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E-learning technologies at the secondary education level: literature review

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Introduction: E-Learning Technologies play an integral role in secondary education, providing flexible and personalized learning environments through online platforms, mobile applications, and interactive resources. These tools have transformed access to knowledge and participation in the educational process, promoting autonomy and self-directed learning. However, significant gaps in research remain, underscoring the necessity for bibliometric analysis to address these gaps. The objective is to examine the current research trends on this topic.

Methods: A bibliometric analysis was conducted in accordance with the PRISMA-2020 guidelines, using the Scopus and Web of Science databases.

Results: The results demonstrate that the years of greatest interest are 2022 and 2021, with a notable increase in the number of publications. The principal references include the work of Hwang and the journal Sage Open. Thematic evolution has progressed from virtual environments to encompass a range of subjects, including the Coronavirus (COVID-19), physical education, training, and motivation. The primary cluster encompasses terms such as "Intellectual Disability" and "Students." The most prevalent keywords are related to the ongoing pandemic, including "COVID-19," "motivation," and "physical education."

Discussion: Additionally, the emergence of new concepts such as "communication" and "effectiveness" is noteworthy. These trends underscore the necessity for a research agenda that prioritizes a more profound examination of these pivotal topics and the rectification of existing deficiencies in the existing literature.

KEYWORDS

autonomy, digital platforms, mobile applications, virtual environment, PRISMA-2020

1 Introduction

E-learning technologies are an indispensable instrument in the field of secondary education, facilitating the establishment of more adaptable and individualized learning environments. These technologies, which encompass online platforms, mobile applications, and interactive resources, have transformed the manner in which students access knowledge and engage in the educational process. At the secondary education level, the utilization of e-learning technologies not only facilitates access to a plethora of educational resources, but also encourages autonomy and self-managed learning, which are pivotal in the development of critical skills in adolescents. The integration of

sophisticated technologies, such as augmented reality, has been demonstrated to enhance the learning experience by rendering it more immersive and engaging. This observation can be extended to the domain of secondary education (Dieck et al., 2018).

Moreover, e-learning technologies have facilitated the expansion of educational opportunities beyond geographical and temporal constraints, thereby offering students continuous learning opportunities that are tailored to their individual needs. Additionally, these technological tools have facilitated the implementation of innovative teaching methodologies, such as project-based learning and collaborative learning, which have been demonstrated to foster greater student engagement and participation. The quality of service on e-learning platforms, including security and the use of cloud services, is a significant determinant of user satisfaction. This is particularly relevant in the context of secondary education, where security and accessibility are primary concerns for educators and families (Li et al., 2021).

The acceptance and effectiveness of e-learning technologies in secondary education also depend on knowledge management factors and the willingness of students to adopt new ways of learning. The acceptance of mobile learning, a key component of e-learning technologies, is contingent upon knowledge management factors, such as ease of use and perceived usefulness. This indicates that, in order to optimize the advantages of these technologies in secondary education, it is essential to consider not only the technical aspects, but also the manner in which these resources are managed and presented to students (Al-Emran et al., 2020).

Furthermore, the integration of e-learning technologies into secondary education gives rise to a number of ethical and social challenges, particularly in relation to the personalization of learning and data management. The ethical challenges that emerge with the utilization of big data and personalized educational technology, such as student grading and tracking, have the potential to significantly impact equity and privacy in education. These challenges highlight the necessity for the development of transparent ethical frameworks and policies that regulate the implementation of these technologies at the secondary education level, ensuring that their utilization benefits all students equitably (Regan and Jesse, 2019).

E-Learning Technologies at the secondary education level have become a fundamental tool to improve the quality of learning and adapt education to the needs of students in the digital age. These technologies allow the creation of interactive and dynamic learning environments that can motivate students and increase their commitment to the educational process. The adoption of technologies such as augmented reality and virtual reality in the classroom not only facilitates the understanding of complex concepts, but also stimulates creativity and critical thinking among students. The integration of advanced technologies in education, supported by theories such as TTF and UTAUT2, can significantly improve the acceptance and effectiveness of these tools, especially in developing countries (Faqih and Jaradat, 2021; Guan et al., 2023).

The importance of E-Learning Technologies in secondary education also lies in their ability to personalize the learning experience, allowing students to progress at their own pace and according to their individual needs. The use of virtual reality-based approaches, such as pottery making, can increase student engagement and enhance their creativity. These types of

technologies not only transform the way lessons are delivered, but also provide students with hands-on experiences that are difficult to replicate in a traditional classroom setting (Guan et al., 2023).

Moreover, the utilization of e-learning technologies in secondary education facilitates the preparation of students for an increasingly digitalized world, in which technological competence is a prerequisite. The integration of augmented reality in science laboratories has the potential to enhance student performance by providing a more efficient means of navigating and comprehending content. This technology enables students to interact with educational materials in a more profound manner, which can result in enhanced knowledge retention and a heightened interest in scientific subjects (Jiang et al., 2022).

It is imperative to address the ethical and academic challenges associated with the utilization of e-learning technologies in secondary education. These include issues such as plagiarism and academic integrity. It is vital to cultivate a culture of academic ethics among students who employ these technologies, given that the ease of access to digital information can heighten the temptation to engage in plagiarism. Therefore, it is crucial that educational institutions not only integrate advanced technologies but also promote responsible and ethical practices in their use. This ensures that students not only benefit from these tools but also develop a sense of academic responsibility (Memon and Mavrincac, 2020).

While there is considerable interest in the use of e-learning technologies in secondary education, there are significant research gaps that justify the need for bibliometrics. Although previous studies have explored the use of mobile technologies and augmented reality in specific educational contexts, such as vocational training and business education, the literature still lacks a systematic analysis that comprehensively covers their application in secondary education. A need has been identified for a more focused approach to how e-learning technologies can be adapted to the specificities of secondary school students, a stage of education that presents particular challenges in terms of motivation and engagement (Churiyah et al., 2022).

Similarly, augmented reality has been studied in its application in fields such as business and economics, but its impact on secondary education has not been explored in the same depth (Jajic et al., 2022). Augmented reality methodologies have mainly been the subject of systematic reviews in higher education courses, leaving a gap in their application at secondary level. This lack of detailed research highlights the importance of conducting bibliometrics to identify trends, methodological approaches and possible areas of future development in the use of e-learning technologies at this level of education (Mukhtarkyzy et al., 2023).

A number of studies have examined the implementation of e-learning technologies in secondary education from specific perspectives. For instance, Hwang et al. (2018) and Lai and Hwang (2015) have examined students' perceptions and adoption of mobile learning in school settings, highlighting its impact on peer interaction and the development of critical thinking. In a similar vein, research by González et al. (2018) has analyzed the role of gamification in physical education, while Mukhtarkyzy et al. (2023) have evaluated augmented reality methodologies in secondary education. However, despite the growing number of studies on this topic, a comprehensive bibliometric analysis that maps the evolution of these trends, identifies predominant research

patterns, and recognizes thematic gaps in the use of e-learning technologies at the secondary level has yet to be conducted.

The present study aims to address this lacuna through a bibliometric analysis grounded in the PRISMA-2020 methodology, leveraging databases such as Scopus and Web of Science to identify pivotal research trends, prominent authors, and nascent concepts within the academic literature. In contrast to previous reviews that focused on specific pedagogical approaches or the impact of particular technologies (Al-Emran et al., 2020; Regan and Jesse, 2019), this study provides a comprehensive view of the field, enabling a more profound understanding of how research on e-learning in secondary education has evolved. Moreover, this research establishes the foundation for a meticulously structured research agenda, predicated on empirical trends. This contributes to the development of more effective strategies for integrating these technologies into educational contexts while ensuring their relevance and long-term sustainability.

Despite the mounting interest in e-learning technologies in secondary education, the extant literature is deficient in a systematic analysis exploring their thematic evolution, main lines of research, and emerging trends. While prior studies have examined specific domains, such as the impact of mobile learning (Hwang et al., 2018; Lai and Hwang, 2015) or gamification in educational environments (González et al., 2018), a comprehensive bibliometric analysis identifying research patterns, influential authors, and thematic gaps in this domain has not been conducted. This study makes a significant contribution to the existing literature by offering a comprehensive global overview derived from advanced bibliometric techniques. This approach enables not only the mapping of the evolution of the field but also the formulation of a research agenda that is firmly rooted in empirical findings (Mukhtarkyzy et al., 2023).

Consequently, the aim of the research is to explore the research trends regarding e-learning technologies used in secondary education. To this end, the following questions were formulated:

- Which are the years in which the most interest has been presented regarding e-learning technologies used in secondary education?
- How has the number of scientific articles on e-learning technologies used in secondary education grown?
- What are the main research references on e-learning technologies used in secondary education?
- What is the thematic evolution derived from the scientific production on e-learning technologies used in secondary education?
- What are the main thematic clusters on e-learning technologies used in secondary education?
- What are the growing and emerging keywords in the research field of e-learning technologies used in secondary education?
- Which themes are positioned as protagonists for the design of a research agenda on e-learning technologies used in secondary education?

This article is structured into several key sections. It begins with the abstract, which provides an overview of the study. This is followed by the introduction, in which the context and objectives of the research are presented. The methodology describes the

procedures and techniques used to collect and analyze the data. The results section presents the main findings of the study. These are analyzed and discussed in the discussion section. Finally, the article concludes with the conclusions, in which the key points of the study are summarized. Possible implications or areas for future research are also suggested.

2 Methodology

The present study employs exploratory research methods to investigate the utilization of e-learning technologies in secondary education. The study is based on a synthesis of secondary research sources. The PRISMA-2020 statement, which provides updated instructions for the creation of systematic reviews, forms the basis for the bibliometric analysis (Page et al., 2021). To guarantee the accuracy and transparency of the collection and presentation of scientific literature on this topic, the PRISMA-2020 protocol has been rigorously adhered to.

2.1 Eligibility criteria

The PRISMA-2020 statement establishes rigorous inclusion criteria to ensure the comprehensiveness and representativeness of the bibliometric review. Studies that analyze e-learning, mobile learning, personal learning, and MOOCs are considered relevant, as are those that focus on GPT chat, technology education, artificial intelligence, and secondary school teaching. The inclusion criteria were meticulously designed to span a comprehensive range of educational technology-related domains, offering a holistic perspective on the adoption and impact of these innovations in secondary education. To enhance the review's integrity, a systematic exclusion process was implemented, structured in three phases. Initially, documents with incorrect or insufficient indexing were discarded to prevent classification errors in the database. As bibliometric analyses are dependent on metadata, the second exclusion phase focused solely on systematic literature reviews, eliminating documents for which the full text was inaccessible. The final exclusion phase involved the filtration of conference proceedings, articles with missing indexes, and texts that did not align with the research objectives, thereby ensuring the quality and relevance of the collected data.

To enhance transparency and methodological rigor, the relevance of the selected studies was evaluated through a multi-stage process. Initially, an automated screening was conducted using predefined keywords and search equations, ensuring that only studies aligned with the research scope were retrieved. This initial screening was followed by a manual selection phase, in which two independent researchers reviewed titles and abstracts to assess their relevance. Studies that met the inclusion criteria advanced to a third phase, where full-text reviews were performed to ensure alignment with the study's objectives. In instances of classification discrepancies, a consensus resolution process was initiated, involving a third researcher. This structured and systematic approach minimized potential biases and ensured that only the most pertinent studies were included in the bibliometric analysis, thereby strengthening the reliability of the findings.

2.2 Source of information

The Scopus and Web of Science databases have been selected as the principal sources of information for this research project due to their comprehensive coverage, interdisciplinary scope and rigorous content selection and review processes. These databases have become the most significant resources in academic and scientific fields. In view of their capacity to provide comprehensive access to the pertinent scientific literature, Scopus and Web of Science were selected as the principal data sources for this study, thus ensuring the validity and reliability of the findings (Huanca-Arohuanca, 2022). Scopus and Web of Science were selected due to their recognition as the leading academic databases that index peer-reviewed publications with high quality standards. The interdisciplinary scope of these databases, coupled with their advanced bibliometric analysis tools, enables precise assessment of trends in scientific production. In contrast to alternative sources, such as Google Scholar, Scopus, and Web of Science employ rigorous indexing criteria, thereby ensuring the reliability and representativeness of the data analyzed.

However, despite their strengths, these databases also present certain limitations. A primary concern pertains to the potential exclusion of pertinent studies published in regional or specialized journals that are not indexed within these platforms. Furthermore, publications in languages other than English, particularly those from local or emerging research communities, may be underrepresented, potentially limiting the global perspective of the analysis. To address these limitations, future studies may consider incorporating other databases, such as Google Scholar or regional repositories, to ensure a more comprehensive examination of the field. Despite these constraints, the selection of Scopus and Web of Science provides a reliable and standardized dataset for evaluating research trends in e-learning technologies at the secondary education level.

2.3 Search strategy

Two bespoke search equations were devised to facilitate a comprehensive and precise search within the two selected databases. In formulating these equations, the inclusion criteria that had already been determined, as well as the distinctive search requirements of each database, were meticulously considered. The construction of the search equations entailed the utilization of Boolean operators to refine and optimize the retrieval of relevant documents. The AND operator was employed to combine key terms, ensuring that results encompassed both concepts simultaneously, as in the search “e-learning AND secondary education.” Conversely, the OR operator was applied to encompass synonyms or related terms, broadening the search and capturing various expressions of the same concept, as in the search “(virtual learning OR online education) AND student engagement.” This strategy enabled a more precise and comprehensive search within the selected databases. The strategic approach, which employs the search functions and capabilities of Scopus and Web of Science, ensures that the collection of scientific literature is aligned with the research objectives. In this regard, the following equations are available for use:

For the Scopus database: (TITLE (“e-learning” OR “mobile learning” OR “personal* learning” OR “mooc” OR “gamification” OR “blended learning” OR “microlearning” OR “augmented reality” OR “virtual reality” OR “chat gpt” OR “Educati* technolog*” OR “artificial intelligence” AND “high school”) AND NOT TITLE (“high* education” OR “universit*” OR “postsecondar*” “elementary” OR “middle” OR “primary education” OR “secondary education” OR “teacher*”) AND NOT KEY (“high* education” OR universit* OR postsecondary*) AND KEY (“competencies” OR “skills” OR “learn*” OR “teach*” OR education*)) AND (LIMIT-TO (SUBJAREA, “SOCI”))

For the Web of Science database: (TI=(“e-learning” OR “mobile learning” OR “personal* learning” OR “mooc” OR “gamification” OR “blended learning” OR “microlearning” OR “augmented reality” OR “virtual reality” OR “chat gpt” OR “Educati* technolog*” OR “artificial intelligence” AND “high school”) NOT TI=(“high* education” OR “universit*” OR “postsecondar*” “elementary” OR “middle” OR “primary education” OR “secondary education” OR “teacher*”) NOT AK=(“high* education” OR universit* OR postsecondary*) AND AK=(“competencies” OR “skills” OR “learn*” OR “teach*” OR education*)).

2.4 Data management

Microsoft Excel[®] was employed for the purpose of managing and analyzing the data collected from the selected databases. The data were extracted and stored using this application, which facilitated the systematic organization of the information collected. Furthermore, the co-authorship network and pertinent bibliometric indicators were rendered in a visual format and subjected to analysis using the free VOSviewer[®] software (Van Eck and Waltman, 2010). The joint use of Microsoft Excel[®] and VOSviewer[®] enabled the creation of graphs and visualizations that facilitated trend analysis, pattern identification and the interpretation of bibliometric data, thereby reinforcing and corroborating the research findings.

2.5 Selection process

In order to mitigate the risk of omitted studies or erroneous categorization during the literature selection process, it is imperative to document the utilization of internal automatic classifiers and the validation strategies employed (Page et al., 2021). This is in accordance with the principles outlined in the PRISMA 2020 statement. Microsoft Excel[®] automation tools were utilized as an internal mechanism for this purpose in the context of the research. All researchers involved in the study collaborated to develop these tools. The independent use of these tools by each researcher during the application of the inclusion and exclusion criteria facilitated a convergence of findings.

2.6 Data collection process

In accordance with the recommendations set forth in PRISMA-2020, it is imperative to delineate the methodologies

employed to collate data from the reports utilized in bibliometric research (Page et al., 2021). Consequently, the decision was taken to utilize Microsoft Excel[®] as an automated tool for this purpose in the present study on the utilization of E-Learning technologies in secondary education. The data from the reports were collected by each author of the study, acting independently as a reviewer. Subsequently, a collective validation process was conducted, during which all authors collaborated. During this phase, data confirmation was carried out, and the data were discussed and reviewed collectively until all results were in complete agreement.

2.7 Data elements

In order to gather results for the data elements of e-learning in secondary education, all articles that were relevant to the research objective were searched. This entailed a comprehensive search for all articles that referenced the utilization of e-learning technologies in this context, encompassing a vast array of pertinent outcomes, metrics, and analyses. However, any omitted or unclear data that did not contribute to the understanding of the body of knowledge on the topic were excluded in order to maintain consistency with the research objectives and scope, and to preserve the integrity and accuracy of the information collected during the bibliometric process. These records were labeled as “non-relevant texts” in order to facilitate the identification of those that did not align with the research criteria.

2.8 Assessment of the risk of bias of the study

The process of assessing the risk of bias in the included studies was conducted in accordance with the methodological approach employed for data collection. The same collaborative and automated methodology was selected for the assessment of risk of bias in each study, given that all authors were actively involved in data collection using the automated Microsoft Excel[®] tool. All authors participated independently in this method, thereby ensuring a consistent and unbiased assessment. Furthermore, all authors reached the same conclusion regarding the risk of bias through the utilization of a strict and standardized procedure, with the objective of guaranteeing the integrity and quality of the results of the bibliometric review.

2.9 Measures of effect

It is imperative to acknowledge that the conventional effect measures employed in the synthesis of primary research findings, such as the risk ratio or mean difference, are not applicable in this context. In this bibliometric study, secondary research sources were used to examine bibliometric indicators, such as the number of publications and citations, rather than direct effect measures. The temporal use of each keyword can also be examined using Microsoft Excel[®] for data processing. Thematic association between documents was determined using VOSviewer[®], which was also used to locate and visualize thematic nodes.

2.10 Synthesis methods

In order to ensure the reliability and consistency of the findings, a rigorous methodological approach was employed to assess the eligibility of the studies included in the synthesis as part of this research. In order to achieve this, the most outstanding characteristics of each study were subjected to analysis, tabulation, and comparison with the previously established inclusion and exclusion criteria. Similarly, bibliometric indicators of quantity, quality, and structure were employed. All documents that successfully completed the three exclusion phases were automatically subjected to these indicators using Microsoft Excel[®], thus facilitating the systematic preparation of the data and the visual presentation of the individual and synthesis results (Durieux and Geveno, 2010).

2.11 Assessment of reporting bias

It is crucial to consider the potential for bias due to the paucity of results in the synthesis, which may be attributable to biases in reporting. It is acknowledged that the inclusion criteria, search methodology and data collection process may be susceptible to bias toward specific synonyms encountered in thesauri, such as the IEEE. Moreover, the exclusion of conference proceedings, incompletely indexed articles and irrelevant texts may result in the omission of crucial data that could facilitate the advancement of subject matter knowledge. To mitigate any potential bias in the synthesis of results and guarantee the rigor of the bibliometric research, these considerations are transparently acknowledged and managed through a meticulous methodology.

2.12 Certainty assessment

The assessment of certainty in the body of evidence is addressed in a comprehensive manner, with a clear differentiation from the primary studies that assess certainty individually. This is achieved by taking into account the definition of bibliometric indicators, the independent application of inclusion and exclusion criteria, and the assessment of certainty. To ensure a rigorous evaluation of the quality of the included studies, any potential biases identified in the methodological design are also reported. Furthermore, the limitations of the study are analyzed in the discussion section, providing a comprehensive assessment of the level of confidence in the findings of the bibliometric analysis and highlighting both areas of strength and uncertainty.

The initial stage of the process was the identification of relevant data. This was achieved through the utilization of specific search techniques in each of the selected information sources, with the objective of ensuring the integrity of the database. Subsequently, a comprehensive process of record deduplication was undertaken. Subsequently, the three phases of exclusion were conducted in accordance with the previously established criteria, which included the exclusion of records with inaccurate indexing, documents that were not fully accessible, and records that did not meet the criteria of thematic relevance. Ultimately, following the aforementioned selection and purification process, a corpus of 259 articles was assembled, which constitutes the basis of this research. [Figure 1](#)

is attached below, detailing the entire proposed methodological design.

3 Results

The bibliometric analysis of article production revealed an exponential growth pattern with 99% confidence, as demonstrated in Figure 2. The most prolific years for publications on this topic were 2020, 2021, 2022, and 2023, indicating a recent surge in interest and research activity in the field of educational technology. As illustrated, the figure demonstrates publication trends over time, with the y-axis values corresponding to increments of 10, thereby indicating that each unit represents 10 publications. Concurrently, the x-axis delineates the years of interest, thereby enabling the observation of variations in publication output over time.

This growth can be interpreted as an indication that educational technology is gaining increasing relevance in academic research, particularly in response to global changes such as the COVID-19 pandemic, which accelerated the adoption of online learning platforms and digital technologies in education. The observed increase in publications can be attributed to a growing integration

of technology into educational systems, as well as the emergence of novel trends, including personalized learning, artificial intelligence in education, and the utilization of digital tools for assessment and pedagogy.

Consequently, these developments present a range of implications for future research. These growth trends suggest numerous avenues for future research. Primarily, the field is poised to persist in its evolution, with the incorporation of emerging technologies such as artificial intelligence and augmented reality to further enhance the educational experience. Furthermore, the pace at which these technologies are adopted across various geographic and socioeconomic contexts could be a salient topic for future studies. It is imperative to investigate the manner in which technological infrastructure and educational policies influence the implementation of these tools across diverse regions, as well as the repercussions of their integration on learning outcomes. Additionally, exploring the access gap and teacher training in the effective use of these technologies could contribute to improving educational equity.

As illustrated in Figure 3, the analysis of the lead authors revealed the existence of three distinct groups of researchers.

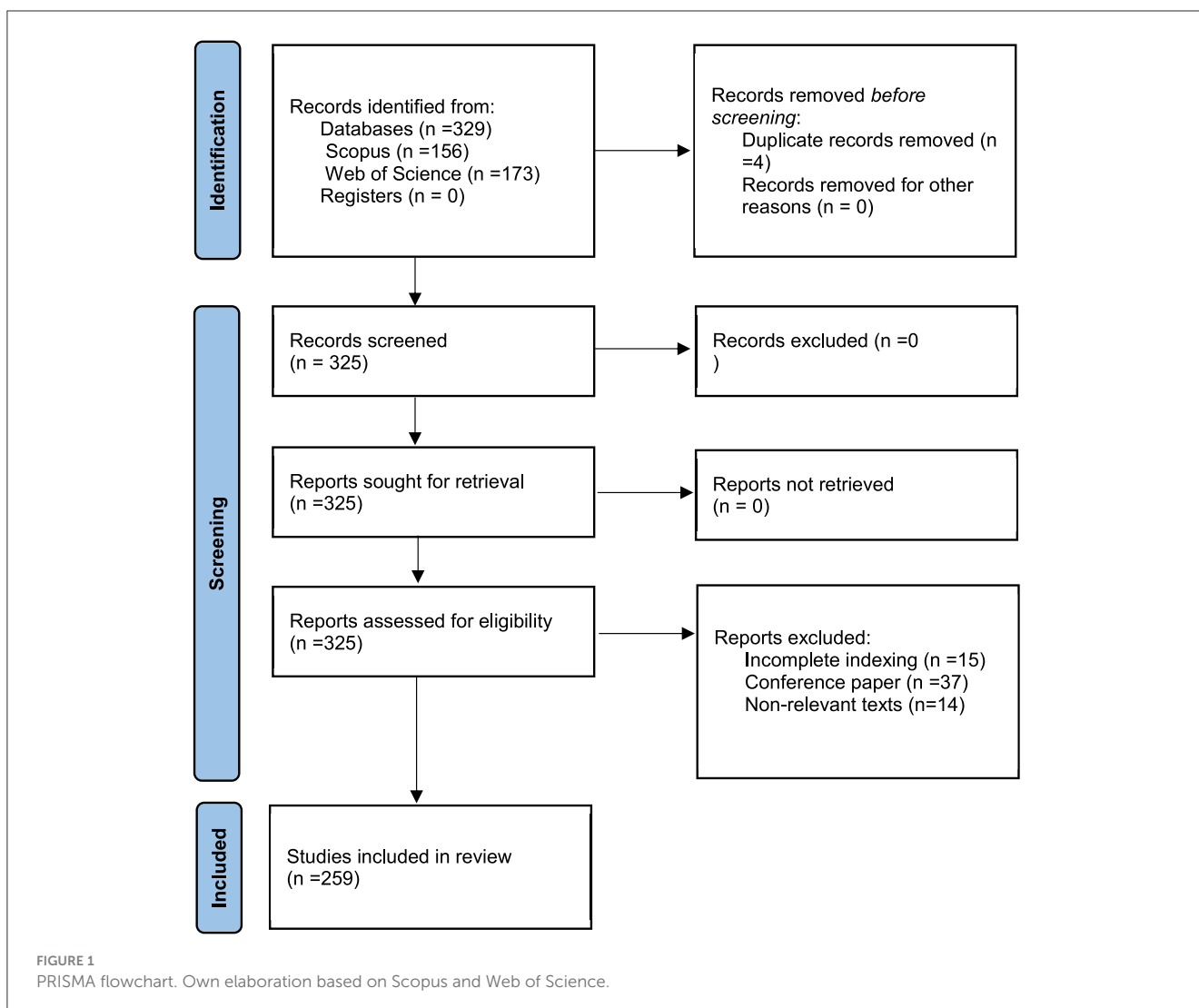
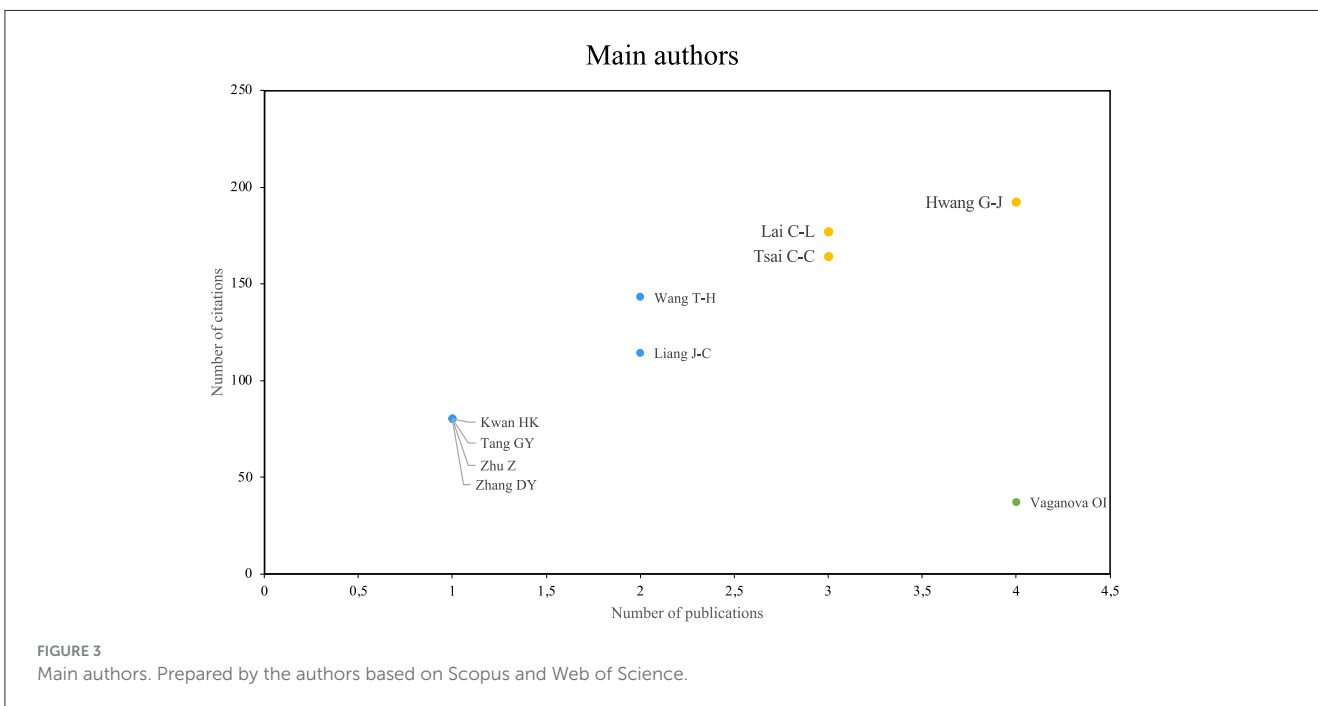
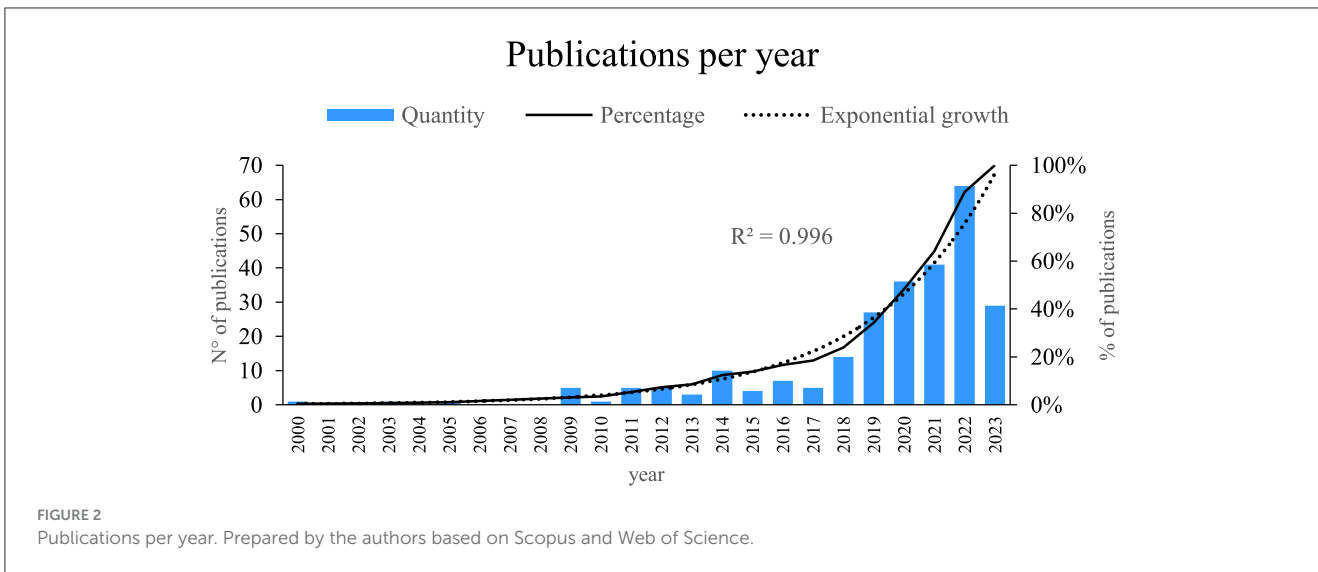


FIGURE 1 PRISMA flowchart. Own elaboration based on Scopus and Web of Science.

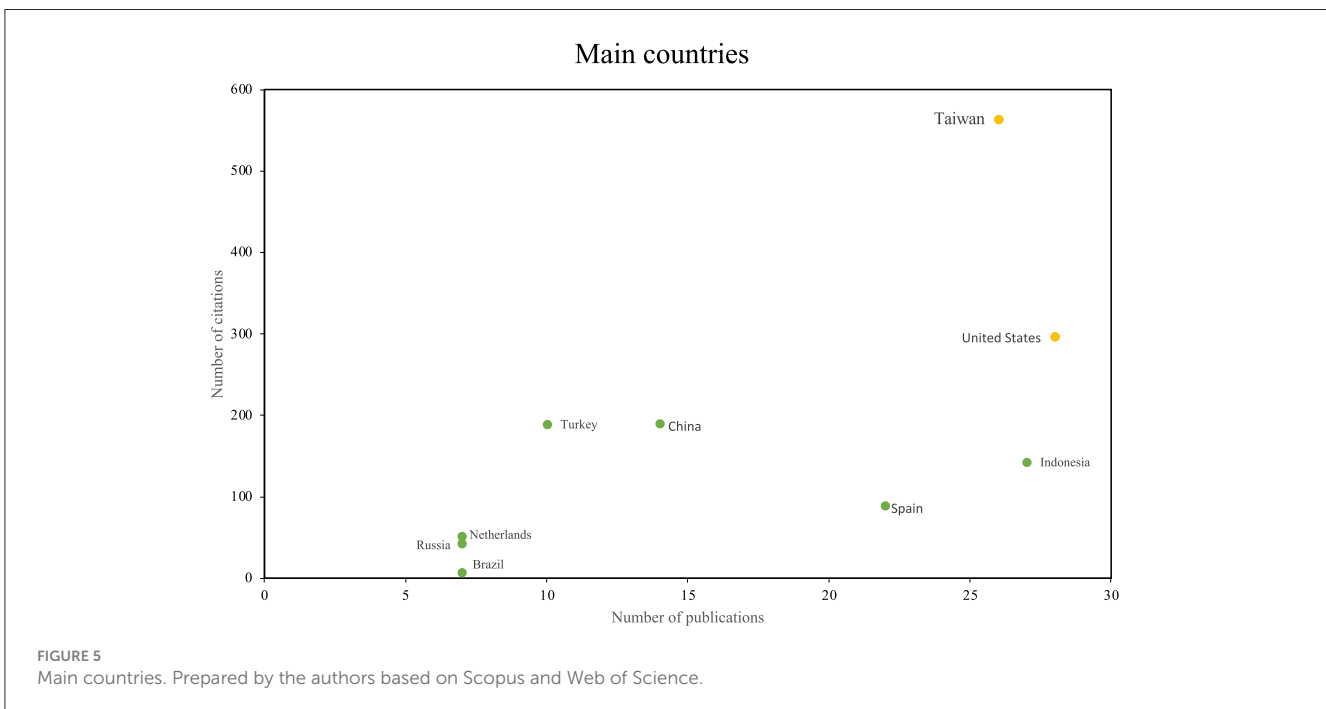
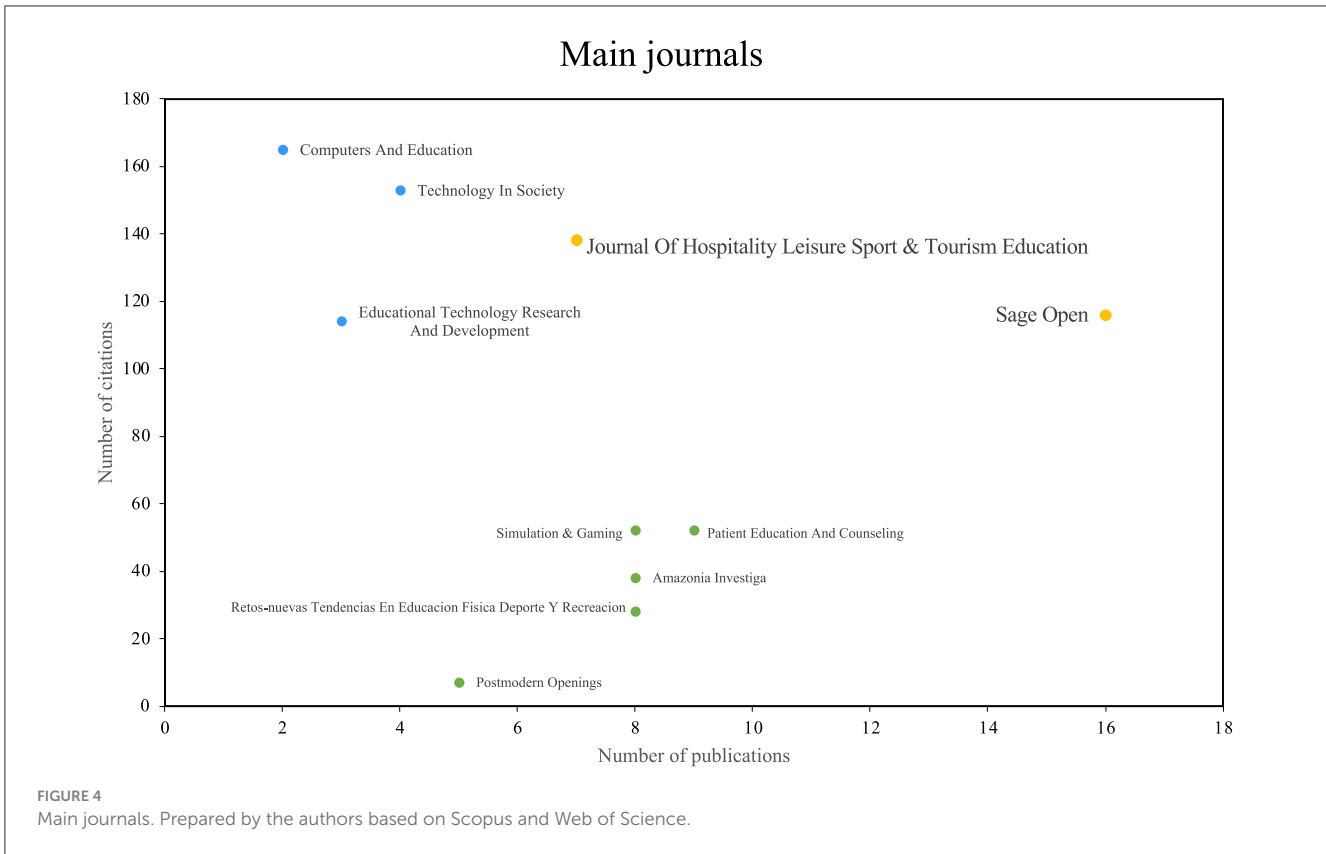


The first category comprises authors such as Hwang et al., who are distinguished by both their scientific productivity and the significance of their research. The second group comprises authors such as Wang and Liang, who have made a notable impact on the academic community despite exhibiting a relatively lower level of scientific productivity. The third group is comprised of the author Vaganova OI, whose relevance is primarily based on her high scientific productivity, despite the fact that her number of citations is relatively low in comparison to the other groups.

The analysis of the primary journals included in this bibliometric study revealed the existence of three distinct groups of academic publications, as illustrated in Figure 4. The initial group comprises journals such as Sage Open and the Journal of Hospital Leisure, Sport & Tourism Technology in Society

and Education. These journals are distinguished by both their scientific productivity and the impact of their publications. Furthermore, journals such as Computers and Education and Educational Technology Research and Development are included in the second group. Despite exhibiting a lower index of scientific productivity, these publications have a significant impact within the academic community. The third group comprises scientific journals such as Patient Education and Counseling, which are primarily distinguished by their high scientific productivity, although their number of citations is relatively low in comparison to the other groups.

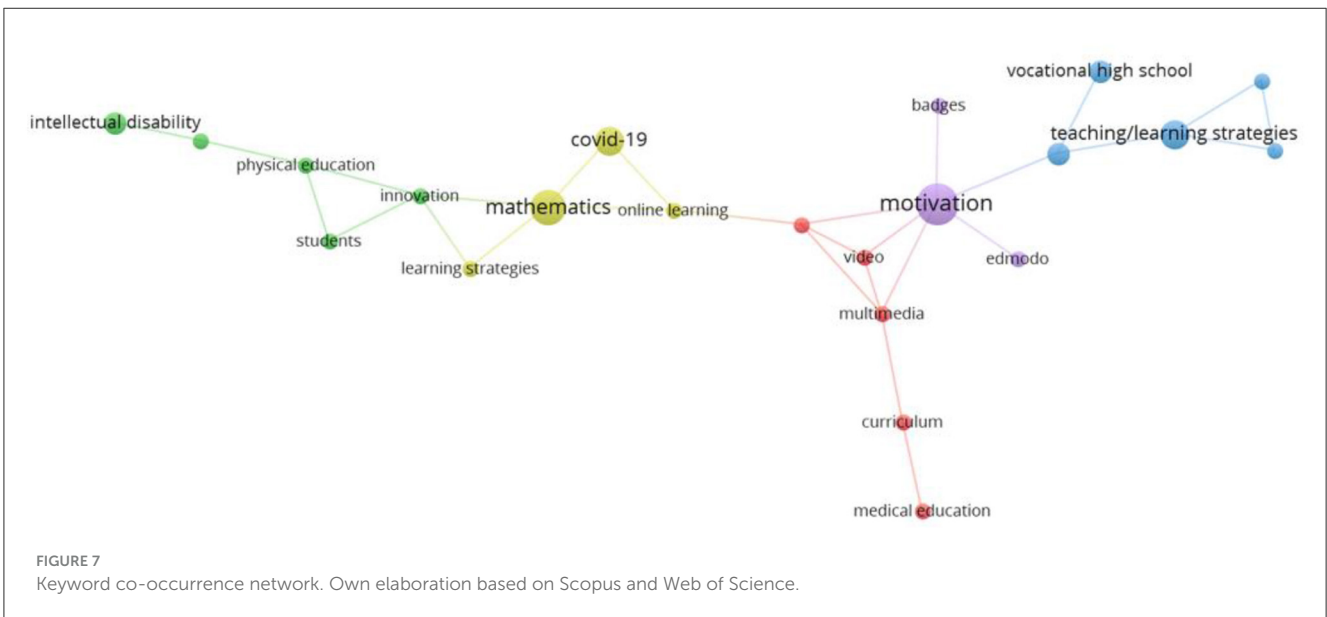
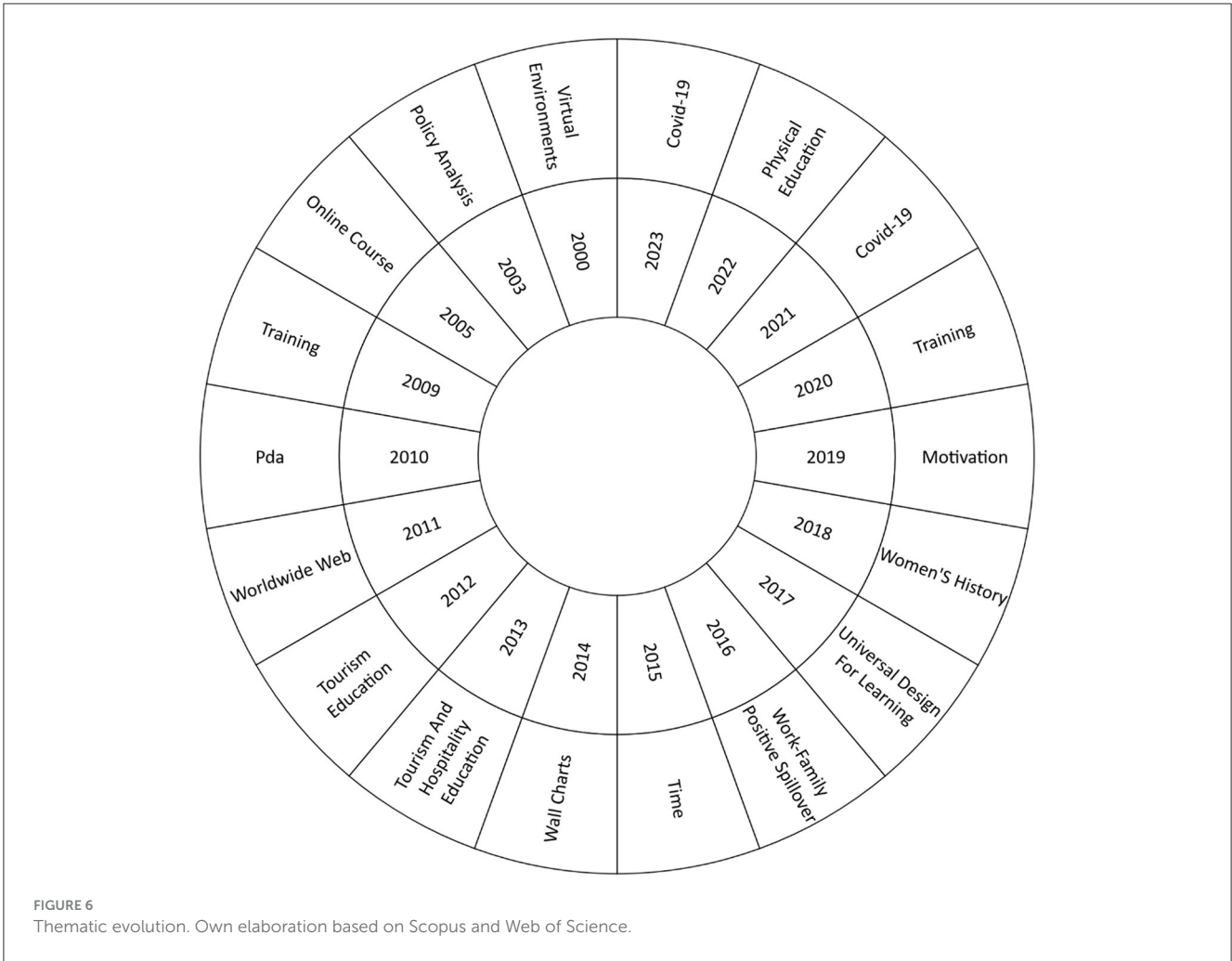
Figure 5 illustrates the disparate clusters of countries that emerge from the analysis of the principal nations. The initial cluster encompasses notable countries such as Taiwan and

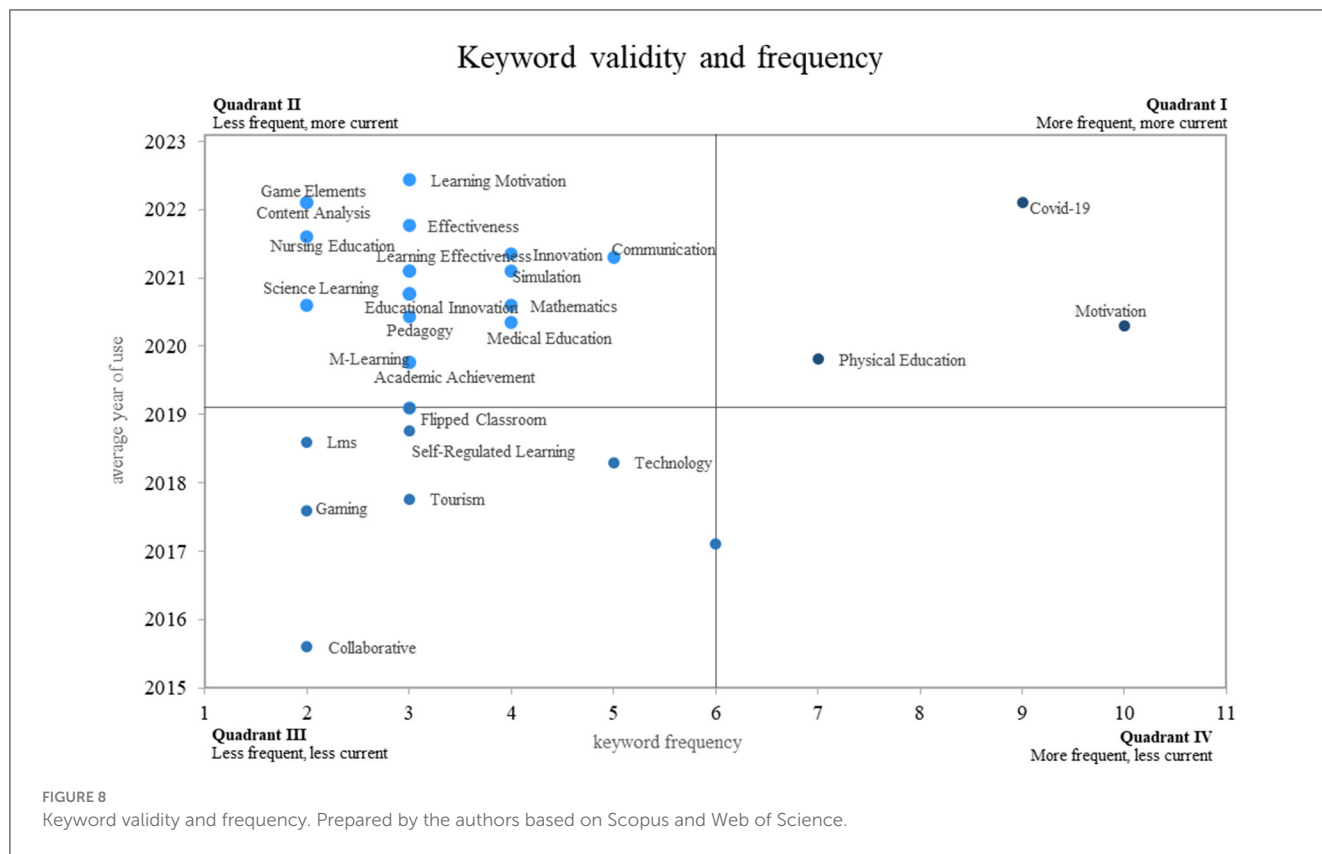


the United States. The subsequent cluster encompasses nations that, despite exhibiting a comparatively lower rate of scientific productivity, exert a profound influence within the academic realm. To illustrate, Indonesia and Spain are countries that merit particular attention due to their high scientific productivity in this field of research. Their contributions enhance the global

understanding of the influence of countries in this scientific domain.

The present study examined the thematic development in the literature on the use of e-learning technologies in secondary education over the years, from 2000 to 2023, as illustrated in **Figure 6**. As a preliminary observation, it is notable that in the





year 2000, the term “virtual environments” emerged as a significant concept in this field of study. Over time, it became evident that the subject matter under investigation had undergone a process of evolution, reflecting the emergence of new research avenues within this field of study. The recent attention given to topics such as “COVID-19,” “Physical Education,” “Training,” and “Motivation” indicates a shift in the research focus toward current and relevant topics in the educational context. This illustrates the evolution and adaptability of research on e-learning technologies in secondary education.

As illustrated in Figure 7, bibliometrics revealed the fundamental organization of the keyword co-occurrence network across five thematic clusters. The most notable of these is the dark green cluster, which suggests a strong conceptual association between the topics represented by terms such as “Intellectual Disability,” “Education Physical,” “Innovation,” and “Students.” The subsequent cluster is red and includes terms such as “video,” “multimedia,” “curriculum,” and “medical education.” Additional clusters are also evident, colored yellow, purple, and blue, reflecting further conceptual affinity elements identified in the literature on the application of e-learning technologies in secondary education.

The framework of this bibliometric study comprises a Cartesian plane, which enables the measurement of both the frequency of use and the usefulness of keywords in the context of the utilization of e-learning technologies in secondary education. The graphical representation in Figure 8 is divided into four distinct quadrants. Notwithstanding their low frequency of use, certain keywords in quadrant 2 merit particular attention due to their high validity, suggesting the emergence of new concepts within

this field of study. Keywords in this quadrant, for example, could include “communication,” “motivation,” “learning effectiveness,” and “mathematics.” Conversely, quadrant 1 comprises established and developing ideas, including “COVID-19,” “Motivation,” and “Physical Education.” These are distinguished by their prevalence and currency in the relevant scientific literature.

4 Discussion

A principal element of this study is the discussion section. On the one hand, it provides a comprehensive analysis of the study findings, while also addressing the limitations of the study, the primary research gaps identified and the practical implications of the findings. This is done in order to promote a deeper understanding and further advancement of this scientific field. The discussion section concludes by presenting a research agenda that identifies crucial areas for further studies on the application of e-learning technologies in secondary education.

4.1 Analysis of the growth of scientific literature on e-learning technologies in secondary education

The scientific production on e-learning technologies at the secondary education level has experienced a notable increase in recent years, particularly between 2020 and 2023. In 2020,

research was conducted to ascertain the impact of blended learning platforms, which combine online learning with traditional methods, on student satisfaction. The effect of these platforms on the teaching of tourism management was also investigated, with the conclusion that student engagement is a crucial factor in their overall satisfaction. This highlights the importance of designing learning environments that are not only accessible, but also encourage active participation (Gao et al., 2020).

The year 2021 saw this trend of exploration continue, with a particular focus on the integration of emerging technologies such as augmented reality into the field of education. In the current year, the researchers investigated the effects of incorporating augmented reality into an educational board game for high school students. Their findings indicated an increase in motivation and acceptance of learning in the context of health education. This suggests that augmented reality not only enriches the educational experience but can also act as a catalyst for improving the acceptance of innovative teaching methods among students (Lin et al., 2021).

The year 2022 was notable for its high level of scientific output, reflecting a heightened emphasis on e-learning technologies, particularly in the context of the ongoing pandemic. In this period, the factors influencing the adoption of augmented reality and virtual reality applications in tourism education were analyzed, with particular emphasis on the acceleration of the need for distance learning tools that the pandemic has brought about (Shen et al., 2022). Similarly, the efficacy of e-learning among students of tourism education during the pandemic was assessed, identifying key factors such as interactivity and accessibility as critical determinants of the success of these technologies in a challenging educational environment (Amin et al., 2022).

In 2023, research continued to evolve with a focus on personalized immersion and experience within e-learning. This involved exploring the use of action observation in virtual reality combined with motor imagery, which demonstrated how these technologies can influence student performance by allowing them to visualize themselves reaching skill levels not yet achieved. This reinforces the idea that e-learning technologies are not only evolving to be more accessible, but also to be more personalized and effective, adapting to the individual needs of students in secondary education (Frank et al., 2023).

4.2 Analysis of research references on e-learning technologies in secondary education

In the results section, the significant contribution of several authors in terms of productivity and impact was highlighted. Hwang, recognized as one of the most influential authors, has developed fundamental research exploring the relationship between high school students' perceptions of mobile learning and their interaction with peers and the tendency toward higher-order thinking. It was demonstrated through an experiment how mobile learning can positively influence students' cognitive skills, which has positioned this author as a key reference at the intersection between educational technology and cognitive development in the school context (Hwang et al., 2018).

Lai, in collaboration with Hwang, has also made significant contributions to the field of mobile learning, particularly from the perspective of teachers. In their study, they analyzed secondary school teachers' perceptions of implementing various mobile learning strategies in science courses within the framework of the national mobile learning program in Taiwan. The work has not only been instrumental in understanding the integration of technology in science education, but has also provided a solid foundation for future research on the adaptation and effectiveness of mobile strategies in different educational contexts (Lai and Hwang, 2015).

Conversely, Tsai has examined the conceptualizations of secondary school teachers in Taiwan regarding mobile learning, elucidating the manner in which these influences impact the implementation of e-learning technologies in the classroom. The authors identified the diverse range of conceptions held by teachers regarding mobile learning, which has been pivotal in elucidating the impediments and prospects for the integration of these technologies in the educational milieu (Hsieh and Tsai, 2017).

Similarly, the contribution of Wang to the development of web-based assessment strategies to facilitate self-regulated learning in an e-learning environment was emphasized. His work proposes web-based strategies for online assessment, which has been pivotal in enhancing pedagogical practices in secondary education, facilitating students' acquisition of independent learning skills (Wang, 2011). In a similar vein, Ilyashenko et al. (2019) has demonstrated the efficacy of a hybrid approach to teaching and learning, combining face-to-face and online methods, in fostering the comprehensive development of students (Ilyashenko et al., 2019).

A number of scientific journals were identified as being particularly noteworthy for their productivity and impact on the subject matter. Sage Open has been identified as one of the most influential publications, known for its interdisciplinary approach and open access, which facilitates the dissemination of innovative research in a range of areas of knowledge. In a relevant study published in this journal, the acceptance of blended learning in executive education was explored. The study underscored the significance of this pedagogical approach in the training of leaders, and contributed considerably to our understanding of the dynamics of blended learning and its impact on higher education. This reinforces the role of Sage Open as a vital medium for the dissemination of studies on modern teaching methodologies (Dakduk et al., 2018).

The Journal of Hospitality, Leisure, Sport & Tourism Education has been acknowledged for its emphasis on educational initiatives within specific domains, including tourism and hospitality. These fields have also witnessed a discernible influence of blended learning. The investigation sought to ascertain the impact of a blended learning platform, in conjunction with student engagement, on satisfaction levels, thereby providing invaluable insights to enhance pedagogical practices in the field of tourism education. The contribution has been pivotal in establishing connections between educational technology and applied disciplines, thereby establishing this journal as an important source for studies that integrate theory and practice in specific contexts (Gao et al., 2020).

The fields of computer science, education, and educational technology research and development have become established as key reference points in the domain of e-learning, due to their significant impact on the advancement of educational technologies. Computers and Education has been instrumental in the investigation of web-based assessment methodologies, as evidenced by research wherein pioneering strategies were put forth to promote self-regulated learning in e-learning environments (Hwang et al., 2018). Concurrently, Educational Technology Research and Development has played a pivotal role in long-term investigations into students' perceptions and interactions with mobile technologies (Hwang et al., 2018).

The field of Patient Education and Counseling also demonstrated notable productivity, particularly in the area of research pertaining to education and training in the health sector. One illustrative example is a study that evaluated the efficacy of various delivery modes for an interactive e-learning program designed to educate healthcare professionals about cultural diversity. This work has been instrumental in the development of educational strategies within the health sector, underscoring the significance of technology in the ongoing education of healthcare professionals. The contribution of this journal has been pivotal in integrating technology into the educational process, demonstrating its capacity to enhance comprehension and application of knowledge in clinical contexts (Hawthorne et al., 2009).

It was observed that Taiwan and the United States have played a prominent role in terms of productivity and impact on scientific production. Taiwan, in particular, has been a leader in the development of innovative strategies to enhance learning in digital environments. For example, web-based assessment strategies were developed to encourage self-regulated learning among high school students. Research has contributed to the advancement of the implementation of e-learning technologies, underlining Taiwan's ability to lead in the integration of advanced technologies in secondary education (Wang, 2011).

Additionally, the United States has exerted considerable influence in the domain of e-learning, particularly with regard to the assessment and confidence placed in digital learning systems. A notable example is the E-Learning Systems Trust Evaluation Model, which has played a pivotal role in enhancing the security and reliability of online learning platforms. Research has been pivotal to the advancement of e-learning, not only in the United States but globally. This reflects the country's leadership in the development of robust and reliable educational technologies (Tan et al., 2014).

Conversely, Indonesia and Spain have distinguished themselves primarily in terms of scientific output in the domain of e-learning. In Indonesia, research has concentrated on the development of blended learning models with the objective of enhancing the scientific critical thinking abilities of high school students. In this regard, a blended learning model based on Edmodo has been proposed, which serves to illustrate Indonesia's commitment to innovation in the field of science education (Wahyuni et al., 2019). In Spain, a notable contribution has been made to the instruction of professional ethics through blended learning programs for physiotherapy students (Aguilar-Rodríguez et al., 2019).

4.3 Analysis of the thematic evolution on e-learning technologies in secondary education

In the nascent stages of the evolution of e-learning technologies in the secondary education sector, the concept of virtual environments played a pivotal role in establishing the foundations of digital learning. The simulation of educational scenarios in virtual environments facilitated the teaching of complex concepts through interaction with three-dimensional models and immersive experiences. A notable example is the EIKON project, in which virtual reality was employed to facilitate the delivery of a technology course at the secondary education level. The efficacy of virtual reality as an instructional tool for technical subjects was demonstrated, with evidence indicating enhanced comprehension and engagement in interactive learning. The research highlighted the significance of virtual environments in education, establishing a foundation for the advancement of novel pedagogical approaches (Kameas et al., 2000).

In the present era, the conceptual approach has undergone a transformation to address contemporary challenges and respond to new educational demands. The impact of the 2023 pandemic has been one of the most extensively researched topics, underscoring the necessity for online and blended learning. A comparative study was conducted to examine the impact of online and blended learning in the context of the pandemic. The findings indicate that the pandemic has accelerated the adoption of these modalities and their integration into educational systems globally. The shift in approach reflected the adaptability and resilience of e-learning technologies in times of crisis, thereby reaffirming their importance in maintaining educational continuity (Ali et al., 2023).

Similarly, the concept of physical education acquired renewed significance in 2022, particularly within the context of primary education. The potential of gamification in physical education to mitigate anxiety about failure in primary school girls was investigated, with a view to fostering a more inclusive and motivating learning environment. This innovative approach has been pivotal in adapting e-learning technologies to domains such as physical education, where physical interaction and movement are paramount (Rodríguez-Martín et al., 2022).

In the field of e-learning technologies applied to secondary education, the concept of training has assumed greater significance in 2021. A recent investigation has underscored the significance of training in the context of online education, with a particular focus on specialized domains such as tourism. This concept emphasizes the necessity for the development of efficacious training strategies that not only instruct students in the utilization of technological tools but also optimize their learning and practical abilities within virtual environments. In the context of secondary education, training is an indispensable element in preparing students to confront academic and professional challenges through the utilization of digital platforms, thereby facilitating a more seamless and efficacious adaptation to the contemporary demands of education. The incorporation of training into e-Learning programs can markedly enhance the efficacy of learning and cultivate a more dynamic and accessible educational environment (Kalbaska and Cantoni, 2021).

The concept of motivation has been a central focus of recent research, as evidenced by the 2019 study on motivational interviewing training for medical students. This study employed a blended learning approach to train students in motivational interviewing techniques, thereby demonstrating the potential benefits of integrating face-to-face and digital methods to enhance motivation and performance in medical training. The findings of this study underscored the pivotal role of motivation in the learning process, particularly in highly academically demanding contexts such as medicine (Keifenheim et al., 2019).

4.4 Analysis of thematic clusters on e-learning technologies in secondary education

In the analysis of the primary network of co-occurrence of keywords in the field of e-learning technologies in secondary education, distinct thematic clusters were identified that reflect the affinity and interrelation between relevant concepts in this field. The primary cluster, indicated by the color green, is distinguished by its emphasis on subjects including Intellectual Disability, Physical Education, Innovation, and Students. This cluster emphasizes the utilization of innovative technologies to enhance accessibility and educational standards for students with intellectual and developmental disabilities. The efficacy of virtual reality exercise games has been demonstrated for secondary school students with intellectual disabilities, thereby underscoring the importance of technological tools in inclusive education (McMahon et al., 2020). Other research has identified gamification through ICT as an innovative alternative in physical education, with the potential to foster student engagement and motivation in physical activities (González et al., 2018). Moreover, the educational impact of mobile learning on students of health professions is emphasized, thereby reinforcing the relevance of this cluster in the context of educational innovation (Koohestani et al., 2019).

The second most important cluster, identified with the red color, groups terms such as multimedia, curriculum and medical education. This reflects a focus on the integration of multimedia technologies in the educational curriculum, especially in medical education. The agility in the adoption of e-learning in secondary schools was explored, highlighting how the incorporation of multimedia resources can improve the educational experience and the adaptation to new methodologies (Mesfin et al., 2018). Conversely, the efficacy of cardiopulmonary resuscitation training for secondary school students was examined through the utilization of a 360-degree immersive virtual reality environment, thereby illustrating the potential of advanced technologies in medical training and the cultivation of indispensable practical abilities (Barsom et al., 2020).

4.5 Analysis of the frequency and conceptual validity around e-learning technologies in secondary education

Quadrant 2 of the Cartesian plane reflected emerging concepts in the scientific field that are gaining greater relevance today

and that will probably continue to be central in the near future. These concepts include the keywords communication, motivation, learning, and effectiveness, which have assumed particular significance in the evolution of educational practices mediated by technology.

The concept of communication in the context of e-learning technologies is of paramount importance, as it enables interaction between students and educators, as well as the creation of a collaborative learning environment. The utilization of educational technology not only enhances communication abilities, such as public speaking, but also fosters active student involvement, which is pivotal in distance learning settings. This focus on communication is vital to guarantee that students feel connected and engaged, even when they are not physically present in the classroom (Ivanova et al., 2020).

Conversely, Motivation learning is a pivotal element that determines the efficacy of e-learning initiatives. It is imperative that students are motivated to actively engage in their learning process in order to achieve optimal outcomes. Various personal, interpersonal, and environmental factors influencing academic self-efficacy in blended learning environments are examined, underscoring the necessity to design learning experiences that maintain high levels of motivation (Wei et al., 2022).

The effectiveness of e-learning technologies represents a pivotal concern for both educators and researchers. The development of Android-based mobile learning media for the teaching of atomic structure and the periodic table was examined, demonstrating that the implementation of mobile technologies can significantly enhance the effectiveness of learning. The continued investigation of the efficacy of these instruments is vital to substantiate their beneficial influence and to ensure the continual enhancement of the methodologies employed in secondary education (Cahyana et al., 2018).

In the analysis of quadrant 1, which encompasses concepts that are growing, leading, and consolidated in the research field, the keywords “COVID-19,” “motivation,” and “physical education” emerge as particularly noteworthy. These terms not only reflect contemporary concerns and challenges in the field of education, but also indicate future trends that will remain relevant in the near future.

The concept of coronavirus disease 2019 (COVID-19) has been a pivotal factor in the restructuring of global educational strategies. The pandemic compelled a swift transition toward blended and online learning models, particularly in disciplines such as physical education, where physical and face-to-face interaction was of paramount importance. This study investigated the implementation of blended learning in physical education during the pandemic, highlighting its effectiveness and the lessons learned that could endure beyond the health crisis. The transition has proved to be a catalyst for innovation in pedagogical methods and is likely to continue to influence the structure of physical education in a post-pandemic environment (Zheng et al., 2021).

Conversely, motivation represents a crucial factor in the efficacy of any educational strategy, particularly within the context of technology-mediated learning. The utilization of augmented reality applications in the teaching of English vocabulary to first-grade students has been demonstrated to enhance both their performance and their motivation to learn. Motivation, therefore, becomes a crucial factor for the success of e-learning initiatives, and its

relevance is evident both at the present time and in the future, as emerging technologies continue to be integrated into the educational process (Lai and Chang, 2021).

The concept of physical education has undergone a significant transformation as a result of the incorporation of technologies such as virtual reality, which has enabled a more inclusive and effective adaptation of physical education. The application of virtual reality in adapted physical education has the potential to facilitate the participation of students with disabilities, thereby enhancing their educational experience. This not only reflects a growing trend in the integration of advanced technologies in physical education, but also indicates a path toward more inclusive and personalized practices, which will continue to evolve and consolidate in the coming years (Kang and Kang, 2019).

4.6 Classification of keywords on e-learning technologies in secondary education according to their function

The principal emerging and expanding keywords associated with the utilization of e-learning technologies in secondary education are categorized in Table 1 and arranged in accordance with their primary functions as documented in the scientific literature. The fundamental features and applications related to each of these functions can be readily discerned through this classification.

The table allows researchers to rapidly and effectively ascertain a synopsis of pivotal terminology that is gaining prominence within this domain of inquiry. It thus facilitates a more nuanced comprehension of the contemporary trends and methodologies that underpin electronic technology research.

4.7 Comparison with other studies

The results of this study are consistent with prior research on the effectiveness and evolving role of e-learning technologies in education, while also highlighting specific trends and gaps that distinguish the field of secondary education. The findings

indicate a substantial increase in research on e-learning between 2020 and 2023, particularly in areas related to student motivation, collaborative learning, and immersive technologies such as augmented and virtual reality. This observation is consistent with the findings of Lai and Chang (2021), who demonstrated that augmented reality applications enhance motivation and performance in early education English vocabulary learning. While the aforementioned study focused on first graders, our findings suggest that analogous trends extend to secondary education, where the integration of digital tools plays a crucial role in fostering engagement. However, our study also underscores that secondary-level research places a greater emphasis on collaborative learning environments and inclusivity, aspects that were not the primary focus of Lai and Chang's work.

Moreover, the increasing adoption of virtual reality for educational purposes aligns with the study conducted by Kang and Kang (2019), which examined its application in adapted physical education. Their research demonstrated that virtual reality facilitates participation and engagement among students with disabilities, a trend that was also observed in our keyword co-occurrence analysis, where "intellectual disability" and "accessibility" emerged as relevant themes. This finding lends further credence to the notion that immersive technologies play a substantial role in promoting inclusive education, particularly for students with special needs. However, our study further identifies that research on virtual reality at the secondary level extends beyond adapted physical education, encompassing broader applications in science education, skill development, and personalized learning experiences.

In a broader context, the bibliometric trends identified in this study corroborate the systematic review by Valverde-Berrosco et al. (2020), which analyzed e-learning research between 2009 and 2018. Their findings indicated that pedagogical innovation, digital competencies, and instructional design were among the most prominent themes during that period. Our results demonstrate that, while these domains continue to be significant, recent research has undergone a shift toward a heightened emphasis on motivation, engagement, and digital accessibility. This shift is particularly notable in light of the increasing reliance on e-learning technologies in the aftermath of the pandemic caused by the novel severe acute respiratory syndrome (SARS-CoV-2) virus. This shift underscores

TABLE 1 Classification of keywords according to their function.

Keyword	Associated tools	Applications	Characteristics
Motivation learning	Gamificación, feedback adaptativo, gamified learning paths	Promoting intrinsic motivation in learning	Stimulates student interest and commitment
Game elements	Simulations, points and rewards, competitions	Incorporating playful elements to improve interactivity	Improve student engagement and focus
Content analysis	Data mining, text analytics, content categorization	Content analysis to optimize teaching	Allows you to adapt and personalize educational content
Learning effectiveness	Learning analytics, assessments, adaptive learning	Evaluating and improving performance and understanding	Facilitates the measurement and improvement of learning and understanding
Motivation	Engagement strategies, incentives, personalized learning	Stimulating student interest and engagement	Align learning with individual preferences and needs
Physical education	Virtual reality (VR), augmented reality (AR), simulators	Integrating technology to improve physical education	Facilitates the safe and effective practice of physical skills

Prepared by the authors based on Scopus and Web of Science.

the evolving priorities in educational research, where student-centered approaches and technological adaptability have gained increasing attention.

Moreover, our study is consistent with the systematic review by Mastan et al. (2022), which evaluated distance learning systems and identified key challenges such as accessibility, technical infrastructure, and student satisfaction. While the aforementioned review encompassed the broader concept of e-learning, our analysis of secondary education research offers a more detailed perspective, particularly with regard to the role of gamification, adaptive learning platforms, and interdisciplinary approaches. The findings of this study suggest that, while general concerns regarding e-learning persist, research in secondary education is increasingly focused on refining digital methodologies to improve engagement and effectiveness. This study offers a comprehensive understanding of the evolution of e-learning technologies, providing valuable implications for both research and policy development in secondary education.

4.8 Theoretical implications

The theoretical implications provide a valuable foundation for future research in this field. The frequency of publications per year reveals significant trends in the attention paid to this topic over time. The increasing number of publications in recent years suggests a growing interest in adapting and improving educational technologies in response to the rapid evolution of the digital environment and the emerging needs of students. This temporal pattern highlights the need for theoretical frameworks that integrate technological and pedagogical evolution, recognizing the influence of global events such as the pandemic caused by the SARS-CoV-2 virus on the shift toward more digital and flexible teaching methods.

The principal theoretical references identified in the bibliometric analysis have shaped the trajectory of e-learning research, establishing the foundations for the comprehension of pivotal concepts such as motivation, learning effectiveness, and inclusion. The shift in focus from virtual environments to areas such as the impact of the pandemic, physical education, training, and motivation demonstrates both the expansion of existing theoretical frameworks and the emergence of new lines of enquiry. This suggests that theoretical models must be adapted to integrate these new approaches, thereby facilitating a more comprehensive understanding of the ways in which e-learning technologies can be deployed in a range of contexts and in response to contemporary challenges.

The examination of keyword co-occurrence and the discernment of nascent and expanding lexical items provide a comprehensive insight into the subject matter that is acquiring prominence within the field. The emergence of concepts such as communication, motivation, learning, and effectiveness reflects a growing interest in the role of interaction and the effectiveness of learning in digital environments. This indicates the necessity for the development of theoretical frameworks that address the potential of e-learning technologies to enhance student communication and motivation, as well as the overall effectiveness of the educational process. It is imperative that theory evolve to

consider these novel variables and their impact on learning in digital contexts.

The identification of research gaps serves to highlight areas where current theoretical understanding may be lacking or where specific research is lacking. For example, the absence of studies that conduct a thorough investigation into the integration of physical education into e-learning platforms, or that assess the long-term impact of motivation in virtual environments, points to potential areas for future research. Addressing these theoretical gaps may facilitate the acquisition of new insights into how e-learning technologies can be improved and adapted to meet specific and emerging educational needs.

4.9 Practical implications

The findings have significant implications for the practical implementation and development of educational strategies in this field. The observed thematic evolution, which has moved from an initial focus on “Virtual Environments” to the inclusion of more recent topics such as “COVID-19,” “Physical Education,” “Training,” and “Motivation,” indicates that e-learning technologies are being increasingly adapted to respond to contemporary educational needs. This emphasizes the necessity for educational systems and digital content developers to maintain flexibility and the capacity to rapidly integrate new technologies and pedagogical approaches in response to global events and alterations in educational requirements.

The identification of the primary thematic cluster, comprising terms such as “Intellectual Disability,” “Education Physical,” “Innovation,” and “Students,” underscores the increasing significance of inclusivity and innovation in technology-mediated education. E-learning tools must be designed in a manner that ensures accessibility for all students, irrespective of their abilities, while also fostering educational innovation that responds to the diverse needs of students. This necessitates the creation of platforms that are both intuitive and adaptable, thereby enabling the personalization of learning and facilitating access to educational resources that promote active and participatory learning.

The analysis of the frequency and recency of keywords allows for the identification of emerging concepts, such as “communication,” “motivation,” “learning,” “effectiveness,” and “mathematics,” as well as growing concepts, including “COVID-19,” “motivation,” and “physical education.” These findings have direct implications for curriculum design and educational planning. The emergence of topics such as “Communication” and “Motivation Learning” indicates that e-learning strategies should prioritize the enhancement of students’ communication and motivational abilities, which are essential for success in digital learning environments. Conversely, the growing significance of “Physical Education” and “Motivation” in the context of technology-mediated education highlights the necessity to integrate physical activities and motivational elements into e-learning platforms, which could facilitate a more balanced and holistic learning experience.

In practical terms, these trends indicate that educational institutions and e-learning developers should focus on the creation of resources that not only respond to traditional academic

demands, but also foster the physical and emotional wellbeing of students. The incorporation of interactive modules that encourage physical activity, coupled with motivational and communicative strategies, has the potential to markedly enhance the efficacy of e-learning programs. Moreover, the emphasis on the efficacy of the technologies employed indicates a necessity for rigorous and continuous impact evaluations to ascertain the extent to which these tools genuinely enhance academic success and comprehensive student development.

In other dimensions, the practical implications of this bibliometry also include the necessity for enhanced collaboration between researchers, educational software developers, and legislators. The convergence of e-learning technology with educational policies necessitates strategic alignment to guarantee that technological advances are translated into tangible improvements in teaching and learning. Similarly, it is crucial to promote interdisciplinary research that explores novel methods of integrating technology with emerging pedagogies, such as project-based learning and personalized education, in order to meet the diverse needs of students.

In broader contexts, this bibliometry highlights the importance of internationalizing e-learning research. The implementation and adaptation of educational technologies in diverse environments can benefit from experiences derived from different countries and cultural contexts, which offer valuable lessons. International cooperation and the exchange of good practices can significantly contribute to the overall improvement of secondary education. This allows technological innovations to be adapted to diverse local realities.

Ultimately, bibliometrics emphasizes the necessity for a sustainable methodology in the advancement and utilization of e-learning technologies. The implementation of these technologies must consider not only their economic viability but also their environmental and social impacts. This encompasses the optimization of resources, the reduction of the carbon footprint of educational technologies, and the promotion of responsible and ethical use of technology in education. It is imperative that sustainability be a fundamental element in the conceptualization and implementation of e-learning initiatives, ensuring the longevity of these benefits and their transmission to future generations.

In order to enhance the discourse, it would be advantageous to examine the potential influence of the findings on the development of future educational policies. The identification of emerging trends, such as the integration of “Physical Education” and “Motivation,” suggests that educational policies should evolve to incorporate approaches that support students’ physical and emotional wellbeing through e-learning. Furthermore, the prominence of themes such as “Inclusion” and “Innovation” underscores the necessity for digital education policies that facilitate accessible learning platforms for all students, irrespective of their abilities. By cultivating policies that encourage the integration of inclusive and adaptive digital resources, educational systems can enhance engagement and personalize learning experiences.

The findings underscore the imperative for policymakers to ensure the long-term sustainability of e-learning technologies, advocating for economically viable and environmentally responsible solutions. The promotion of international collaboration and the exchange of best practices can facilitate

the adaptation of educational technologies to diverse cultural contexts, thereby enhancing the quality of secondary education on a global scale.

A bibliometric analysis reveals a significant surge in research on e-learning technologies between 2020 and 2023, particularly in areas related to student engagement, physical education, and collaborative learning. The keyword co-occurrence analysis highlights terms such as “collaboration,” “engagement,” and “interactive learning,” indicating a discernible transition toward student-centered methodologies. Furthermore, the burgeoning focus on emerging concepts such as “augmented reality” and “virtual learning” signifies an escalating interest in immersive technologies that enhance personalization and interactivity in education. These findings underscore the imperative to formulate adaptive educational strategies that promote active engagement and cater to individual learning requirements.

Furthermore, the identification of thematic clusters underscores a growing emphasis on intellectual disability and inclusive education in e-learning research. The association of terms such as “accessibility” and “learning effectiveness” underscores the importance of designing digital environments that accommodate diverse student populations and promote educational equity. Exploration of methods to optimize emerging technologies to enhance inclusion remains imperative, particularly in contexts where access to digital tools is limited. By integrating these insights, the study strengthens the connection between bibliometric trends and their practical implications for secondary education, providing a foundation for future research and the advancement of more effective pedagogical approaches.

4.10 Limitations

One of the principal constraints of contemporary bibliometrics is the limitation of the databases employed. Although Scopus and Web of Science are acknowledged for their comprehensive scope and rigorous methodology, they do not encompass the entirety of global scientific output. It is therefore possible that relevant research published in other repositories or in journals not indexed in these databases has been omitted. This may restrict the scope for generalizing the findings and may also result in a bias toward studies from countries or institutions with greater representation in these databases.

A further limitation intrinsic to the methodology employed is the reliance on the analytical tools utilized for data analysis. Microsoft Excel[®] and VOSviewer[®] provide valuable functionalities for the visualization and analysis of bibliometric indicators. However, they have limitations in terms of the capacity for in-depth qualitative analysis. The interpretation of the data may be influenced by the parameterization of the tools and the methodological decisions regarding the selection of terms and co-occurrence thresholds, which could impact the identification and categorization of emerging and consolidated trends.

4.11 Research gaps

The primary research gaps identified in the academic literature are presented in [Table 2](#) of this bibliometric study on the utilization

TABLE 2 Research gaps.

Category	Research gaps	Justification	Questions for future researchers
1-Thematic gaps	<ul style="list-style-type: none"> Effectiveness of technology integration in the secondary education curriculum. Evaluation of online teaching and learning strategies specific to secondary education. 	These gaps focus on better understanding how E-learning technologies can effectively adapt and benefit secondary education.	What is the impact of the integration of E-learning technologies on the academic performance of secondary school students? What are the most effective online teaching strategies for secondary education?
2-Geographic gaps	<ul style="list-style-type: none"> Comparison of the adoption of E-learning technologies in different geographical regions in secondary education. Analysis of cultural and socioeconomic factors that influence the implementation of technologies in secondary education at a global level. 	These gaps seek to explore the differences in the adoption and effectiveness of E-learning technologies in different parts of the world.	How does the adoption of E-learning technologies in secondary education compare across different countries or regions? What cultural and socioeconomic factors influence the implementation of these technologies globally?
3-Interdisciplinary gaps	<ul style="list-style-type: none"> Integration of multidisciplinary approaches in research on E-learning technologies in secondary education. Exploring collaborations between technology and education experts in the implementation of E-learning strategies in secondary education. 	These gaps focus on the need for closer collaboration between disciplines and multidisciplinary approaches to address the challenges and opportunities of E-learning technologies in secondary education.	How can researchers from different disciplines collaborate to address the challenges of secondary education with E-learning technologies? What are the benefits of an interdisciplinary perspective in research on this topic?
4-Time gaps	<ul style="list-style-type: none"> Analysis of long-term trends in the use of E-learning technologies in secondary education. Evaluating the sustainability and evolution of online teaching strategies and approaches in secondary education. 	These gaps focus on understanding how the use of E-learning technologies in secondary education will evolve and be maintained over time.	What are the long-term trends in the adoption of E-learning technologies in secondary education? How can educational institutions ensure the sustainability of their online teaching approaches over time?

Prepared by the authors based on Scopus and Web of Science.

of e-learning technologies in secondary education. To address these knowledge gaps and gain a deeper understanding of the impact of e-learning technologies on secondary education, future studies must devote greater attention to these areas.

The identified gaps permit researchers to enhance educational practices and facilitate informed decision-making in the domain of secondary education by addressing these gaps. The identification of research gaps in the domain of e-learning technologies at the secondary education level underscores the necessity for future studies that extend beyond bibliometric analysis and delve into experimental and longitudinal research. For instance, an experimental study could be conducted to assess the effectiveness of augmented reality-based learning environments in enhancing students' motivation and academic performance. By comparing groups of students exposed to traditional teaching methods vs. those using immersive digital tools, researchers could provide empirical evidence on the pedagogical value of these technologies. Similarly, controlled trials could examine the impact of gamification strategies on student engagement, particularly in challenging subjects such as mathematics and science, where maintaining motivation is particularly difficult.

Furthermore, longitudinal studies could explore the long-term impact of e-learning adoption on students' academic progress, digital literacy, and career readiness. A longitudinal study that follows students from secondary education into higher education or the workforce could provide valuable insights into how sustained exposure to e-learning technologies influences their learning outcomes and professional competencies. Furthermore, research focusing on underrepresented populations, such as students with disabilities or those in low-resource environments, could evaluate the accessibility and inclusivity of current digital

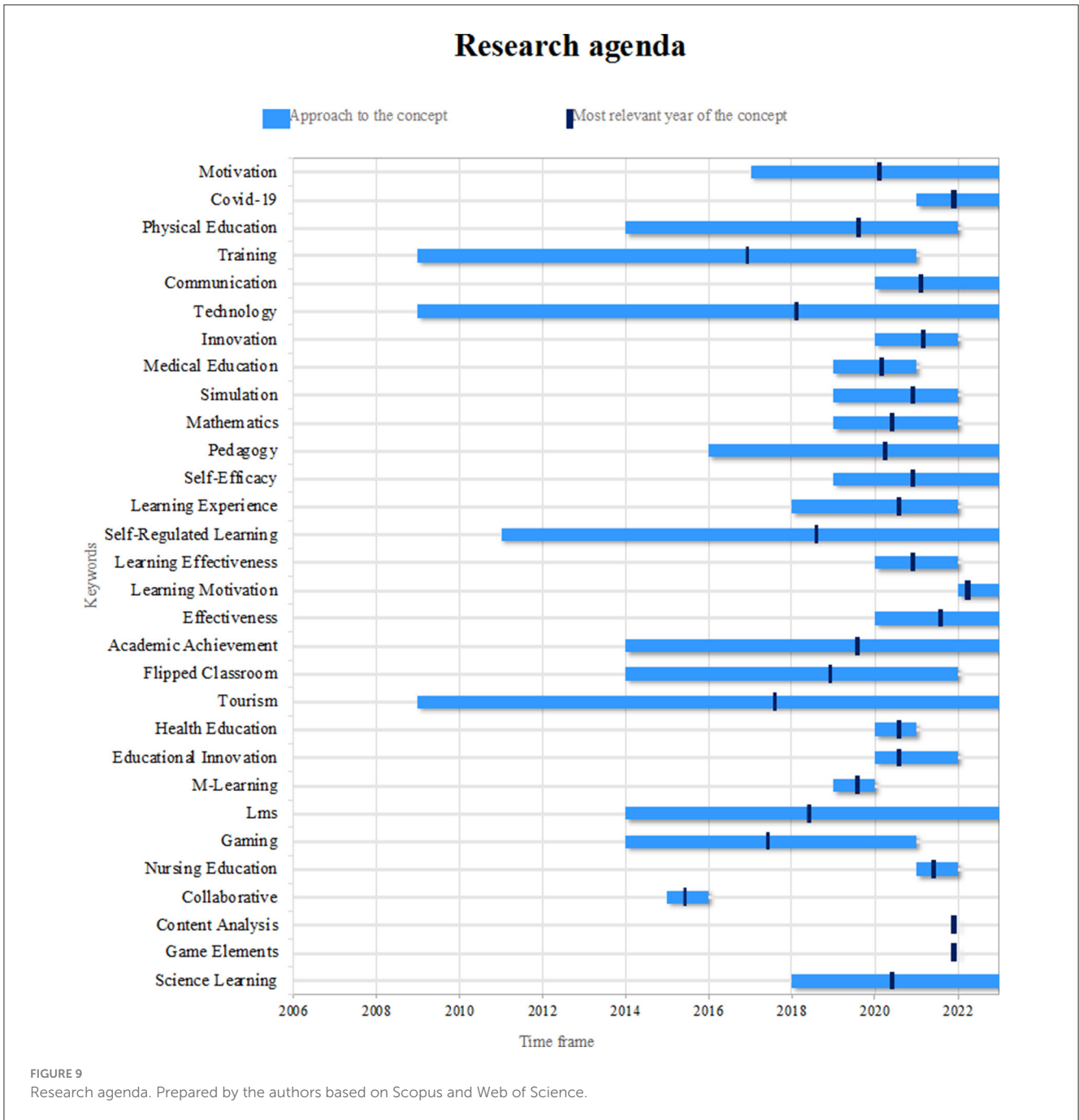
learning platforms. These studies would not only address existing research gaps but also inform policymakers and educators on best practices for integrating e-learning technologies in diverse educational contexts.

4.12 Research agenda

The research agenda presented has been developed from an exhaustive analysis of the 30 concepts identified in Figure 9, which reflect the most relevant and emerging areas in the field of e-learning technologies used at the secondary education level. This allows for a comprehensive understanding of current trends and gaps in the existing literature. By considering these key concepts, the agenda seeks to provide a solid basis for future research aimed at deepening the topics that have proven to be of high relevance and potential for academic and practical development in this field.

The concept of motivation has become a pivotal aspect of e-learning technologies for the secondary education sector, given its pivotal role in influencing student engagement and performance. In the present era, the design of educational platforms and tools is increasingly focused on the implementation of strategies that foster intrinsic and extrinsic motivation, as these are fundamental to the improvement of student participation and academic success. Further research could investigate how various technologies and online teaching methods can be enhanced to boost student motivation, taking into account factors such as interactive design, gamification, and personalized feedback.

To further the study of motivation, research can be conducted to assess the impact of different e-learning technologies on student motivation in specific contexts. These could include



learning difficult subjects or adapting to digital platforms. Furthermore, discrepancies in motivation between disparate student groups, such as those with disparate learning styles or skill levels, can be examined to develop more efficacious and personalized interventions that foster interest and persistence in the digital environment.

The term “technology” in the context of e-learning technologies is fundamental to the advancement and implementation of new educational methodologies. Its importance lies in the ability of technologies to transform the teaching-learning process through innovative tools that facilitate interaction, collaboration, and access to educational resources at the secondary education level. Furthermore, technology allows for personalization of learning and

access to a variety of digital resources that enrich the educational process. Future research may focus on how new technologies, such as artificial intelligence and augmented reality, can be effectively integrated into the classroom to improve teaching and learning.

Future research on technology should investigate the impact of specific technological innovations on different aspects of learning and teaching. Furthermore, it would be beneficial to examine how the implementation of new technologies affects equity in access to education and the quality of learning in varied contexts, including schools with limited resources and different cultural backgrounds.

The concept of learning motivation is a relatively recent addition to the field of e-learning technologies. It emphasizes the significance of strategies designed to sustain student interest

and engagement in a digital context. As e-learning platforms become more prevalent in secondary education, it is imperative to comprehend the means of cultivating motivation to learn in order to develop efficacious educational experiences. Further research could examine the impact of diverse pedagogical approaches and technologies on motivation to learn, and how these approaches can be adapted to align with individual student requirements.

Moreover, the factors influencing learning motivation at different stages of the learning process could be investigated, as well as the impact of content personalization and social interaction on student motivation. Furthermore, studies could analyze the variation in motivation to learn across different disciplines and educational contexts, thereby providing a more comprehensive understanding of effective learning support in e-learning environments.

The advent of the Coronavirus Disease 2019 (COVID-19) has had a profound impact on the field of e-Learning Technologies, largely due to its far-reaching implications for global education and the accelerated transition to online learning. The pandemic has underscored the necessity for efficacious technological solutions to guarantee the continuity of education in emergency situations. In the future, research may focus on how the experience of learning during the pandemic has shaped students' and educators' perceptions of e-Learning Technologies, and what insights can be gleaned to enhance the resilience and flexibility of the education system.

Furthermore, it would be beneficial to examine the impact of the pandemic on equity in access to e-learning technologies and to identify strategies for addressing the digital disparities that have emerged. Furthermore, an analysis of how disparate countries and regions have modified their pedagogical methodologies during the pandemic can inform the formulation of more efficacious and responsive strategies in the future.

The concept of physical education within e-learning technologies has gained prominence as a means of investigating the potential of digital tools to enhance physical education at the secondary education level. The incorporation of technologies such as virtual reality and simulators in physical education facilitates enhanced interaction and motivation, while also furnishing resources for practice and learning beyond the conventional classroom setting. Further research should concentrate on the impact of these technologies on learning and participation in physical education, as well as on how they can be employed to overcome the limitations of the physical environment.

Further studies could investigate the impact of digital physical education on students' health and wellbeing, and how these tools can be optimized to provide more effective learning experiences. Additionally, research could examine how technology can facilitate the inclusion of students with special needs in physical activities, promoting greater participation and equitable access to physical education.

The concept of training has been consolidated in the field of e-learning technologies as a crucial dimension for the development of skills and competencies at the secondary education level. Training in the utilization of digital tools and e-learning platforms is imperative for educators and students alike, facilitating an efficacious adaptation to online pedagogical methodologies.

Further research could investigate the potential of e-learning technologies to facilitate more effective and personalized training, as well as assess the impact of such training on educational effectiveness and the professional preparation of students.

Moreover, it would be advantageous to examine the impact of diverse training approaches in digital technologies on students' academic performance and technological proficiency. Furthermore, studies could examine the extent to which ongoing training in the use of digital tools can contribute to the professional development of educators and improve the implementation of e-learning technologies in the classroom.

The concept of innovation is of paramount importance in the field of e-learning technologies, as it serves as the driving force behind the creation and adoption of novel tools and methodologies with the aim of enhancing the educational process. The advent of innovation in this field has enabled the development of solutions that address the current challenges facing secondary education, such as the necessity for more personalized and accessible teaching. Further research could concentrate on the manner in which technological innovations are transforming the processes of learning and teaching, and on the ways in which these innovations can be effectively implemented in a variety of educational contexts.

Furthermore, research could be conducted on the impact of innovations on educational equity and learning quality. An analysis of how new technologies are changing educational practices and the way students interact with content could inform the development of future educational tools and strategies.

5 Conclusions

The findings of this study directly address the research objectives by highlighting key trends in e-learning technologies and their impact on secondary education. By identifying emerging themes such as inclusion, motivation, and interactive learning, this research provides valuable insights that align with the initial goals of understanding technological advancements and their implications for educational practices.

The bibliometric analysis yielded significant insights into the evolution and contemporary state of research in this field. Firstly, the years of greatest interest in the topic were 2022 and 2021, indicating a recent surge in academic attention toward this area. This growth is evidenced by an exponential increase in the number of scientific articles, which demonstrates a significant rise in interest and output in the field of E-Learning Technologies in secondary education.

In terms of research references, the contributions of authors such as Hwang et al. are particularly noteworthy, as they have made significant advances in the development of literature in this field. The principal journals in which research on this topic is published are Sage Open, the Journal of Hospital Leisure Sport & Tourism, and Technology in Society. It is notable that Taiwan and the United States are the countries in which the greatest quantity of research is produced and which have the greatest impact on the field.

Thematic evolution in scientific production has demonstrated a notable shift from an initial focus on virtual environments

to a more expansive approach encompassing contemporary issues such as the Coronavirus, physical education, training, and motivation.

Thematic clusters identified in the literature demonstrate the conceptual affinity between terms such as intellectual disability, physical education, innovation, and students, indicating areas of high relevance and connection within the field. Furthermore, the keyword analysis indicates that concepts such as the Coronavirus, motivation, and physical education are gaining prominence and stability, while communication, motivation learning, and effectiveness emerge as new areas of interest.

This study underscores the significance of e-learning in secondary education and offers a contemporary viewpoint on the potential of emerging trends, such as augmented reality and inclusive education, to transform teaching methodologies. By identifying research gaps, the study establishes a foundation for future studies that will further explore the long-term effectiveness of these technologies. Moreover, the findings of this study serve as a guide for the development of educational policies that promote accessibility, student motivation, and personalized learning, ensuring that digital integration in education remains both innovative and equitable.

In order to maximize the impact of these findings, it is recommended that policymakers promote the implementation of strategies that facilitate the integration of emerging technologies in secondary education. Concurrently, educators stand to benefit from training programs that augment their competencies in the utilization of digital tools, thereby ensuring a more inclusive and effective learning experience. These measures would contribute to a more equitable and sustainable adoption of technologies in the educational sector.

In conclusion, the design of a future research agenda should prioritize the deepening of current leading concepts, including those related to the ongoing pandemic, motivation, and physical education. Additionally, it is essential to explore the emerging concepts identified, as this approach will enable a comprehensive understanding of current and future trends, ensuring that research is aligned with educational needs in the context of e-learning technologies in secondary education.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

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