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Innovations in science education: A bibliometric exploration of trends and future directions

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Abstract

This article carries out a bibliometric research review to present the evolving landscape of innovations in science education. The study acknowledges the dynamism of the contemporary educational practices and uses the bibliometric analyses for identification of trends, assessment of impacts of scholarly outputs, and mapping the future directions in the field of science education innovation. Starting with a review of the standard bibliometric indicators, e.g., citation analysis and co-authorship, the review lays down the theoretical basis for the understanding of the scientific impact of the innovations in science education. The analysis, moreover, consists of identifying thematic foci and emerging topics through keyword mapping, which together present a holistic picture of the intellectual map of the field. The review points to seminal works and trends, demonstrating the nature of interdisciplinarity in research in science education innovation. By the analysis of collaborative networks and research hotspots the research not only demonstrates the present status of the field, but also predicts its future directions, which could help researchers and educators at the same time. Also, as a retrospective tool, the article explores the general relevance of bibliometric insights for educators, administrators, and other researchers. It highlights the application of bibliometrics in evidence-based decision-making, curricula design and international collaboration, because it is common knowledge that it can trigger the great revolution in innovative science education. This bibliometric review generates useful outcomes, which are beneficial to academic discussions and provide guidelines for future research efforts as a key reference for researchers who would like to have a deep, general overview of the innovations in science education.

Keywords: innovations, science education, bibliometric analysis

INTRODUCTION

Innovations in science education should be understood as new implementation of new objectives, education content, methods, and form; common work of teachers and learners (Dutchak, 2023). Science and innovation now have the unique role that they can implement in the education system, where they have taken over the functionality of inducing analytic thinking, possessing the technology to test hypotheses, and tackling important problems in the society according to Sierra et al. (2022). When it comes to science classes, the students' perceptions of innovativeness do matter, and it has been confirmed that the students generally have high perceptions of innovativeness with some factors, such as gender, grade level, or artisanship in science fairs, being important determining the students' perceptions as stated by Muradoglu et al.

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Contribution to the literature

- This article takes a comprehensive tour to highlight the latest trends in the bibliometrics of outdoor and informal education which has sparked the interests of scholars in experiential pedagogy beyond the traditional classroom settings.
- It measures the changes in publications and citation networks scientifically and shows how playing outside has an effect on the children's involvement in the process and scientific literacy.
- Through the synthesis, this study contributes to the digging out of the efficient educational interventions, giving an idea to teachers, researchers, and policymakers on the idea of using outdoor and informal learning as a part of the science curricula.

(2022). In international education, the most popular innovative trends are information and communication technology (ICT), assets blending, artificial intelligence (AI), and game play, and others (Ren et al., 2021). Invigorating innovation management has become an important factor especially in the context of educational process conduction; and innovation is an inalienable tool of educational reforms (Pérez et al., 2023).

Science education innovations encompass the introduction of new objectives and content, improved methods of instruction, and joint activities between teachers and students, as well as an active participation not only in the process of studying (Romanovskyi & Romanovska, 2020). These innovations firstly are meant to work on conditions existence in which innovative projects and other activities can be carried out by education system this is their primary role according to Dutchak (2023). The concept of "innovates of higher education" or "higher education innovates" is a new scientific direction in higher education, comprising an overall innovative change in various areas of higher education, such as teaching, research, technology, development and more (Garner et al., 2017). Technological pedagogy is the other side of the coin in innovative education: here is out-of-the-box thinking, which is directed to the creation of the environment, where learners expand their skillset during the process of new product developing.

LITERATURE REVIEW

Science education has seen a dramatic change in recent years. According to Garner et al. (2017), developing social-emotional competencies in early science STEM learning can improve science education. This approach makes their pedagogy more comprehensive and more attractive for students. Another example of this is their concept of "eco-reflexive science education" (Sjöström et al., 2016) enhanced the students' environmental consciousness and thus the changes towards sustainability that they made in their curriculum. This means that the students can now understand not only science but the sustainability of science and so the environment in which they live.

Mukhammadjonovich et al. (2023) found that while "conceptual representational practices" was a far more effective form of learning than traditional "conceptual problem solving" there was still "no significant difference in scientific reasoning" among students. What they achieved was that a blended learning format teaching materials could be developed based on the three target scientists. Their work now needs to be developed for other scientists and then the strategy tested with a larger target cohort. There have of course been rapid gains in educational technology tools in recent years to which they could apply big data analytics for improved learning. They must of course find a way to push progress to a wider range of topics and learners.

In the last few years there has been considerable attention on the innovations in the research of scientific education and more emphasis on the computational thinking (CT) training of pre-service teachers (PST). Dong et al. (2023) conducted a systematic literature review on 38 papers published from 2011 to 2021 on preservice CT of teachers. Lessons learned classified training paths for PSTs helping with the development of CT skills, in correlation with the factors that influence CT and CT ability. Besides, an essential part of the research was designing testing modules that would improve CT skills of PSTs to adjust teaching methods. On the contrary, Metruk (2022) looked at the challenges of English language learning with smartphones, putting forth issues, for instance, the phone size, connection problems, and the imbalance in developing skills.

The impact of teaching methods that is up to date with latest teaching methods have revealed to be useful in building students' comprehension of scientific concepts (Kossybayeva et al., 2022; Muhlisin, 2019). The application of active-based social learning, practical-approaches to problem solving, and project-based learning have been witnessed as a way of improving the students' perception of learning, enhancing positive self-esteem, and moving the rate of educational progress according to Abaniel (2021). Besides, research proved that the students mastered the concepts more effectively, academic achievements increased, and students developed meta cognitive skills (Kurniawan, 2019). In addition to that, research on using the approach of modeled elicitation activities has been found to enhance the learner's critical thinking ability, understanding of concepts, and learning activities (Ogunji et al., 2019).

There are still some educational contexts with very limited levels of awareness and poor application of creative teaching techniques that are might be due to problematic facilities, inadequate skills, and classroom structure to sum up, innovative approaches to teaching can really improve the understanding of students for scientific, but their power may be constrained by various external factors.

Unconventional approaches to science teaching, beyond teaching only practical questions, offer a chance to improve students' cognitive abilities and communication skills (Afikah et al., 2022). Problem-based learning and inquiry-based instruction strategies are highly effective methods of improving critical thinking skills. In particular, problem-based learning is closely related to communication skills that result from working in a team (Udu et al., 2022). Recent studies indicate that there exist educational approaches, for example, the learning activities package (LAP), which increase their science subject's storage. Incorporating different teaching strategies in computer science courses will enable students to be cultured and competent in information as well as to attain the relevant 21st century skills (Muradoglu et al., 2022). Students' judgements about innovations during science lessons vary between different grade levels, their academic achievements in science, and if they have ever attended a science fair according to Udu (2018). Trends of the present age in higher education include integration of ICT, AI, and gamification. The creative approaches encompass current views and anticipate the future, to find solutions for actual problems and for demands of the present moment.

METHODOLOGY

Data Collection

Credible sources of articles met a stringent set of selection criteria to analyze a precise set of materials. The criteria specified innovative science education articles' direct focus on the emerging of techniques exclusively within science education that included studying new methodologies, improvements, and innovations of the discipline. The title and abstract studies, followed by a rigorous examination of keywords formed the basis of the selection, thus grants an objective understanding of each article in line with the subject of the research. In synergy, Scopus data base that is widely regarded as the leading repository, has been strategically chosen as the main outlet for pulling journals, due to its holistic coverage of scholarly literature, especially in education. The applied method involved an orderly combination of keywords, Boolean operators, and controlled vocabulary, which is well-liked to innovative science education. This was intended to work like a wide and precise net, capturing only those articles, which are of so much relevance to the topic. The choice to adopt the Scopus database was justified by the fact that it is evident that the Scopus is widely known to inclusive in its nature and ranges from scholarly journals, conference proceedings and other publications, therefore contributing to the comprehensiveness of the dataset. This scientific article collection was attained through application of strict selection criteria and use of Scouring the Scopus database with a refined search strategy that embraced the nuances, which was a key element in the process of data collection for this bibliometric analysis to come up with a robust and representative bibliographic collection. This method creates an ideal environment for follow ups in other areas of the development of science innovations education, which includes trends, contributions, and development of the discipline, in question.

Inclusion & Exclusion Criteria

The development of a sturdy structure helped in the assurance of the integration of scholarly rigor and authenticity in the dataset. The choice of criteria involved picking up peer-reviewed articles and thus, committing to professionalism and the necessity of research being properly reviewed by appropriate peers. This policy was designed to capture only those articles that had passed through a rigorous and comprehensive screening process and were, thus, of very high-quality research papers.

On the other hand, the purpose of our exclusion criteria was to keep the academic level of the paper high by removing the non-peer-reviewed works. Non-peer-reviewed sources, which may include grey literature or conference abstracts that have not undergone subsequent peer review, were purposefully omitted from the bibliometric assessment to maintain the scholarly standards critical for the strength of the analysis. Through the specifically chosen criteria in selection and exclusion, we have ensured that the considered articles go through stringent evaluating procedure, which corresponds to high scholarly standards of peer-reviewed literature. Besides, the final data product reflects the strong reliability and quality parameters, thus enhances the quality of the upcoming bibliometric study on reforms of science education.

Data Analysis Techniques

This section encompasses two crucial subtopics applying the bibliometrics indexes and statistical methods, among other determinants. The Bibliometric Indicators comprise quantitative measures that are employed to analyze and uncover such subjects as the write-ups on the accomplishments in the study domain of science education. This work will focus on studying the various dimensions of scientometrics and provide dispassionate commentary on how the contributions of

the scientific community fit into the puzzle of science education reform.

It is imperative to say that a statistical method is indeed an important part of data analysis, where the statistical model undergoes application to make the dataset understandable and to give out significant information. There are different statistics really such as Descriptive statistics, inferential statistics, and correlational analyses, which are used to detect patterns and relations in the books, which are associated with a given data set. This kind of methodology is to build a logical framework that can not only provide the evaluators with all the information needed for the discussion of science education reforms, but also brings a more organized understanding of the quantity of strengths and weaknesses. Both types of indicators are considered along with statistical methods during the data analysis. The methodology designed in this way forms a powerful platform that helps arrive at useful insights in science education innovation.

DATA ANALYSIS & FINDINGS

Trends in Science Education Innovations

Overview of publication trends

This study shows a time series from 2004 to 2024 covering the timelines of important contributions within the scope of science education innovations. Data exhibits distinct factor phases, depicting different research output over years. In 2004, as initiation, low in volume and scholarly, the accumulated publication in the subsequent years begins to grow, evidenced by substantial increase in years 2005, 2006 and 2007. A pronounced upswinging tendencies are observed in 2008, which is evidence of a substantial researcher's interest and enthusiasm in recent science education innovations. This trajectory goes steadily upward through successive years and then shows up sometimes in 2011, 2012, and 2013, with these absolute highs depicting overall attention to research and the systemic shift that is continuously taking place. As you can see, years 2014 marks the apex of the wave, which continues through 2015 and ends in 2016. Thus, these three years stand out as a kind of concentration of scientific work and may also reflect a pure development of certain thematic lines. As the temporal axis spirals into 2017, 2018, and 2019, the data highlight variations but a clear, yet fluctuating pattern, of the study output. In the end, the periods expressing 2020, 2021, 2022, 2023, and 2024 denote the recent, at present phase that is observable among scholars and researchers continuing to make contributions in the field of science education. Thus, it showed the everlasting applicability associated with the disciplines as well as the dynamic nature of innovative science education evolution. This chronological analysis traces the trends in publication and provides a more holistic picture of the timeline of change in intellectual milieu and hidden themes of science education innovations as can be seen from **Figure 1**.

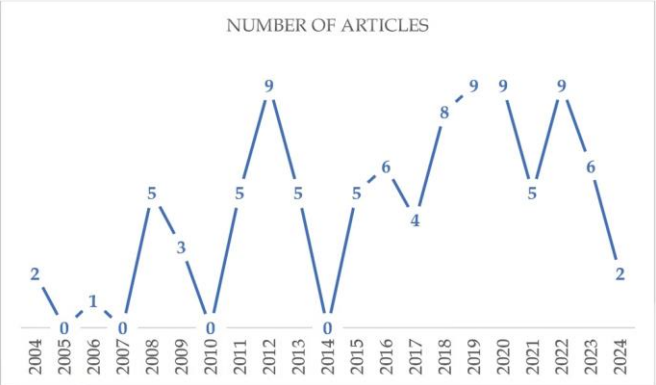

Figure 1. Distribution of number of articles per year (Source: Authors' own elaboration)

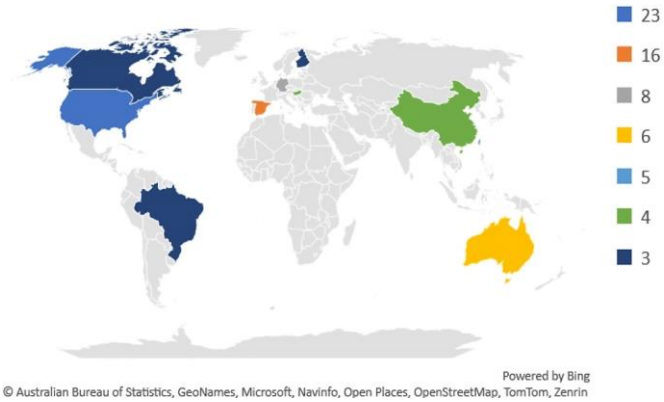

Figure 2. Geographic distribution of articles (Source: Authors' own elaboration)

Geographic distribution of articles

When looking at a geographic distribution of articles pertaining to science education refinement using the method of bibliometric analysis, you will find that specific countries are more prominent. The prominent power comes from the United States, always generates 23 articles, which is being proved as it is the most influential country regarding to science education. Shortly after that there is a strong impact by Spain, who is showing 16 articles evidence that shows the level of engagement by the researcher. German, Australia, and Taiwan publish eight, six, and five articles, evidence, which these countries are gems among countries that are involved actively in the discourse for innovative educational methods. Progressively, noteworthy achievements are seen in China, Hungary, Brazil, Canada, and Finland as they made immense contributions–the first country produced four articles, the second country three articles, and those of the rest are also included in this global platform. It is noticeably diverse distribution that indicates universal work and commitment of various parties to improve and revise the innovatory educational approaches in the field of science teaching (**Figure 2**).

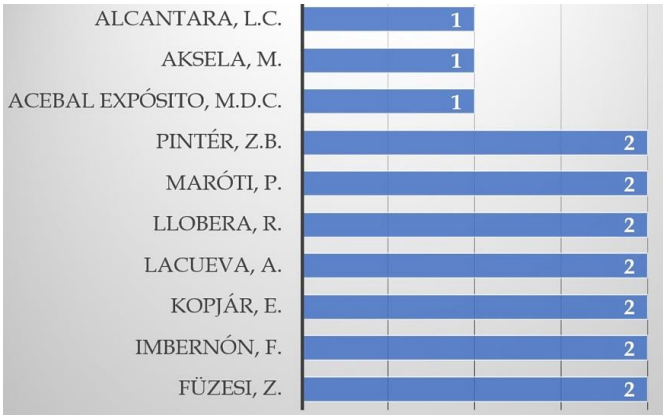

Figure 3. Distribution of prolific authors (Source: Authors' own elaboration)

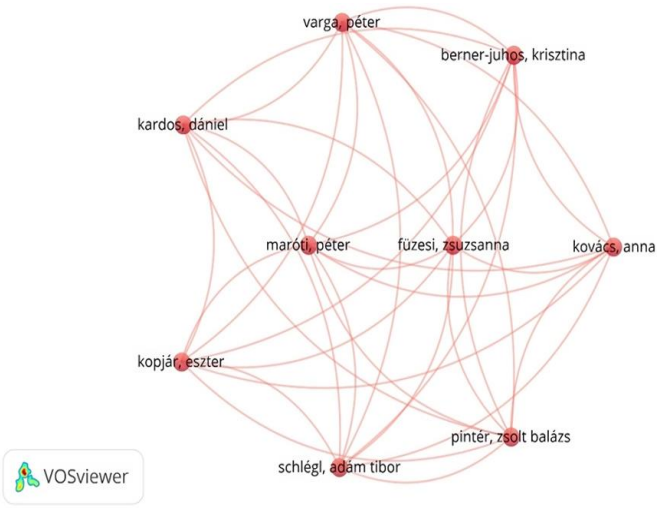

Figure 4. Networks between prolific authors (Source: Authors' own elaboration)

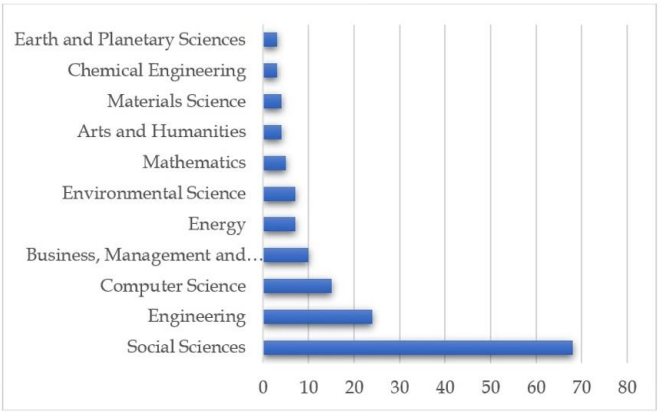

Figure 5. Subject area distribution of articles (Source: Authors' own elaboration)

Identification of prolific authors

The complete analysis in the bibliometric study on innovations in science education showed that there is a complex interaction of the productive authors in their contributions to science education. Among the noteworthy contributors, Fuzesi, Z., Imbernón, F., Kopjár, E., Lacueva, A., Llobera, R., Maróti, P., and Pintér, Z. B. alerted themselves as the ones who have written two articles during the data set. By this action researchers have a chance to demonstrate their continuous dedication and skills to the science education innovations development and sharing.

Probing further, Füzesi, Z., Imbernón, F., and Kopjár, E. provide a similar pattern of engagement, which can perhaps be accounted for by either being part of an area of current research or a certain niche in general psychotherapy. The same pattern is suggested by Lacueva, A., Llobera, R., Maróti, P., and Pintér, Z. B. These authors have a shared goal of furthering their knowledge about affabilious pedagogy.

The array of different productions highlights that a collaborative environment prevails within the group, thus chances of an intense exchange of ideas and working methods are increased. Besides this group, authors Acebal Expósito, M. D. C., and others, Aksela, M., and Alcantara, L. C. to name a few, contribute one article each, hence increasing the pool of contributors. Such variety is also not merely a sign of multifaceted nature of the issue, but it also tells us that there are probably some complementary perspectives (**Figure 3**).

In addition, **Figure 4** displays networks between prolific authors.

Subject area distribution of articles

Through an organizational structure of the bibliometric analysis in science education, an innovative landscape of researchers is being outlined. Social Sciences account for most of the subjects highlighted in the published articles, which cover 68 articles in total. This positioning indicates the intersectionality of science education within the sociocultural area, which stresses that the development of new teaching approaches is relevant as much for the common good as for society in general. While engineering is mentioned in 24 articles in second place, it is obvious that a good number of the contributors had concern in putting more emphasis on the practical implementation and technical aspects of introducing innovative methods in science education. However, 15 articles in computer science and business, management, and accounting (10 articles) also reveal the interdisciplinary aspect of the subject. It demonstrates how technology and business perspectives play a role in reformation of learning. This distribution of the subject areas demonstrates not only the wide range of the themes, but also stresses the cooperative and multidisciplinary character of the projects aimed at expanding the innovative techniques in science education in several areas of knowledge (**Figure 5**).

Temporal analysis of publications

This study covers bibliometric analysis of the articles about innovations in science education in peer reviewed

journals including Sustainability, Education for Information and Research in Science Education, etc. subjecting to bibliometric methods of analysis, to reveal the directions of development of scientific debate regarding the innovative ideas in science education. This study covers an array of data from Scopus for mentioning the top journals like Journal of Baltic Science Education, Computing in Science and Engineering, Cultural Science Education, and Science and Education. Variety of sources guarantees a particular high quality and wide range of views because human knowledge and education are complex and multifaceted systems.

The main objective of the temporal analysis part is to clarify the growth and progression of all the science ideas, techniques, and thought frameworks within the realm of science education. The researcher wants to study the history of the discipline through the publishing trends in prestigious journals such as Ensenanza De Las Ciencias, EURASIA Journal of Mathematics, Science and Technology Education, and International Journal of Innovation and Learning. He or she will be looking at the critical events that shaped the research agenda of the discipline. This minute scrutiny of temporal factors helps us gain a thorough understanding of how science as a dynamic activity moves from one stage to another providing knowledge on the emerging concepts and the paths that innovations travel over time.

The covering of journals like Journal of Computing in Higher Education, Journal of Science Education and Technology, and Journal of Science Teacher Education with the multiple perspectives, complements the study as it is temporal and diversified in nature. The article goes into details of analyzing, particularly in these platforms, the relationships between numerous areas of research and the spread of innovative educational strategies. This is then followed by the response of researchers collectively to the new educational paradigms. Ultimately, this article turned out to be an exciting prospect presenting the chronological aspects of the academic world as well as a considerable input to the on-going research on progress in science learning (**Figure 6**).

Most occurred keywords

Regarding the science of teaching, the wealth of 63 phrases of the word "science education" clearly shows its extensive application and meaning. The scholars specializing in science educational innovation bibliometrics walk through this bulk of information while analyzing the emerging patterns, trends, and central contributions. The "innovation" towards the beginning contains 31 occurrences, and it emphasizes the dynamic nature of scientific pedagogy. It is obvious that this phenomenon implies the constant search for new and advanced methods and approaches.

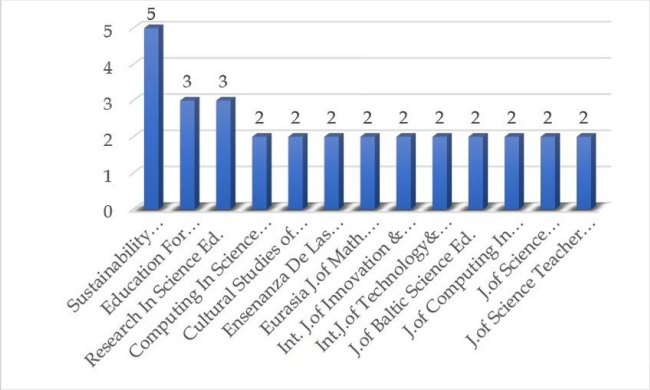

Figure 6. Distribution of number of articles per peer-reviewed journals (Source: Authors' own elaboration)

Table 1. Number of most occurred keywords in articles

Keywords	Number of keywords
Science education	63
Innovation	31
Bibliometric analysis	17
Early childhood education	13
Distance education	9
Total	133

The 17 times "bibliometric analysis" is used as a keyword itself is a good indicator for the complexity and rigor of approaches researcher have taken while scrutinizing the scholarly output within the area of science education and innovation. The process of critical analysis allows one to spot the major works and key authors as well as dominant themes that helped shape the field. Moreover, the high frequencies of "early childhood education" with 13 occurrences prove the increasing acknowledgment of the formative period as the crucial stage for shaping the curious and open-minded mindsets of students. Scientists in bibliometric analysis of scientific innovations in science education possibly examine a lot of material discussing the first years of education and their use in encouraging young children to follow scientific thinking (**Table 1**). This suggests a modern aspect to the talk on science education. Researchers are making exploration of how innovations in distance education give swift diffusion of scientific information. When scientists are immersed in such a vast number of texts, incorporation of bibliometric analysis becomes critical to differentiate the paths of science education research and to find out how the innovations evolve the instructional techniques. Finally, the combination of these keywords indicates an environment that is complex and arcane, where bibliometric analysis proffers researchers' way markers for the voyage through science education research (**Figure 7**).

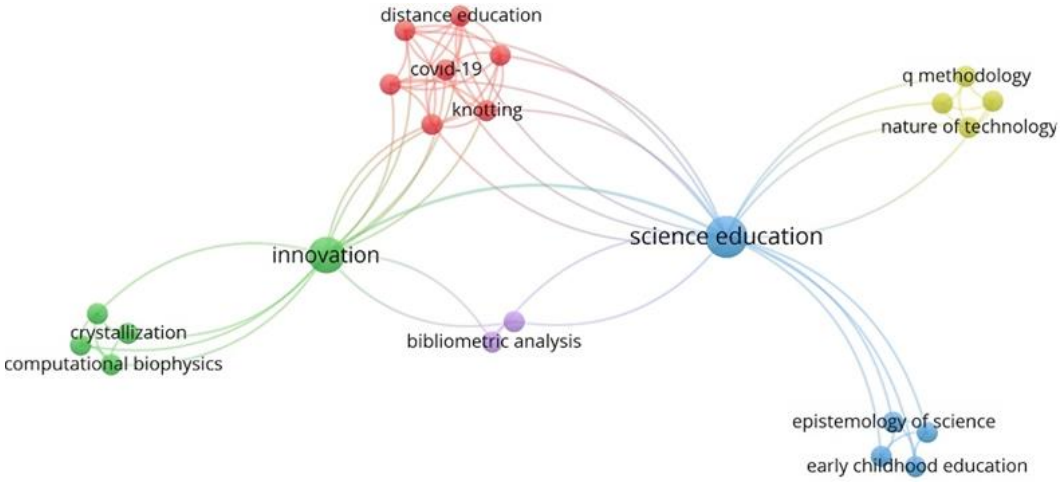

Figure 7. Collaboration networks between keywords (Source: Authors' own elaboration)

DISCUSSION

The results of the study, including the bibliometric analysis of innovations in science education, can be summarized, as follows. There has been a notable rise in the publication activity concerning online learning and online education since 2019, apparently because of pandemic (Zakaria et al., 2023). Secondly, specialized literature on information technologies in adapted education grew since 2003, with the topics of the articles changing accordingly, while they were published in discrete journals (Mentel et al., 2023). Thirdly, research on case studies in innovations in science education has grown enormously and continuously over the last five years, with three main research directions identified: STEM education at higher education institutions, STEM education that also includes arts and cognates and STEM education tasks at K-12 education (Phuong et al., 2023). Finally, through the analysis of articles of technology in science education using bibliometrics, researchers unleash vital information, which highlights the relationship between science education and technology according to Bozkurt and Ozturk (2022).

The bibliometric investigation of innovations in science education has said some primary sources. One of the most cited papers was the study by Diem and Wolter (2012). It was entitled "gender and education" and has been cited the most everywhere (Zakaria et al., 2023). A very popular article is the investigation by Maltese, published in 2019, which involved the highest local citation rate (Jarin et al., 2021). These articles offer priceless data about the subject of science education, and they have added knowledge on gender sensitive issues and regionally based education processes. Furthermore, besides the identification of International Journal of STEM Education and Journal of Science Education and Technology as among the most cited journals in this field, the analysis also highlighted according to Tas and Bolat (2022). These citations (Ertem & Aypay, 2023; Kadirhanogullari & Kose, 2023; Kundakci & Atay, 2023; Masalimova et al., 2023; Medias et al., 2023; Savas, 2022) are essential to both the researchers and the experts working in the field of science education and ensure that they utilize the insights as well as the findings of other experts when designing future research and implementing these practices.

Doing a bibliometric analysis of where articles related to science education innovations are published reveals that there are certain nations that stand out as they have the most prominent contributions to scientific discussions. The United States is characterized by its dominance in this area, accounting for the highest number of articles: 23. This creates the impression of the United States is the leading country in promoting science education (Dogan, 2023). Right behind, Spain contributed 16 articles, a figure that shows a very high participation among the Spain's researchers. Similarly, Germany, Australia and Taiwan have produced a significant amount of research articles with a count of eight, six and five, respectively. This study thus shows these countries as trendsetters and leading nations who try to break out of the traditional educational pattern in science teaching. The next remarkable fact is that the progress made by countries such as China, Hungary, Brazil, Canada, and Finland are worth acknowledging. These countries have produced excellent pieces of writing ranging from four to three articles, which is evident of their significant contributions to the debate on science education. The wide spectrum of articles provides evidence of a universal dedication and active participation of multiple players who are united by the one goal to improve and perfect innovative educational strategies in a science discipline on a global level (Baek & Doleck, 2020).

In short, using bibliometric analysis to map out the regions, where the total number of scientific innovation journal papers is studied, one steps into a kaleidoscope of countries all over the globe active and eager to boost education in science. The eminence of nations such as the United States and Spain gets to the foreground to mark the significance of these countries' respective

contributions to and leadership in championing the agenda of science education innovation.

Also, among the highly diverse important countries like Germany, Australia, Taiwan, China, Hungary, Brazil, Canada, and Finland contribute to the growth of world education system by sharing their innovative methods and unique approaches (Pham et al., 2023). Through the collaborative and inclusive practice of science education refinement on an international level this shared commitment to promoting excellence and innovation in the teaching and learning practices of everyone involved is made manifest, which creates an opportunity for all students' and teachers' worldwide to take ownership in the refinement of this approach we all share.

The bibliometric study on innovations in science education has identified an intricate arena of active authors who supply the field with the points raised up for discussion. From this list of authors, Fuzesi, Z., Imbernón, F., Kopjár, E., Lacueva, A., Llobera, R., Maróti, P., and Pintér, Z. B. appear to be the most dedicated ones as they each published two articles in our study (Ertem & Aypay, 2023). This shows that they possess steadfastness in addition to expertise in developing as well as distributing science education innovations. A subsequent assessment finds some of the writing styles adopt similar patterns, which may be due to the author's preference of researchers and communities or and may be the case of authors having specialized in particular psychotherapy domain. Along with this, authors like Acebal Expósito, M. D. C., Aksela, M., and Alcantara, L. C. are among the few authors contributing just a single article each, which helps in increasing the number of contributors and thus enriching the scope of perspectives within the domain. The work of this group of outstanding authors does not only get ideas exchanged and practices shared but also inspires a more creative and interdisciplinary teaching/learning approach in science education. The networks shown in **Figure 4** indicate the closely knit nature and the cooperative spirit among these authors, which is usually a driving force and a guiding principle for the development and improvement of science education.

Bibliometric analysis of innovations in science education literature constitutes a varied area of researchers and themes, which indicates a widespread interest in the phenomenon in the context of the interdisciplinary field of knowledge-building processes in science. Socio sciences become the leading discipline, with 68 of the analyzed articles revealing the relation to the problem of socio-cultural context of science education (Dogan, 2023). This, in turn, justifies, among other things, the adoption of new teaching methods that are more effective for educational development and benefit the improvement of the whole society. Technically, engineering is the second dominant field, and 24 works only prove the professional preference; obviously it is much more complicated topic than just a technical, it represents the technical aspects of the science education innovation. Besides that, it proved to be interesting that computer science (15 articles) and business, management, and accounting (10 articles) play their role as well, indicating that there was collaboration from other fields in the educational reform activities. This subject distribution area touches on the variety of the themes covered but also demonstrates that projects designed to introduce science innovations in education connect the multi-faceted nature of the world and landscape of knowledge (Smetana & Bell, 2012).

These results of the research of majority keywords in area of science education revolution explain extensive and intensive scope of investigations in domain science. Here is the evidence that underpins "science education:" it was mentioned 63 times, which shows the diversity and the general importance of 'scientific education' field by including different parts of teaching and learning procedures (Jia et al., 2024). Furthermore, the keyword of "innovation" occurs 31 times, which underlines the dynamicity in scientific pedagogies by placing the argument that scientists are constantly in process of finding new fronts. Secondly, the high recurrence of the phrase "bibliometric analysis" (17 times) clearly shows that the researchers working on these studies must be knowledgeable and experienced so that they can thoroughly and accurately examine scholarly output in connection with science education innovation. Given the remarks associated with words like "early childhood education" (which occur 13 times), early education's significant part in enlightening the scientific curiosity and mindset development of students has been recognized by the people. The clear hint given by modern scientists in the discussions of science education indicates that there is a need for innovation in instructional methodology such as those related to distance learning. These keywords together clearly illustrate that the science education research is a multifaceted and complicated one, where a bibliometric analysis still is an indispensable bridge to walk through complicated scholarly communications and to spot and compare the development priorities.

CONCLUSIONS & IMPLICATIONS

The research studies on science education innovations have established few significant ideas. Also, students' perceptions regarding innovativeness in science lessons is supposed to be examined as importantly the innovative persons are to be educated (Muradoglu et al., 2022). Additionally, the teaching-learning process underwent intensive progress with the advent of science and inventions, especially in the field of science education (Sofyan & Abdullah, 2022). Moreover, many teaching innovations and techniques,

including flipped classrooms and project-based leaning, have been employed in other countries by which good outcomes have reported with reference to students' engagement, learning, and critical thinking (Garner et al., 2017). Finally, it is through educational innovation that the educational system of our country can enhance the quality of education by adding active and experiential learning, authentic assessment, and high impact practices. Moreover, providing arts and social emotional learning materials together with science curriculum classes can help five-year-olds discover more the usefulness of science in our daily lives.

Although the topic of innovative science education has several conclusions and implications, the paper narrows down on the following findings and meaning to begin with, instead of the teaching methods that are commonly enacted as lecture presentation. Science subjects will be improved and retained in students' knowledge with innovation of LAP (Udu et al., 2022). Lastly, STEM education is experiencing a paradigm shift, as the path to learning, and teaching methods are changing by shift from a theory-based learning to a creative and innovative one (Sierra et al., 2022). Moreover, full potential comes through with open science and construction of educational frameworks addressing learning and growth barriers for a new generation (Avsec & Ferk Savec, 2021). Next to this, science and innovation have so large a sway on the teaching and learning processes and this influences greatly the logical reasoning, making decisions and facilitating whole-system teaching in various fields of learning (Franses & Wride, 2015). Last but not least, the education system should be orientated at the provision of a new type of thinking and acting of an individual, where the competencies of knowledge management and application of humanitarian knowledge are the main components.

Innovative science education can imply various outcomes. Primarily, innovative learning techniques, including learning activity package, are what strengthen the students' retention of their knowledge in science subject areas. In addition, the implementation of new teaching techniques aimed at government subjects will help students in senior secondary schools to achieve better results and a more comprehensive understanding. Firstly, this means an emphasis on creative thinking and students being allowed to imagine as well as the students being given power to be creative through the innovative science education initiatives. The system can therefore be more productive. Additionally, the support of creative behavior among pre-service science and technology teachers may link the gap between education system and economy hence, efficient flow of science and technology knowledge.

The inventive science education study has brought to light a set of research gaps. They included research gaps on individuals' (personal and cognitive factors), environmental aspects that influenced innovative behavior of science teachers too. The other research gap is examining the skill coverage of advanced knowledge within university courses as there is a higher proportion of courses taught by those who are actively researching the topic. At the same time, complication may be due to lack of knowledge about successful promotion of educational innovations in computer science education. Many works related to the topics are done without referral to the existing literature on the subject. For instance, as a supplement, studies are periodically needed to evaluate ongoing research and define climate change research gap purpose to achieve a sustained science planning and assessment. Later there will be a research gap in education, neuroscience, or science processes in particular in which the learning abilities and strategies of students studied through the use of neuroimaging tools will be understood.

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