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Visualizing digital transformation in entrepreneurship education: a bibliometric analysis study from 2018 to 2022

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Entrepreneurship education (EE) through digital transformation has recently received scholarly attention, with an exponential increase in publication and citation rates. A bibliometric analysis by visualizing connected networks using Vosviewer is used in the analysis to investigate trends, research topics, and notable works in the field of digital transformation in entrepreneurship education. The comprehensive review scans the evolution of this integrated topic based on 204 papers taken from Web of Science from 2018 to 2022. Results show that digital transformation has significantly impacted various industries and sectors, including entrepreneurship education. The increased scholarly activity in the domain of digital transformation and entrepreneurship education suggests that it is an active and vibrant area of inquiry, attracting the attention and contributions of a diverse range of researchers and practitioners. The integration of digitalization with entrepreneurship education is an important building block for entrepreneurship development. Future research could consider a wider data source to better understand trends in digital integration in entrepreneurship education and its development.

KEYWORDS

bibliometric analysis, digital transformation, entrepreneurship education, visualization, co-citations

1 Introduction

Digital transformation in entrepreneurship education refers to the integration of digital technologies and practices into the teaching and learning processes related to entrepreneurship. Digital transformation has profoundly impacted almost all sectors, including entrepreneurship education and business modeling. The new paradigms that are emerging as a result of technological and social breakthroughs generated from the vast use of information and communication technologies are generating a transformative processes (Díaz-García et al., 2022).

Digital transformation is the adoption and integration of digital technology (which includes digital artifacts, digital infrastructure, and digital platforms) in a variety of domains, with the primary goal of transforming how businesses function and provide value to customers (Mirzagayeva and Aslanov, 2022). Digital transformation is typically defined as digitizing previously analog machine and service operations, organizational

duties, and management procedures (Paunov and Caroline, 2017). It is divided into three categories: technological preparedness (e.g., ICT investments), digital technology exploration (e.g., research and development), and digital technology exploitation (e.g., patents and trademarks) (Jafari-Sadeghi et al., 2021). It refers to the process of leveraging digital technology to develop new business processes and entrepreneurial activities, or to adapt current ones, as well as to build new cultures and consumer experiences in response to changing business and market requirements (Ransbotham et al., 2016).

The overview of digital technology and the current environmental volatility are profoundly changing the way organizations compete, eroding firm borders and reshaping value-generation processes (Jonsson et al., 2018). According to Iannone and Caruso (2023), digitalization enables more efficiency, optimize many steps in production processes, constantly monitoring the process with almost no margin of error, and provides valuable support for organizations in pursuing sustainable developments (Iannone and Caruso, 2023). Although digital transformation is gaining importance, we know little about the challenge of ambidextrous learning in that context or how to manage the challenge (Wu et al., 2021). In the teaching of entrepreneurship education, complexities are brought about by the multiplicity of what “entrepreneurship education” entails and extend digital transformation can or should be adopted for effective learning. According to conventional wisdom in entrepreneurship education, educational institutions have a significant impact on the development of entrepreneurial skills (Fagadar et al., 2021). The route to entrepreneurship is becoming easier with constantly expanding technology, and increasingly inventive advertising breakthroughs on social media (Maulana et al., 2023). If digital transformation can enhance innovation and entrepreneurship education (Liao et al., 2024) the question becomes, to what extent, recently, has digital transformation in entrepreneurial education gained scholarly attention? This would be evidenced in an exponential surge in publication and citation numbers (Tiberius and Weyland, 2023).

Several bibliometric studies on digital transformation in entrepreneurship education (specifically) and higher education (in general) have been carried out in the past (Dissanayake et al., 2022). It will be important to mention one of the earlier analysis on entrepreneurial education (EE) done by Rizza (2011). The science citation index expanded (SCI) and social sciences citation index (SSCI) were used in the study. This study focused on Europe and was on entrepreneurship education and not on EE. Providing these preliminary results (trends) was novel and important. Díaz-García et al. (2022) carried out a bibliometric analysis on digital transformation in higher education. The analysis covered the period 1900 to 2021, sampling articles from the Web of Science (WoS) database. This could be the longest period covered on such studies on this topic. Bibliometric analysis studies from the Web of Science database to determine the extent of research on entrepreneurship education at universities was carried out.

The selection of the period is worth noting as one may not have expected the existence of entrepreneurial education or digitalisation around 1900s. A sense and need for inclusivity could have driven the choice. The importance of the study is that it could

have provided the longest review period on this subject to date. The study however covered “education” in general and not EE. Other studies that analyzed, digital transformation in education (not EE), are Özdemir et al. (2023) and Acuña et al. (2023). The former revealed the developments in the historical process of digital transformation in education between 2000 and 2023 in the Web of Science database and the latter scanned the Web of Science (WoS) database, between the years 2014 and October 2022. Another study by Phuong et al. (2023) used the Scopus database from inception (2004) to January 2023. The only study we could identify that focuses on digital transformation and EE is by Rosele et al. (2024). It used the Scopus database for data extraction covering the period 2004 to 2023. It utilized Bibilioshiny complemented by Microsoft Excel for metadata visualization. An analysis of the previous studies reveals that most of them focused on digital transformation in education in general and only one (or possibly a few) focused on EE specifically.

Prior studies focused on different time frames, on different data sources and used different methods of analysis. The present study’s uniqueness and contribution is in its focus on EE. It is only one of very few studies with this focus, meaning that its findings will add to currently limited findings on the topic. The only other identified study is by Rosele et al. (2024). While Rosele et al. (2024) used the Scopus data base and the Bibilioshiny/Microsoft Excel visualization approach, this study utilized the WOS database and the bibliography and VOS viewer analysis. This provides an alternative viewpoint and enables a comparative analysis. The period of analysis is also different from the other study, with this study focusing on the period 2018 to 2022. This period was selected in response to the challenges forced on entrepreneurship education by the Covid-19 pandemic. This study’s findings add to the findings of earlier studies, especially in terms of the EE focus, the data base used, methodology and period (where research responses to the pandemic need to be better understood).

The study therefore set out to answer the following research questions (RQs):

RQ1: Which publications, journals, and keywords are most influential in the field of digital transformation and entrepreneurship education research in the period under study?

RQ2: What are the trends in publications and citations related to digital transformation within entrepreneurship education in the period under study?

RQ3: What research streams are currently being explored, and which potential research streams are likely to emerge in the future?

In line with the studies briefly discussed earlier, an overview of digital transformation in higher education and digital transformation in entrepreneurial education is presented next.

2 Literature review

2.1 Digital transformation in higher education

Significant parts of higher education institutions’ teaching, research, engagement, and management operations are being affected and changed because of digital transformation. As stated

by Garcez et al. (2022), digital transformation has changed the means for acquiring knowledge in higher education institutions, changing the student-lecturer and teaching-learning interactions (Garcez et al., 2022). Digital transformation has also emerged as a driving force for innovative, inclusive, and sustainable growth (Xiaoyu and Guoqing, 2019).

The emergency of coronavirus epidemic 2019 (COVID-19) and the resulting social alienation was the primary impetus for the adoption of digital methods to respond to education and business needs. The resulting shutdown accelerated and increased the necessity for a speedy transition to digitalization (Corvello et al., 2022). The virtual work environment became the primary means of engagement during the pandemic (Contreras et al., 2020). Covid's indirect effect has been an increase of the use of information and communications technology (ICT) tools by the people, as well as an increase in the digital competencies of individuals (Manco-Chavez et al., 2020). Due to the relevance of COVID-19 pandemic, the number of studies of digital transformation in higher education has substantially increased.

In summary, the pandemic had a significant impact on organizational digital transformation, allowing experts to investigate how these phenomena dynamically evolve and what their most evident implications. As stated by Alenezi et al. (2023), digital transformation has gained momentum and contemporary higher education institutions (HEI) have been embracing new technologies and transforming their practices, business models and processes. Adapting to digital technology has primarily been examined as a process that occurs in many areas, such as banking and mechanical engineering, but this is insufficient in higher education. Similarly, in the context of higher education institutions (HEIs), critical players for sustainable development, there is a theoretical lack in comprehensive reviews on the subject (Trevisan et al., 2023). A substantial number of educational stakeholders are concerned about the issue of digitization in higher education institutions, and indicate that digital skills are becoming increasingly relevant in every context, notably in the workplace (Alenezi et al., 2023). As a result, one of the primary goals for colleges has been to promote digital information literacy as a critical set of abilities for creating future managers and entrepreneurs.

The higher education sector is in the eye of the digital revolution, undergoing an on-going digital transformation process that is projected to result in considerable changes to the current business model (Rof et al., 2020). With the goal of reaching a global ranking and academic distinction, a huge number of universities have decided to prioritize competition and higher academic quality, in which digital transformation allows for the employment of electronic systems in the teaching process (Brdesee, 2021).

Digital transformation has resulted in significant changes in the status of numerous companies; nonetheless, this has proven troublesome for higher education institutions. Problems include a lack of leadership and cultural change, low levels of innovation and financial support, and limited integration into curricula and teaching activities. It might also be claimed that the situation differs in developed and developing countries, as well as amongst universities. The disparity is unrivaled in universities located in underdeveloped countries. To remain viable,

educational institutions must innovate to match with the digital environment in which they operate. Furthermore, they must pay more attention and adjust their priorities to lead the digital transition. This calls for additional investigation and opinions on the subject.

2.2 Digital transformation in entrepreneurship education

The digital transformation of economic operations has had an impact on entrepreneurs' work by giving instruments to help themes, particularly in a dynamic environment. According to Secundo et al. (2021), entrepreneurs must adapt to the changing circumstances as digitalisation spreads and people become more comfortable and skilled with digital technologies.

New ways of managing entrepreneurship centers involve a more massive adoption of digital technologies (Secundo et al., 2020a,b). The emergence of novel and powerful digital technologies, platforms and infrastructures has transformed innovation and entrepreneurship in significant ways (Nambisan et al., 2019). Entrepreneurship education plays a fundamental and complex role in preparing the early stages of the business and also in digitalization (Salamon, 2020).

Entrepreneurship education is one of the most popular management education disciplines since it combines theory and practice (Ratten and Jones, 2021). It is important because it promotes the global economic wellbeing (Ratten and Usmanij, 2021). Higher education institutions (HEIs) are important components of the entrepreneurial ecosystem. They are anticipated to generate entrepreneurial capital, which is a driver for regional economic and societal growth (Stolze and Sailer, 2021). HEIs students must be trained to start businesses using innovation technologies. The use of technology is critical for societal transformation (Altinay and Altinay, 2018) especially in entrepreneurship education where practical, hands on skills and mental skills are to be cultivated or transferred (Cantú-Ortiz et al., 2020). The advancement of digital technology can assist entrepreneurship students in acquiring information more quickly and easily, paving the path for the identification of new opportunities and innovations in communities (Fahmi and Savira, 2021). High-quality digital infrastructure underpins practically every area of a modern and dynamic economy and society (Stankovic et al., 2021). According to Varblane et al. (2008), managerial and organizational competence is improved and treated at the same level of importance as technological competence is realized by entrepreneurship students.

Recently, the integration of digital technologies is reshaping the society globally (Hansen, 2019) and the nature and activities of entrepreneurship have also made fundamental change (Gawer and Cusumano, 2014). Digital technologies were creating new opportunities for innovation and have emerged as the primary driver of change in entrepreneurship education (Dabrowska et al., 2022). They have the ability to revolutionize the way work is done in both intellectual professions (Salamon, 2020) and more traditional settings, for example, by boosting execution speed and precision (Corvello et al., 2022). Even while some studies have emphasized

the relevance of digital technologies as a strategic tool for spin-off development and entrepreneurship education, few studies have focused on the examination of digital technologies across all aspects of entrepreneurship education activities and processes (Rippa and Secundo, 2019).

The practice of entrepreneurship education differs from continent to continent, from region to region, country to country and also vary across institutions (Secundo et al., 2020a,b). The implementation of national entrepreneurship policies results in the creation of supported programs across various member states (Stolze and Sailer, 2021). Digital technologies are viewed as important for the sustainability of entrepreneurship; however, cultural and time constraints are highlighted as the most important barriers to the adoption of digital technologies, confirming the difficulties in the digital transformation of entrepreneurship education (Secundo et al., 2020a,b). This is problematic since the entrepreneurial approach to teaching entrepreneurship contradicts standard teaching methods. Academic evaluation systems assess knowledge and skills rather than behavior (Afsana and Likitha, 2020). Using bibliometric analysis and visualization techniques, this study seeks to map the main publications, and research areas in the field of digital transformation in entrepreneurship education. The results are expected to add to the current literature and assist stakeholders in making informed decisions about curriculum development, and policy formulation in the context of entrepreneurship education.

3 Research design and methodology

When doing a bibliometric study, it is critical to identify the source of the published research to be analyzed to ensure its relevance. We choose the articles for our sample using the Web of Science (WoS). This database is well-known in the scientific community, owing to its comprehensive coverage of published research in various academic disciplines. The search parameters are particularly important in the creation of the articles since they allow us to focus our research to certain relationships and find the most relevant ones (Enciso-Alfaro and García-Sánchez, 2022). The scientific data analysis was carried out based on bibliometric mapping techniques, which are the application of quantitative ways to visually portray scientific knowledge using bibliographic data (Aria and Cuccurullo, 2017). Top journals and experts from all disciplines have published several very impactful works employing bibliometric tools to investigate the evolutionary nuances of different subjects and capture emerging trends (Mukherjee et al., 2022). Bibliometric analysis is a common and rigorous method for exploring and analyzing vast amounts of scientific data (Donthu et al., 2021; Ragazou et al., 2022). Because these databases have a considerable number of bibliographic references, the VOS viewer was chosen for use in visual representation analysis to show the relationships between concepts and ideas (Burlacu et al., 2021). The bibliometric research aims to provide a preliminary scientific map on current study of the innovation and entrepreneurial action transformed by digital technologies (Utomo and Cham, 2023).

In recent years, the use of bibliometric analysis method has grown. Its popularity can be attributed to (1) the advancement,

availability, and accessibility of bibliometric software such as VOSviewer and scientific databases such as Web of Science, and (2) the cross-disciplinary pollination of bibliometric methodology from information science to entrepreneurial education in digital transformation research. More crucially, the appeal of bibliometric analysis in educating entrepreneurs in digital transformation research is not a passing trend, but rather a reflection of its utility for (1) processing enormous amounts of scientific data and (2) delivering high impact research. Bibliometric research offers unique potential for contributing to theory and practice (Mukherjee et al., 2022). Furthermore, bibliometric analysis is a literature review process that allows for an understanding of current knowledge and evaluates the research produced in a certain topic over a specific time of examination (Muchangos, 2022).

3.1 Data collection and searching strategies

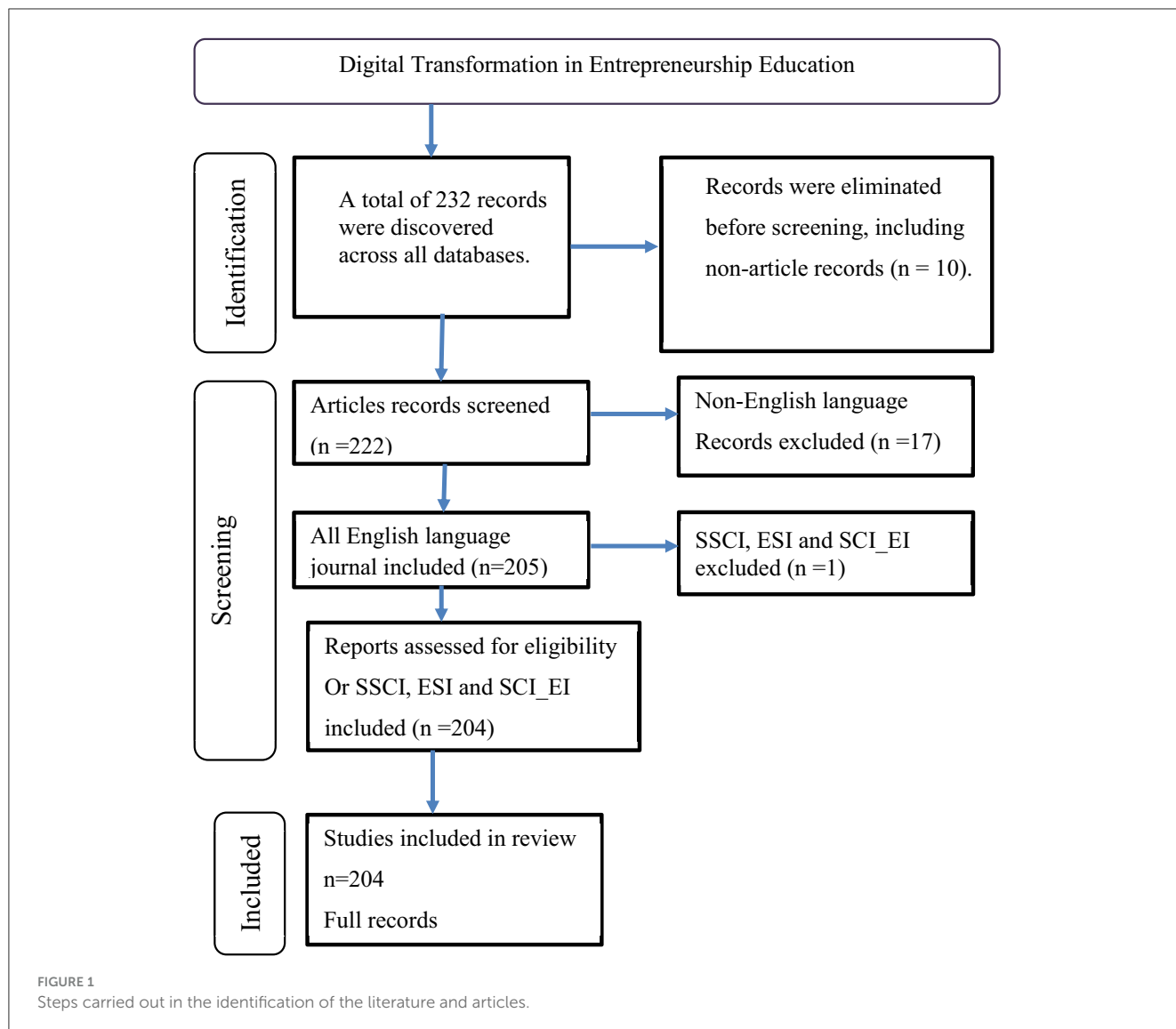
The data was gathered using the Web of Science search engines, with the following search terms: “Entrepreneurship education” AND “Entrepreneurship training” AND “Entrepreneurial education” AND “Entrepreneurial training” AND “Digital transformation” AND “Technological transformation” and a publication year ranging from 2018 to 2022 (Figure 1). Reviews in the literature entrepreneurial education and digital transformation were done. These search variables were created using the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines and charts (Andrade-valbuena et al., 2018; Liberati et al., 2009; Pahlevan-Sharif et al., 2019). Word terms from the title, keywords, title, and abstract fields were used to create search phrases. The Web of Science search engine returned a total of 232 articles. The bibliometric analysis was carried out on 204 published journal articles after the exclusion criteria was applied.

3.2 Data cleansing and standardization

In systemic reviews, data consistency and purification are critical. Standardization of codes (co-occurrence and keywords) was done by hand in this study, and the information of each article examined individually (Lojo et al., 2018). The Web of Science was used to migrate the article library first. Keywords in articles needed to be consolidated; thus, related terms were reduced and standardized.

3.3 Data analysis

To extract data and examine its interrelationships, VOSviewer (version 1.6.17) was utilized. VOSviewer is used to plot the created maps, network visualization, bibliography, and (link) (Van Eck and Waltman, 2021). Different clusters are used to organize the items. Following these steps, the library was exported as a plain text data file and processed for sophisticated bibliometric analysis from Web of Science. Furthermore, in this study the researchers used the co-occurrence analysis method via keyword unit analysis by full counting techniques. Based on the bibliometric analysis,



a minimum of five (5) keywords of occurrences was selected. Of 1413 keywords, 31 meet the threshold based on the data analysis. Overall, bibliometric studies are instrumental in advancing both theory and practice by providing insights into the current state of research and highlighting significant contributions within a discipline. The combination of robust databases like WoS and effective visualization tools like VOSviewer enhances the ability to conduct meaningful bibliometric analyses. The foreign research used the relevant documents of the core collection through search term from Web of Science database (Feng et al., 2023).

4 Results and discussions

This analysis examines the evidence for contribution of digital transformation to entrepreneurial education. The standard systematic review processes to synthesize the results from 204 studies is used to meet the eligibility criteria finding: Business (39 publications), Management (28 publications), Environmental

Science (20 publications), Educational Research Education (16 publications), and Environmental Studies (15 publications) being the top three peer-reviewed journals in Table 1. This result (with business and management at the top) may not be surprising given that entrepreneurship education is situated in the business and management domain. Entrepreneurship education teaches among other things, to start businesses and on how to best manage those businesses started. The next higher results, “environmental science or environmental studies” and “educational research education” could be explained by the fact that entrepreneurship education teaches the exploration of opportunities in the “environment”. This environment includes currently popular research area of Sustainable Development Goals (SDGs). Research on SDGs is widely encouraged and promoted at many universities worldwide. SDGs are closely linked with entrepreneurship education especially in developing economies where adverse environmental effects are being experienced. “Education research education” could be seen as a pedagogical issue which closely links with entrepreneurship education. Moreover, digital process and services innovation

TABLE 1 Summary of main journals analysis research on digital transformation and entrepreneur's education, 2018–2022.

S.No	Web of science categories or journal types	Number of published articles	Percentage	Impact factor, 2022
1	Business	39	19.118	4.86
2	Management	28	13.725	8.08
3	Environmental Sciences	20	9.804	6.796
4	Education Educational Research	16	7.843	3.09
5	Environmental Studies	15	7.353	1.263
6	Green Sustainable Science Technology	14	6.863	0.78
7	Economics	11	5.392	1.178
8	Chemistry Multidisciplinary	10	4.902	2.307
9	Materials Science	10	4.902	3.623
10	Engineering Electrical Electronic	9	4.412	0.225
11	Chemistry Physical	8	3.922	2.348
12	Multidisciplinary Sciences	8	3.922	9.412
13	Computer Science Information Systems	7	3.431	1.167
14	Psychology Multidisciplinary	7	3.431	2.323
15	Regional Urban Planning	7	3.431	0.69
16	Engineering Industrial	6	2.941	3.37
17	Telecommunications	5	2.451	4.497
18	Computer Science Artificial Intelligence	4	1.961	14.05
19	Computer Science Theory Methods	4	1.961	0.827
20	Engineering Chemical	4	1.961	13.273
21	Physics Applied	4	1.961	2.348
22	Social Sciences Interdisciplinary	4	1.961	0.20
23	Biotechnology Applied Microbiology	3	1.471	3.53
24	Chemistry Applied	3	1.471	5.294
25	Geography	3	1.471	2.676

suggests that digital capability should be driven by technology, solutions and digital business concepts (Utomo and Cham, 2023).

Figure 2 depicts the evolution of the number of publications per year from the beginning in 2001 to 2022 which aligns with our result for the period of study, 2018 to 2022. The bibliometric analysis shows that research output on the topic of digital transformation in entrepreneurship education has steadily increased over the last decade. This shows that the academic community is becoming more interested in and concerned about this problem. Correspondingly, the number of citations received by these publications also increased over time. This indicates that the research in this area is gaining more visibility and recognition, as scholars are increasingly building upon the work of their peers and incorporating the findings into their own studies. Overall, the upward trend in publications corresponds with an increase in citations, suggesting that as more research is published, the body of work becomes more influential. The significant rise in both publications and citations from 2018 onward could indicate heightened interest or advancements in the field, leading to

increased scholarly activity and recognition. The bibliometric analysis performed provides a rigorous and comprehensive picture of the study on digital transformation that may be useful to business owners, creative thinkers, managerial practitioners, and researchers interested in the quest of advancing or locating new information in this sector. Maulana et al. (2023) conducted a research trends and visualization mapping on the issue of digital entrepreneurship using bibliometric analysis.

During the COVID-19 pandemic, the global transition to remote learning and digital entrepreneurship corresponds with the post-2019 spike in publications and citations. Secundo et al. (2021), for example, described how universities quickly embraced platforms such as Zoom and Moodle, which sparked research on digital pedagogy in entrepreneurship education. In a similar vein, Corvello et al. (2022) highlighted how the pandemic accelerated research on virtual entrepreneurial workflows because lockdowns required digital solutions to ensure business continuity. In general, research on teaching digital entrepreneurship gained a lot of momentum as remote learning became more commonplace. This

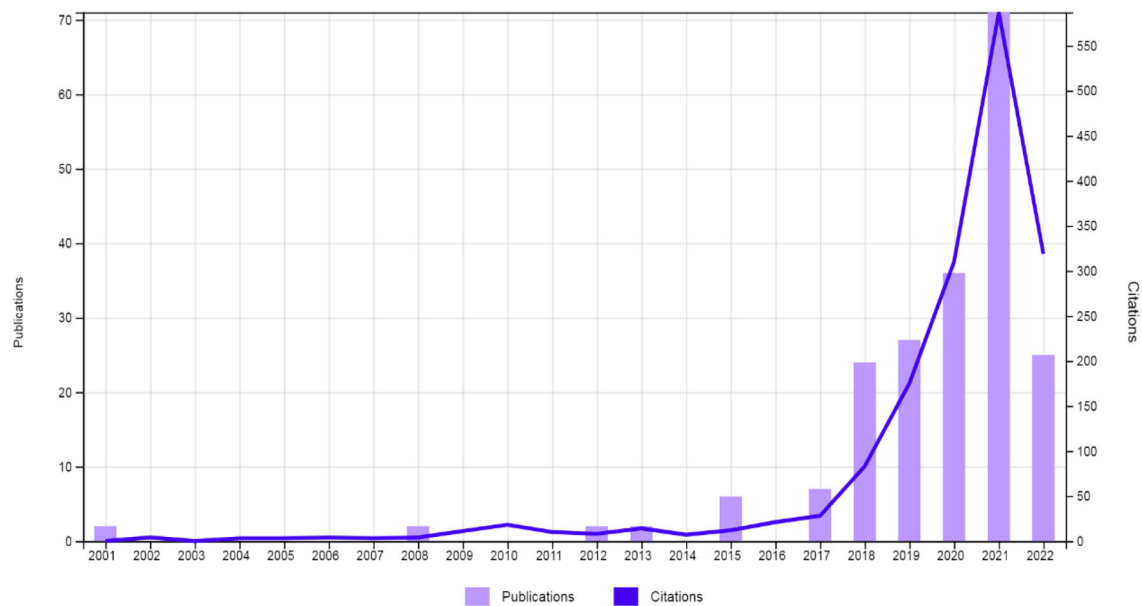


FIGURE 2
Annual development of publications and citations.

increase in scholarly interest is in line with studies by [Contreras et al. \(2020\)](#), which showed how quickly digital education research grew in reaction to disturbances brought on by COVID-19. Apart from the pandemic, the trends in citations also show a more general global trend of acknowledging the importance of digital skills for entrepreneurship.

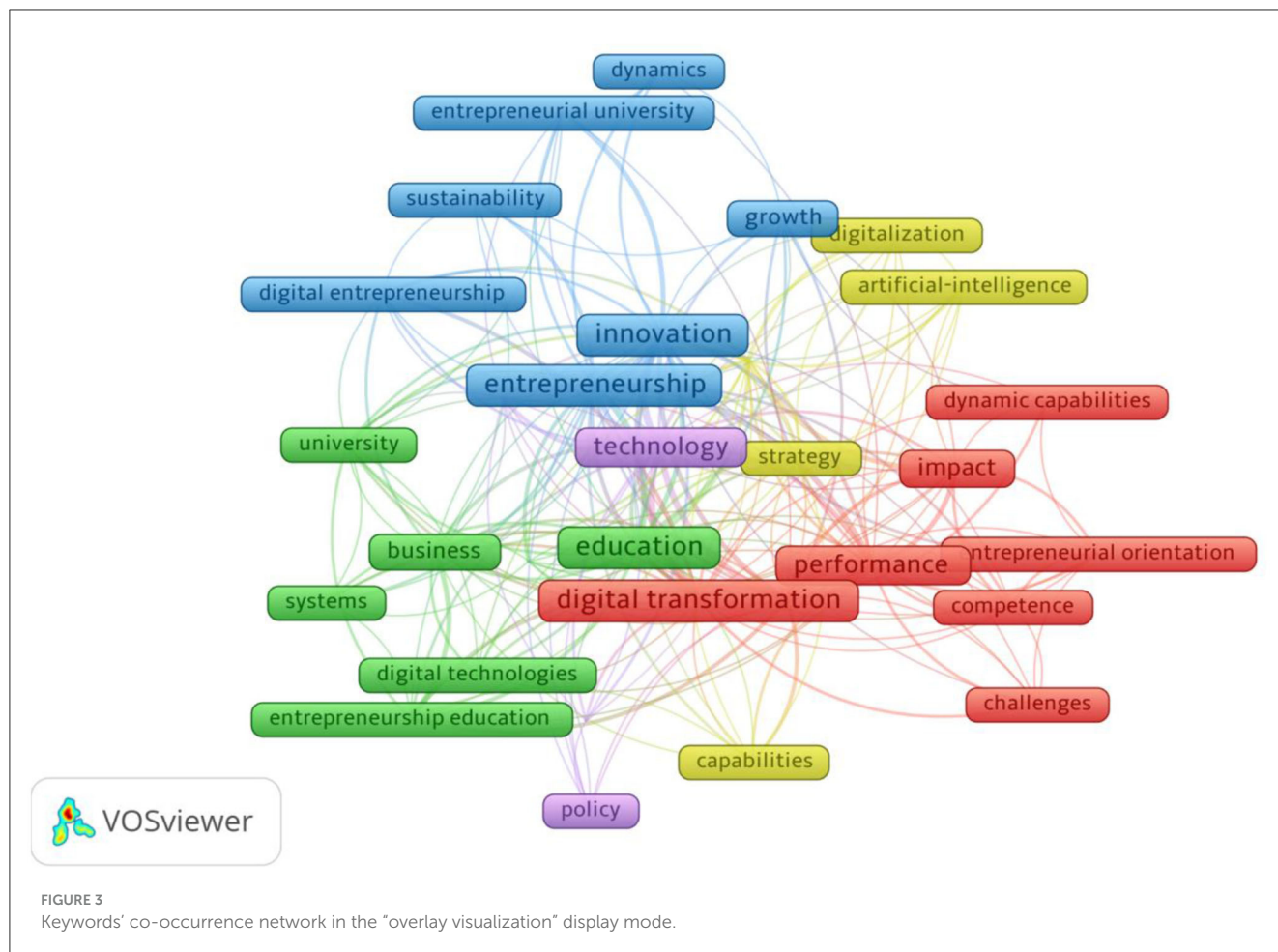
As indicated in [Figure 3](#), a series of characteristics allow us to conclude that digitalization transformation can become the determining factor of education with direct implications in innovation, entrepreneurship, and technology. These features are summarized as follows: Node(s): Each node in a network represents an entity keywords, and in this case a keyword, wherein: (1) the size of the node indicates the occurrence of the keyword (i.e., the number of times that the keyword occurs), (2) the link between the nodes represents the co-occurrence between keywords (i.e., keywords that co-occur or occur together), (3) the thickness of the link signals the occurrence of co-occurrences between keywords (i.e. the number of times that the keywords co-occur or occur together), (4) the bigger the node, the greater the occurrence of the keyword, and (5) the thicker the link between nodes, the greater the occurrence of the co-occurrences between keywords. Each color represents a thematic cluster, wherein the nodes and links in that cluster can be used to explain the theme's (cluster's) coverage of topics (nodes) and the relationships (links) between the topics (nodes) manifesting under that theme (cluster). The keyword co-occurrence and bibliographic coupling analyses revealed the main research themes and emerging topics, as digital technologies, entrepreneurship education, and the impact of digital transformation on entrepreneurial mind-sets and skills.

Digital transformation and the subsequent widespread digitalization of the invention function have frequently been linked to increased opportunities for search and recombination ([Lanzolla et al., 2021](#)). Digital transformation in the education

sector has entailed the engagement of sustainable management, in order to adapt to the changes imposed by new technologies ([Abad-Segura et al., 2020](#)). [Table 2](#) indicate the main overlay visualization co-occurrences of terms by key words full counting. The top seven in terms of total co-occurrences with keywords were Digital transformation (26), Entrepreneurship (24), Education (22), Innovation (22), Technology (20) Management (19) and Performance (19).

In addition, the five main overall link strengths were Innovation (64), Entrepreneurship (60), Technology (60), Digital transformation (55), and Management (55) among the full count, respectively. Furthermore, digital transformation and the resultant innovation of business models have fundamentally altered consumers' expectations and behaviors, putting immense pressure on traditional firms, and disrupting numerous markets ([Verhoef et al., 2021](#)). Entrepreneurship has been considered a new science in the promotion of economic development, which has led to a rapid development in the education entrepreneurs ([Wu et al., 2018](#)). The business model canvas and business plan are common tools used in entrepreneurship training ([Türko, 2016](#)). Academic entrepreneurship literature in response to the introduction of strong digital technologies provides an overview of the state of research, defining a future research agenda on digital academic entrepreneurship ([Secundo et al., 2020a,b](#)).

According to other research, high-quality digital infrastructure is the foundation for practically every area of a contemporary and innovative economy and society ([Stankovic et al., 2021](#)). As stated by [Athanasios and Vasiliki \(2019\)](#), students' digital and entrepreneurial abilities enabled them to develop new, valuable products and services. [Giones and Brem \(2017\)](#) point out that technology entrepreneurship is an established concept in academia, and higher education institutions have been feeling great pressure to advance in digital transformation



(Cruz-Cárdenas et al., 2022). Other researches have pointed out that the digital transformation of entrepreneurial education and the usage of digital tools with built-in artificial intelligence algorithms is improving the effectiveness of education in terms of increasing entrepreneurship (Lesinski et al., 2023). The aspect of intention resonates with the broader appreciation of entrepreneurial education, learning “about” (awareness) or “how to” (practice). The strongest correlation with respect to keyword co-occurrence was between innovation, entrepreneurship, technology, digital transformation, and management. This indicates the necessity for effective implementation of emergent digital technologies to foster entrepreneurship education activities and the dissemination of information among university students (Secundo et al., 2020a,b).

Our findings are in line with more general patterns in research on digital transformation, like the exponential rise in publications after 2018, which Díaz-García et al. (2022) observed in their examination of higher education. Their study concentrated on general education, but our findings particularly draw attention to entrepreneurship education (EE) as a separate subfield. Furthermore, the prominence of terms like innovation, technology, and management reflects patterns seen in bibliometric research on entrepreneurship education (Tiberius and Weyland, 2023) and digital transformation (Verhoef et al., 2021), highlighting the subjects' interdisciplinary character. However, our study focuses on the consequences of digital transformation for entrepreneurship

education, whereas Verhoef et al. (2021) studied it from a general business perspective.

Our analysis of 2018–2022 shows a stronger post-pandemic spike in EE research than Díaz-García et al. (2022), who examined a longer timeframe (1900–2021). This highlights COVID-19's catalytic role in driving digital adoption, a nuance that was less evident in earlier studies. In a similar vein, earlier research (e.g., Secundo et al., 2020a,b; Rippa and Secundo, 2019) found limitations in the understanding of digital technologies across all EE domains. Future studies should fill up the gaps in the investigation of sustainability-related entrepreneurship education and AI-driven pedagogy. Furthermore, our study directly addresses the dearth of bibliometric studies that are EE-focused in comparison to more general educational research. Furthermore, our post-2020 data includes pandemic-driven changes in digital EE strategies, which was not included in pre-2020 analysis.

5 Conclusion

Understanding the current research environment, identifying major research subjects, and displaying the relationships between various concepts can all provide valuable insights for academics, educators, and policy makers. Among the areas discovered by bibliometric analysis in terms of prospective

TABLE 2 The number of co-occurrences' and total link strength from full counting keywords.

S.no	Keywords	Occurrence	Total link strength
1	Innovation	22	64
2	Entrepreneurship	24	60
3	Technology	20	60
4	Digital transformation	26	55
5	Management	19	55
6	Education	22	48
7	Performance	19	46
8	Transformation	17	41
9	Business	8	30
10	Impact	11	28
11	Entrepreneurship Education	6	25
12	University	6	20
13	Knowledge	8	19
14	Strategy	6	19
15	Digital Entrepreneurship	6	15
16	Capability	5	14
17	Competency	5	14
18	Digital technology	5	14
19	Growth	10	14
20	Efficiency	6	13
21	Entrepreneurial orientation	5	13
22	Entrepreneurship University	6	13
23	Digitalization	5	12
24	System	7	11
25	Artificial intelligence	5	10
26	Challenges	5	10
27	Information	6	10
28	Dynamics	5	8
29	Policy	5	8
30	Sustainability	6	8
31	Dynamic capabilities	5	7

innovation, entrepreneurship, technology, digital transformation, management, and education have a high total linking count.

Overall, bibliometric studies are instrumental in advancing both theory and practice by providing insights into the current state of research and highlighting significant contributions within a discipline. The combination of robust databases like WoS and effective visualization tools like VOSviewer enhances the ability to conduct meaningful bibliometric analyses.

This study's findings are useful for researchers, educators, and policymakers interested in entrepreneurship education

and digital transformation. The visualization techniques can help identify research gaps, foster interdisciplinary collaborations, and guide the development of innovative approaches to better prepare entrepreneurs for the digital age. This understanding can guide curriculum development and pedagogical strategies. By mapping out existing research, visualizations can highlight opportunities for collaboration among researchers, educators, and industry practitioners, fostering interdisciplinary partnerships to enhance education.

Although the research questions have been answered, as the study provided matrices and trends as initially set out, however certain weaknesses need to be recognized. For example, most of the 204 articles were not read or analyzed content-wise to further understand what the authors are saying about digital transformation and EE or digital transformation and higher education. Doing so would enable better understanding of qualitative arguments and discussions that would provide deeper insights on the subject and the relationship between the two facets. From such a task, better recommendations to stakeholders would likely be generated. Some of the studies that were reviewed tended to be broader as they bibliographed authors and source countries or regions of the studies. If done in this study, this could have provided more insight especially regarding the covid period, on which the study was premised.

6 Practical implications

In order to tackle curriculum integration, we suggest implementing AI-powered platforms like KABADA (Lesinski et al., 2023), a tool that uses scenario-based simulations and real-time feedback to improve entrepreneurial skills. Virtonomics and SimVenture are examples of virtual business simulations that could help close the gap between theory and practice by providing hands-on learning opportunities for risk management and digital marketing (Wu et al., 2018). To further emphasize eco-innovation and keep up with the growing importance of SDGs in entrepreneurship education, sustainability-focused modules should use frameworks such as the Sustainability Business Model Canvas (Abad-Segura et al., 2020). Therefore, we offer particular resources for incorporating digital learning into courses on entrepreneurship, such as AI-powered platforms that enable flexible learning environments. By bridging the gap between theoretical understanding and practical application, these technologies can promote a more experiential approach to teaching entrepreneurship.

We advise modeling policy development after programs like the EU Digital Education Action Plan 2021–2027, which places a high priority on funding for teacher preparation and digital infrastructure (Stankovic et al., 2021). Universities and tech companies should collaborate to co-develop courses that reflect industry demands through public-private partnerships (Secundo et al., 2020a,b). In terms of pedagogy, combining agile frameworks (Jafari-Sadeghi et al., 2021) and design thinking approaches (Athanasios and Vasiliki, 2019) will encourage

creativity and iterative problem-solving, giving students the tools they need to succeed in dynamic digital contexts. These suggestions are supported by evidence-based procedures from referenced papers as well as our keyword analysis (e.g., artificial intelligence, sustainability).

7 Limitations and future research

This study acknowledges several methodological limitations that may impact the findings. Firstly, the research exclusively utilized the Web of Science database for the literature review. The Web of Science (WoS) database is a significant advantage for providing older data. The WoS covers a longer period, allowing for analysis of trends over a longer time period and better ability to get the citation counts of the articles. The review was primarily focusing on English-language publications while excluding those in other languages. English language has become the dominant language of scientific communication, particularly in international journals and conferences. Many researchers, even those from non-English speaking countries, publish their most important work in English to reach a wider audience. Lastly, given the timeframe of the literature reviewed, which spans from 2018 to 2022, the findings may not reflect the most current research developments or emerging trends in the field.

The future directions, such as exploring AI and blockchain applications, are now more targeted and compelling. Furthermore, research should explore the role of entrepreneurship education in facilitating the digital transformation of businesses and communities. Advanced technologies, like artificial intelligence and machine learning, could be employed to analyze and visualize data related to digital transformation within entrepreneurship education. Finally, longitudinal studies are needed to evaluate the long-term effectiveness of different educational strategies and assess the sustained impact of digital transformation on entrepreneurship education.

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TB: Methodology, Writing – original draft, Writing – review & editing. AC: Writing – review & editing. BE: Conceptualization, Writing – review & editing. BW: Writing – review & editing. SD: Conceptualization, Methodology, Visualization, Writing – review & editing.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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