academic consensus on the priorities shaping the future of higher education. These trends suggest that institutions not only embrace new technologies, but also critically examine their pedagogical value, ethical considerations, and relevance to the labor market. Furthermore, significant attention to pandemic-induced changes underscores a sector's agility and responsiveness to external disruptions. Overall, citation distribution illustrates an active, globally relevant research agenda that is shaping

policies and practices toward more adaptive, technology-enhanced, and future-ready higher education systems.

### 3.3. Co-citation analysis

**Table 3** shows the co-citation analysis of the top 10 documents highlights the foundational theoretical and methodological frameworks shaping research on innovations in higher education. Prominently cited among these is Braun and Clarke's [25] seminal work on thematic analysis, which garnered 69 citations and a total link strength of 23. Its strong influence demonstrates the extensive application of qualitative methodologies in examining complex dimensions of educational innovation, particularly in exploring perceptions, experiences, and contextual factors.

**Table 3.** Top 10 documents with the highest co-citation and total link strength.

| Documents | Citation | Total link strength |
|---|---|---|
| "Braun V, Clarke V. Using thematic analysis in psychology, qualitative research in psychology. 3(2). pp. 77–101. [25]" | 69 | 23 |
| "Transforming our world: The 2030 agenda for sustainable development. [9]" | 40 | 20 |
| "Rogers E. M, Diffusion of innovations. [11]" | 33 | 27 |
| "Lave J, Wenger E. Situated learning: legitimate peripheral participation. [26] | 26 | 21 |
| "Fornell C, Larcker DF. Evaluating structural equation models with unobservable variables and measurement error, j. mark. Res. 18. pp. 39–50. [27]" | 23 | 19 |
| "Ajzen I. The theory of planned behavior, organizational behavior and human decision processes, 50(2). pp. 179–211. [29]" | 23 | 12 |
| "Cohen J. Statistical power analysis for the behavioral sciences. [28]" | 21 | 7 |
| "Yin RK. Case study research: Design and methods. [30]" | 18 | 11 |
| "Kolb DA. Experiential learning: experience as the source of learning and development. [7]" | 18 | 9 |

Source: Author interpretation based on VOSviewer analysis.

The inclusion of Transforming Our World: The 2030 Agenda for Sustainable Development [9], which recorded 40 citations and a total link strength of 20, highlights the significant influence of sustainability frameworks, particularly SDG 4 (Quality Education), on educational reforms and research directions. This finding demonstrates how global development agendas continue to shape innovation initiatives in higher education.

Rogers' [11] Diffusion of Innovations, with 33 citations and the highest total link strength of 27, further affirms the continuing relevance of innovation diffusion theory in explaining the adoption and dissemination of educational technologies and pedagogical innovations across academic institutions. In a related perspective, Lave and Wenger's [26] Situated Learning theory, which obtained 26 citations and a link strength of 21, underscores the importance of social learning contexts and communities of practice in promoting meaningful educational transformation.

From a methodological perspective, the works of Fornell and Larcker [27], which received 23 citations and a total link strength of 19, together with Cohen's [28]

statistical power analysis and Ajzen's [29] Theory of Planned Behavior, demonstrate the strong integration of quantitative frameworks and behavioral theories in evaluating the adoption of educational innovations.

Yin's [30] *Case Study Research* methodology, with 18 citations and a link strength of 11, reflects the continued emphasis on comprehensive and context-based investigations of innovation practices within specific educational environments. Similarly, Kolb's [7] Experiential Learning Theory, which also obtained 18 citations and a link strength of 9, emphasizes the sustained importance of active and learner-centered learning approaches in higher education.

Overall, the co-citation network reveals a significant convergence of qualitative and quantitative methodologies, behavioral and learning theories, and global development frameworks, illustrating a holistic and interdisciplinary perspective in the study of educational innovation. The combination of methodological rigor and theoretical diversity provides a deeper understanding of how innovations are designed, adopted, and assessed in higher education, thereby supporting the attainment of SDG 4 and broader educational transformation goals.

The co-citation network visualization revealed four distinct clusters, as shown in **Figure 2**. Each cluster was identified and interpreted based on representative publications, with the labels derived through the author's inductive analysis and understanding of the prevailing thematic focus within the four clusters.

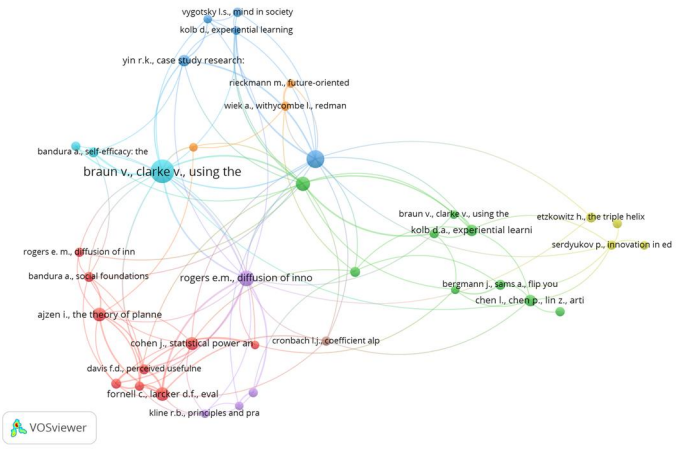


**Figure 2.** Co-citation analysis of the innovation in higher education.

Co-citation analysis of educational tools in business education revealed distinct research clusters on entrepreneurship. The red cluster, centered around Ajzen's [29] Theory of Planned Behavior and Chen and Mohd Salleh [31] argue that opportunity recognition plays a significant role in shaping entrepreneurial intentions in the digital age.. The blue cluster emphasizes how educational interventions shape student motivation, self-efficacy, career intentions, and innovation competencies. The green cluster, dominated by Braun and Clarke [25], links to qualitative methodologies like thematic analysis, suggesting these methods are essential for assessing student experiences and curriculum design. Finally, the yellow cluster, links business education to strategic management and competitive advantage, implying research interest in how education translates into sustainable real-world success. The strong

interconnection between entrepreneurial motivation, educational methodologies, and business strategy highlights the importance of methodological rigor in assessing business education tools. This complex network is further illuminated by triangulating these findings with the broader intellectual landscape. The overall co-citation network highlights the foundational role of learning theories, such as experiential learning by Kolb [7], situated learning by Lave and Wenger [26], and the diffusion of innovations by Rogers [11], which underpin themes like technology-enhanced and active learning (Cluster 2). Furthermore, the prominence of sustainability goals, notably the reference to Transforming Our World: The 2030 Agenda for Sustainable Development, reinforces the alignment of educational innovations with global objectives, such as SDG 4. The keyword analysis confirms students as the central focus, informed by pedagogical theories and diffusion models evident in the co-citation findings. Overall, this triangulation suggests that innovation in higher education is not only driven by technological adoption but is also deeply rooted in human-centered pedagogical frameworks, orienting the field toward sustainable and inclusive educational futures.

**Table 4** summarizes the co-citation analysis by presenting its clusters, cluster labels, number of articles, and representative publications.

**Table 4.** Co-citation clusters on the innovation in higher education.

| Cluster label | Number of articles | Representative publications |
|---|---|---|
| Learner-Centered Pedagogies and Technological Integration in Educational Innovation | 8 | R: A Language and Environment for Statistical Computing [32]; Bergmann and Sams, Flip Your Classroom: Reach Every Student in Every Class Every Day [33]; Braun and Clarke, Using Thematic Analysis in Psychology [25]; Chen et al., Artificial Intelligence in Education: A Review [5]; Kolb, Experiential Learning: Experience as the Source of Learning and Development [7]; Lave and Wenger, Situated Learning: Legitimate Peripheral Participation [26]; Prince, Does Active Learning Work? A Review of the Research [34]; Wenger, Communities of Practice: Learning, Meaning, and Identity [26]. |
| Theoretical and Methodological Foundations of Technology Acceptance and Behavioral Studies | 7 | Davis, Perceived Usefulness, Perceived Ease of Use, and User Acceptance of Information Technology [35]; Fornell and Larcker, Evaluating Structural Equation Models with Unobservable Variables and Measurement Error [27]; Hair et al., When to Use and How to Report the Results of PLS-SEM [36]; Henseler et al., A New Criterion for Assessing Discriminant Validity in Variance-Based Structural Equation Modeling [37]; Rogers, Diffusion of Innovations (5th ed.) [11]. |
| Foundational Theories of Behavior, Cognition, and Innovation Adoption | 6 | Ajzen, The Theory of Planned Behavior [29]; Bandura, Self-Efficacy: The Exercise of Control [38]; Bandura, Social Foundations of Thought and Action: A Social Cognitive Theory [39]; Braun and Clarke, Using Thematic Analysis in Psychology [25]; Dhawan, Online Learning: A Panacea in the Time of COVID-19 Crisis [3]; Rogers, Diffusion of Innovations [11]. |
| Psychological Frameworks and Adoption of Innovation in Education | 5 | Ajzen, The Theory of Planned Behavior [29]; Bandura, Self-Efficacy: The Exercise of Control [38]; Bandura, Social Foundations of Thought and Action: A Social Cognitive Theory [39]; Braun and Clarke, Using Thematic Analysis in Psychology [25]; Dhawan, Online Learning: A Panacea in the Time of COVID-19 Crisis [3]; Rogers, Diffusion of Innovations [11]. |
| Experiential Learning, Case Study Inquiry, and Education for Sustainable Development | 5 | Kolb, Experiential Learning: Experience as the Source of Learning and Development [7]; United Nations, Transforming Our World: The 2030 Agenda for Sustainable Development [9]; Stake, The Art of Case Study Research [40]; Vygotsky, Mind in Society: The Development of Higher Psychological Processes [41]; Yin, Case Study Research: Design and Methods [30]. |
| University-Industry-Government Synergies and the Transformative Role of Higher Education | 4 | Compagnucci and Spigarelli, The Third Mission of the University: A Systematic Literature Review on Potentials and Constraints [1]; Etzkowitz and Leydesdorff, The Dynamics of Innovation: From National Systems and "Mode 2" to a Triple Helix of University–Industry–Government Relations [12]; Etzkowitz, The Triple Helix: University–Industry–Government Innovation in Action [42]; Serdyukov, Innovation in Education: What Works, What Doesn't, and What to Do About It? [4]. |
| Research Methodologies and Competency-Based Approaches for Sustainable Higher Education | 3 | Creswell and Creswell, Research Design: Qualitative, Quantitative, and Mixed Methods Approaches [13]; Rieckmann, Future-Oriented Higher Education: Which Key Competencies Should Be Fostered Through University Teaching and Learning? [43]; Wiek et al., Key Competencies in Sustainability: A Reference Framework for Academic Program Development [44]. |

The co-citation cluster analysis provides a structured and coherent view of the intellectual foundations shaping innovation in higher education. The analysis identified four distinct clusters, each representing a significant dimension of the field.

*Cluster 1 (Red): Learner-Centered Pedagogies and Technological Integration in Educational Innovation*

This cluster emphasizes the intersection of learner-centered pedagogies and technology in driving educational innovation. Foundational theories such as Kolb's [7] Experiential Learning, which promotes learning through reflection and experience, and Lave and Wenger's [26] Situated Learning, which situates knowledge in social contexts, underpin this approach. Jenkins et al. [45] extends this with Communities of Practice, fostering collaborative learning and shared meaning. Prince's [34] review confirmed that active learning enhances engagement and outcomes, validating participatory instruction.

Technological integration transforms these pedagogies. Dieu [6] Flipped Classroom model redefines classroom dynamics by leveraging digital tools for interactive learning. Chen et al. [5] demonstrated how AI personalizes learning and optimizes instruction. Tools such as R further enable data-driven teaching decisions. Braun and Clarke's [25] Thematic Analysis supports deep qualitative inquiry into learner experiences. Collectively, this cluster demonstrates how theory-informed, technology-enhanced approaches create adaptive and evidence-based learning environments in higher education.

*Cluster 2 (Green): Quantitative Models and Theories for Innovation Adoption in Education*

This cluster highlights quantitative models and theoretical frameworks essential for understanding innovation adoption in education. Cronbach's [46] Coefficient Alpha laid the foundation for reliability in educational measurement. Fornell and Larcker [27] advanced structural equation modeling (SEM) to assess latent constructs, while Hair et al. [36] further refined contemporary guidelines for discriminant validity and model evaluation in partial least squares SEM (PLS-SEM). Cepeda et al. [47] clarified guidelines for partial least squares SEM (PLS-SEM), improving analytical precision.

- Theoretical foundations include Davis's [35] Technology Acceptance Model (TAM), which introduced perceived usefulness and ease of use as predictors of acceptance, and Rogers's Diffusion of Innovations [11], which explains how innovations spread through communication and social systems. Together, these works show that combining robust statistics with behavioral theory provides a rigorous basis for understanding and validating educational technology adoption in higher education.

*Cluster 3 (Blue): Behavioral Theories and Digital Innovation Adoption*

This cluster explores behavioral and adoption theories that explain individual engagement with educational innovations. Ajzen's [29] Theory of Planned Behavior emphasizes intention, attitude, and control as predictors of adoption, while Bandura's Self-Efficacy [38] and Social Cognitive Theory [39] link belief in personal capability to openness to new technologies. Braun and Clarke's [25] Thematic Analysis adds qualitative depth to understanding learners' motivations. Dhawan [3] contextualized these theories during the COVID-19 shift to online learning, identifying opportunities

and barriers. Rogers's [11] Diffusion of Innovations frames these individual behaviors within institutional systems. Together, these works reveal how personal and contextual factors shape sustainable innovation adoption in higher education.

*Cluster 4 (Yellow): Psychological Frameworks and Innovation Adoption in Education*

This cluster merges psychological and statistical perspectives to explain innovation adoption. Davis's [11] TAM remains central, identifying perceived usefulness and ease of use as drivers of technology acceptance. Cohen's [28] Statistical Power Analysis reinforces methodological reliability in behavioral research. Fornell and Larcker [27] and Kline [48] provide SEM frameworks for assessing psychological constructs and behavioral intentions. The Education for Sustainable Development Goals: Learning Objectives [49] situates these models within global educational priorities, linking innovation to sustainability competencies. This cluster underscores that integrating behavioral models with quantitative analysis yields evidence-based insights into educational innovation aligned with global development aims.

*Cluster 5 (Yellow): Experiential Learning, Case Study Inquiry, and Education for Sustainable Development*

This cluster connects experiential learning, qualitative inquiry, and sustainability goals to promote innovation in higher education. Kolb's [7] Experiential Learning Theory views learning as transformation through experience, while Vygotsky's [41] Sociocultural Theory emphasizes social interaction in cognitive growth. Stake [40] and Yin [30] advance case study methodologies for examining innovations in authentic contexts. The 2030 Agenda for Sustainable Development [50] and SDG 4 emphasize education's role in sustainability. Together, these frameworks illustrate how experiential and case-based approaches can deepen engagement, contextualize learning, and align higher education with societal goals.

*Cluster 6 (Cyan): University-Industry-Government Synergies and the Transformative Role of Higher Education*

This cluster examines how higher education institutions (HEIs) act as innovation hubs through collaboration with industry and government. Etzkowitz and Leydesdorff's [12] Triple Helix model conceptualizes innovation as a product of university–industry–government interactions. Etzkowitz [42] further elaborates on these partnerships as mechanisms for knowledge co-creation and social progress. Compagnucci and Spigarelli [1] expand the model through the university's "third mission," emphasizing social and economic engagement. Marshall et al. [4] identifies best practices and barriers in educational innovation. Collectively, these studies highlight how HEIs drive transformative change by fostering collaborative ecosystems that advance institutional and societal development.

*Cluster 7 (Orange): Research Methodologies and Competency-Based Approaches for Sustainable Higher Education*

This cluster bridges methodological rigor and sustainability-focused competencies. Creswell and Creswell [13] emphasize the use of qualitative, quantitative, and mixed methods to investigate innovation comprehensively. Rieckmann [43] identifies core sustainability competencies—systems thinking and anticipatory skills—as essential for higher education reform. Baena-Morales and

Merma-Molina [8] propose a framework for embedding these competencies into curricula. Together, these works demonstrate how rigorous methodologies and competency-based design enable universities to prepare learners for complex global challenges and foster sustainable, future-ready institutions.

## 3.2. Co-citation analysis

Co-word analysis was conducted using the same database. Among the 4478 identified keywords, 103 satisfied the minimum threshold of 10 occurrences, resulting in the formation of two clusters. The keywords with the highest co-occurrence frequencies were *Higer education* (1161), *innovation* (430), and *educational innovation* (315). **Table 5** presents the top 15 co-occurring keywords together with their frequency of occurrence and total link strengths.

**Table 5.** Top 15 keywords in the co-occurrence of keywords analysis.

| Ranking | Keyword | Occurrences | Total link strength |
|---|---|---|---|
| 1 | Higher education | 1161 | 2646 |
| 2 | Innovation | 430 | 1205 |
| 3 | Educational innovation | 315 | 904 |
| 4 | Covid-19 | 119 | 375 |
| 5 | taching | 115 | 576 |
| 6 | Learning | 113 | 599 |
| 7 | Sustainability | 112 | 452 |
| 8 | Education | 110 | 460 |
| 9 | Student | 101 | 551 |
| 10 | Students | 88 | 393 |
| 11 | Sustainable development | 83 | 327 |
| 12 | University sector | 82 | 401 |
| 13 | High education institutions | 77 | 140 |
| 14 | e-learning | 74 | 281 |
| 15 | university | 72 | 216 |

Co-occurrence analysis of keywords in innovation research within higher education reveals key thematic concentrations defining the field. Higher education emerged as the most dominant keyword (1161 occurrences; 2646 link strengths), emphasizing institutional transformation [1] Innovation (430; 1205) and educational innovation (315; 904) follow, reflecting ongoing efforts to enhance learning and institutional effectiveness [51]. The prominence of COVID-19 (119; 375) underscores the pandemic's role in accelerating innovation, especially in remote learning [3]. Keywords such as teaching (115) and learning (113) highlight pedagogical redesign, while e-learning (74) signifies sustained digital engagement [5]. Terms like sustainability (112) and sustainable development (83) align with SDG 4: Quality Education [9]. The recurrence of student (101) and students (88) reflects learner-centered approaches [7]. Overall, the strong link strengths indicate an interconnected ecosystem integrating technology, pedagogy, and sustainability in higher education innovation.

**Figure 3** presents the network map derived from the co-word analysis, which revealed five distinct clusters. These clusters were identified and labeled through the author's inductive interpretation of the recurring keywords. The findings further showed that the clusters were closely interconnected and exhibited partial integration with one another.

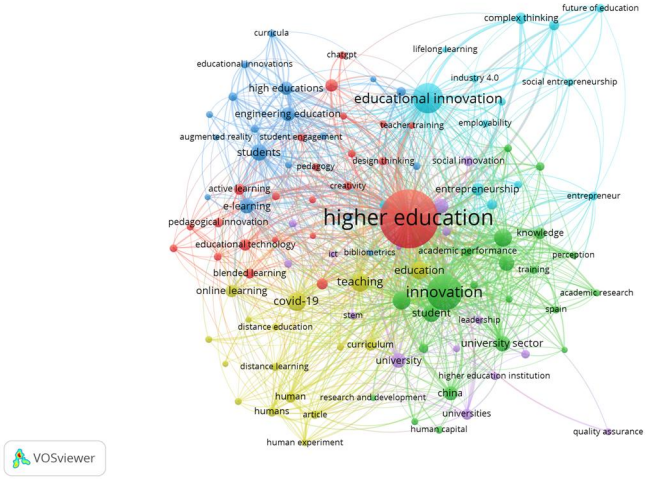


**Figure 3.** Co-word analysis on the innovations in higher education.

- Cluster 1 (red): This cluster centers on technology-driven pedagogical strategies, such as *active learning*, *blended learning*, *online learning*, and *e-learning*. The integration of *educational technology* and *gamification* reflects the field's response in enhancing learner engagement and flexibility [5]. COVID-19 (*pandemic*, *distance education*) has prominently appeared, underscoring how the crisis accelerated digital adoption [3]. These pedagogical shifts align with learner-centered approaches that promote autonomy and active participation in virtual environments [6].
- Cluster 2 (green): Focusing on *sustainability*, *sustainable development*, and *social innovation*, this cluster aligns closely with global goals, particularly SDG 4 [49]. The connection between *innovation*, *university sector*, *leadership*, and *higher education institutions* highlights the institutional push toward sustainable transformative practices [1]. Concepts such as *human capital* and *academic research* point to the broader socioeconomic impact of educational innovation.
- Cluster 3 (blue): This cluster highlights emerging tools (*virtual reality*, *augmented reality*, *engineering education*, *ChatGPT*), pointing to the adoption of cutting-edge technologies for future-ready learning. The inclusion of *student engagement*, *curricula*, and *educational innovations* emphasizes the redesign of learning experiences to enhance critical thinking and prepare learners for complex digital futures [43,44].
- Cluster 4 (yellow): Linking *entrepreneurship*, *social entrepreneurship*, *employability*, and *lifelong learning*, which illustrates higher education's role in fostering entrepreneurial mindsets and career readiness [12]. The themes of *future of education*, *industry 4.0*, and *complex thinking* reflect the

competencies required in an innovation-driven economy, preparing graduates for dynamic labor markets [43].

- Cluster 5 (violet): This smaller but significant cluster includes *quality assurance*, *universities*, *research and development*, and *bibliometrics*. The emphasis on *China* and *Spain* suggests a regional focus on publication patterns and institutional strategies. This cluster points to how institutions leverage the research impact and quality assurance mechanisms to drive innovation in education [27,46].
- Cluster 6 (Cyan): This thematic group highlights *human*, *humans*, *human experiment* and *diffusion*, suggesting an emphasis on human-centered research and behavioral understanding of innovation adoption [11,35]. This cluster connects deeply with psychological frameworks that explain how innovation is accepted and diffused in educational contexts.

Collectively, these clusters illustrate a dynamic, interconnected research landscape. Innovation in higher education is not limited to technological advances, but extends to sustainable development, entrepreneurial competencies, institutional strategies, and human-centered learning design. The interplay of pedagogical methods, emerging technologies, institutional leadership, and global goals underscores the transformative role of higher education in preparing learners for an unpredictable and fast-evolving future [4,7].

**Table 6** presents a summary of the co-word analysis, including the cluster labels, number of keywords, and representative keywords for each cluster.

**Table 6.** Co-word analysis on the innovation in higher education.

| Cluster no and color | Cluster label | Number of keywords | Representative keywords |
|---|---|---|---|
| 1 (red) | Transformative Strategies for Entrepreneurial and Sustainable Higher Education | 28 | Collaboration, curriculum design, digital transformation, digitalization, employability, entrepreneur, entrepreneurial university, entrepreneurship, entrepreneurship education, experiential learning, higher education, higher education institutions, ICT, industry 4.0, innovations, internationalization, knowledge management, lifelong learning, organizational change, professional development, quality assurance, research, social innovation, STEM, sustainable development goals, transformation, triple helix, universities |
| 2 (green) | Institutional Innovation, Human Capital, and Sustainable Development in Global Higher Education | 23 | Academic performance, academic research, China, digitization, economic growth, educational development, higher education institution, human capital, innovation, institutional framework, knowledge, perception, questionnaire survey, research and development, Spain, stakeholder, student, sustainability, sustainable development, sustainable development goal, training, university, university sector |
| 3 (blue) | Innovative Pedagogies and Technology-Enhanced Learning for Student Engagement and Skills Development | 19 | Active learning, assessment, blended learning, creativity, critical thinking, design thinking, educational technology, evaluation, flipped classroom, gamification, machine learning, motivation, pedagogical innovation, pedagogy, project-based learning, student engagement, teacher training, teaching innovation, university students |
| 4 (yellow) | Technology-Driven Educational Innovations and Future-Oriented Learning Environments | 19 | Augmented reality, bibliometrics, challenge-based learning, computer aided instruction, curricula, e-learning, education 4.0, education computing, educational innovations, engineering education, high educations, learning systems, mobile learning, open innovation, students, systematic review, teaching and learning, technological innovation, virtual reality |
| 5 (violet) | Human-Centered Education, Leadership, and Diversity in Curriculum and Teaching | 12 | Article, curriculum, education, female, human, human experiment, humans, leadership, learning, male, medical education, teaching |

**Table 6.** (*Continued*).

| Cluster no and color | Cluster label | Number of keywords | Representative keywords |
|---|---|---|---|
| 6 (Cyan) | Pandemic-Driven Technology Adoption and the Rise of Online Education | 6 | Covid-19, covid-19 pandemic, diffusion of innovation, distance education, distance learning, online education, online learning, pandemic, technology, technology adoption |
| 7 (Orange) | AI-Enabled Educational Innovation and Critical Skills for Future-Ready, Inclusive Learning | 8 | Artificial intelligence, ChatGPT, complex thinking, educational innovation, future of education, gender, professional education, social entrepreneurship |

# 4. Discussion

## 4.1. Theoretical implications

This bibliometric analysis offers valuable theoretical contributions to the discourse on innovation in higher education in the context of advancing Sustainable Development Goal 4 (Quality Education). The study first reinforces the enduring significance of human-centered learning theories, such as Experiential Learning Theory [7], Sociocultural Theory [41], and Communities of Practice [26]. These frameworks remain crucial as institutions adopt technology-enhanced and student-centered pedagogies to improve collaborative and experiential learning outcomes. Second, the findings highlight the continued applicability of technology adoption models—specifically Rogers' Diffusion of Innovations [11], Davis's Technology Acceptance Model [35], and Ajzen's Theory of Planned Behavior [29]—which explain the acceptance dynamics of emerging tools like AI and VR accelerated in the post-pandemic era. Crucially, the analysis reveals a growing theoretical convergence between innovation diffusion theories and sustainability education frameworks. The prominence of the United Nations' 2030 Agenda for Sustainable Development [50] and works by Baena-Morales and Merma-Molina [8] and Rieckmann [43] position innovation not merely as a technological pursuit, but as a strategic means to achieve the global mandate for sustainable, inclusive education. Furthermore, the strong references to research methodologies, including Creswell's mixed-methods approach [13] and the structural equation modeling of Fornell and Larcker [27] and Cepeda et al. [47], demonstrate how methodological rigor supports robust theory building in this field. Finally, co-citation clusters underscore the rising relevance of interdisciplinary frameworks like the Triple Helix model [12], signaling a theoretical shift toward understanding universities as collaborative hubs that integrate entrepreneurial, technological, and policy-oriented theories into complex innovation ecosystems. This study therefore enriches the theoretical landscape by consolidating diverse perspectives to promote holistic, systems-oriented approaches for future research.

## 4.2. Practical implications

The findings of this bibliometric analysis offer meaningful practical insights for policymakers, institutional leaders, and educators striving to advance innovation in higher education and achieve SDG 4. Strategic actions are needed across five key areas. First, institutions must prioritize digital transformation through strategic investment in infrastructure and the integration of tools like AI and virtual reality to boost learning access and flexibility. Second, curriculum reform is essential, demanding tighter

alignment with labor market needs through the embedding of practical and experiential learning to build graduates' future-ready skills. Third, successful change requires faculty empowerment via targeted professional development and incentives for adopting transformative pedagogy. Fourth, fostering cross-sector collaboration, notably through the Triple Helix framework, is vital for knowledge exchange and co-creating sustainable solutions. Finally, the analysis underscores the urgency of building institutional resilience by institutionalizing flexible and hybrid learning models that can seamlessly adapt to future disruptions. By focusing on technological integration, employability, faculty support, collaboration, and resilience, stakeholders can advance meaningful innovations for inclusive, equitable, and quality education.

## 5. Conclusion

This bibliometric analysis provides a comprehensive mapping of the research landscape on innovations in higher education aligned with SDG 4: Quality Education. By analyzing 1259 Scopus articles published between 2020 and 2024, the study identified key trends and six thematic clusters, including digital transformation, AI integration, pedagogical reform, employability, sustainability, and cross-sector collaboration. The findings confirm an accelerating shift toward digital, flexible, and scalable education models, driven by emerging technologies and the need for educational resilience. The research reveals a globally engaged community addressing the urgent need to innovate practices to fulfill the aspirations of SDG 4, providing essential guidance for institutional strategy and curriculum reform. Despite this robustness, the study has limitations, being restricted to Scopus-indexed articles within the Social Sciences subject area, which potentially excluded interdisciplinary work (e.g., engineering, health) and foundational earlier papers. Furthermore, bibliometric methods do not capture the qualitative depth or contextual nuances of individual studies, such as regional variations or policy impacts.Building on these insights, future research should incorporate multiple databases and a broader interdisciplinary scope to achieve a more comprehensive view. Qualitative or mixed-methods research is needed to provide deeper insight into the contextual implementation and long-term sustainability of innovations adopted during the COVID-19 pandemic. Finally, given the rapid evolution of AI, critical studies examining the ethical considerations and humanization of learning within increasingly automated educational environments are essential.

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