Impact of COVID-19 on Science Teaching: A Bibliometric Analysis

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Abstract: This paper aims to examine the trends around research in science teaching following the outbreak of the COVID-19 pandemic. This event had a significant impact on education institutions, as it led to the shift to online learning that challenged educators in terms of planning, implementing, and dealing with issues such as the deteriorating mental and physical health of students. This is reflected in the trends of researchers. Contemporary trends around science teaching seem to focus on new teaching practices, modes, areas of investigation, and the impact of modern technology. However, there is limited bibliometric research examining the impact of COVID-19 on science teaching. Hence, 12,840 documents published from 2020 onwards were collected and analyzed from the Scopus platform. The analysis depicted a general interest of researchers around this topic. Findings regarding the focus and area of study, country, and the yearly rate of publication are aligned with those that focus on the individual impact of the COVID-19 pandemic on teaching and science education. This can give insights to the general trends regarding the future of science teaching.

Keywords: Bibliometrics, COVID-19, research trends, science education.

To cite this article: Karampelas, K (2024). Impact of COVID-19 on science teaching: a bibliometric analysis. European Journal of Mathematics and Science Education, 5(2), 67-79. https://doi.org/10.12973/ejmse.5.2.67

Introduction

The outbreak of the COVID-19 pandemic significantly impacted education and teaching institutions. Due to the lockdown and social distancing conditions, education was shifted to distance learning mode. New tools and practices of digital education were developed to help with this transition, and in a few cases, such as higher education and in-service training, these modes remained in use even after the end of the lockdown. This situation has shed light on several issues around dimensions of teaching. Teaching management and delivery, as well as student health and motivation, are a few of the dimensions that call for research and investigation as they are associated with the effectiveness of distance learning (Ratten, 2023).

Robinson et al. (2023) classified three different levels that describe the effects of distance learning on teachers during the COVID-19 pandemic. The first level indicates the teachers, who expressed that they feel stressed and anxious to effectively fulfill their duties as teachers while dealing with the health risk of contracting the virus. The second level indicates the classroom context, as the relationship between teachers and students was overshadowed by uncertainty and the challenges of managing resources and access to digital tools. Teachers showed concern regarding students who did not possess sufficient resources to attend online classes, as well as those students who were already facing issues with academic performance or problems in their family environment. The last level indicates school leadership. Teachers felt that school leadership and authorities had rather high demands, stemming from a combination of the already existent expectation for learning outcomes and the new strict focus on students’ health and safety. All of these interrelated levels justify the conclusion that distance learning was associated with greater reforms in the field of teaching and could not be considered simply as a matter of implementing a new tool or practice.

Reshi et al. (2023) stressed the importance of identifying the appropriate pedagogies and teaching approaches that will help learners acquire knowledge with the help of online learning or through a combined face-to-face and online teaching method, which is commonly employed following the lockdown. Such an approach should be selected by identifying various points such as the model of teaching, curriculum, planning, student motivation, and assessment. This, in turn,
includes the use of digital tools that can provide the necessary professional development for teachers. Certainly, any approach selected and applied in the educational arena should be student-centered. Students face issues that have to be considered. The authors also point out that online learning and isolation have caused several health problems to students, particularly mental health issues. Moreover, access to online learning tools was not always easy for learners of lower socioeconomic backgrounds. This led to inequalities in several cases.

Similarly, Sidi et al. (2023) concluded that teachers had both positive and negative experiences in terms of online teaching during the COVID-19 pandemic. These experiences are dependent on certain factors. The first is the teachers’ competency and ability to use online modes of learning, which is relevant to their training and professional development. The second includes the peer and technical support they received from their school in relation to the general, specified conditions. Hence, it may be said that these factors are imperative to consider in case a reform is implemented in schools. Similarly, the authors concluded that students had both negative and positive experiences. On the one hand, there was more familiarization with digital technologies. On the other hand, there was perhaps exposure of their personal lives, as they were being taught and observed in their home environment.

Specifically, in science teaching, several studies have pointed out that COVID-19 outbreak and the transition to online teaching has triggered discussion and debate regarding certain aspects of science teaching. More specifically, it is thought that there should be more emphasis on aspects such as critical thinking, scientific discourse, philosophy of science and the interrelation between science, technology and society. Science teaching should also pay attention to environmental and health issues. This way, learners will become more qualified in future to deal with similar outbreaks, in combination with challenges such as misinformation and education barriers (Bergman, 2022; Dillon & Avraamidou, 2020; Macias et al., 2022; O’Brien, 2021; Rogayan & Dantic, 2021). Moreover, when it comes to learners Mahdiannur et al. (2024), concluded that learners might feel that online learning helped them adapt to new flexible learning modes, with online resources and investigation. However, there was lack of the desired interaction with educators and participation in actual science experiments and hands-on activities, which did not assist the development of critical thinking.

Generally, there has been interest on behalf of education researchers around the impact of COVID-19 on teaching for both educators and learners (Reshi et al., 2023; Robinson et al., 2023; Sidi et al., 2023). There has been research specifically on the impact on science teaching as well (Mahdiannur et al., 2024; O’Brien, 2021; Rogayan & Dantic, 2021). A bibliometric study would enhance these research studies. That’s because it could clarify and give insights on research trends around this topic. This is the scope of this research. This requires thorough reviews of literature around the main themes of this topic along with relevant previous research (Donthu et al., 2021; Lim & Kumar, 2024).

Literature Review

Science Teaching

The fundamental theories on science teaching emphasize the development of scientific literacy, which is considered to be the fundamental goal of science education. Several attempts have been made to define this concept. According to a definition presented by the Organisation for Economic Co-operation and Development or OECD, (2003, p. 127), “Scientific literacy is the capacity to use scientific knowledge, to identify questions and to draw evidence-based conclusions in order to understand and help make decisions about the natural world and the changes made to it, through human activity.” This definition is continuously updated due to the changes and reforms at the social level. In general, scientific literacy is composed of three different dimensions. The first refers to scientific knowledge and concepts that learners are required to master and apply whenever necessary. The second refers to scientific processes through which this knowledge is applied. The third refers to contexts, situations, and cases of science-based problems and challenges, where the knowledge and processes are implemented (Laugksch, 2000; OECD, 2003, 2019). The topics included in science sessions and curricula include states of matter, plants, animals, ecology and ecosystems, photosynthesis, mechanics and forces, energy and heat, electromagnetism, light and sound, astronomy, human anatomy, and health and hygiene (OECD, 2003).

The most appropriate contemporary teaching approach to scientific literacy is inquiry-based learning, which is a student-centered approach that depicts several advantages. This approach enables learners to acquire a better understanding of the inquisitive way in which scientists work. It is known that knowledge gain does not occur through a single delivery by the teachers. Instead, learners engage in an inquiry process, which includes problem-solving strategies. The learners are faced with a situation in a certain context and topic that relates to science, for which they recognize the problem and form a research question. Subsequently, they hypothesize and investigate data after data collection, experimentation, discourse, communication, explanation of answers, and discourse. In this manner, learners acquire a deeper understanding of the nature of science. Inquiry-based learning, therefore, includes all dimensions of scientific literacy required by teaching, as it involves learning knowledge by implementing specific scientific processes to provide answers in relevant contexts (Bergman, 2022; Dillon & Avraamidou, 2020; Macias et al., 2022; National Research Council [NRC], 2000; OECD, 2003, 2019).

Technological development has had a significant impact on education, and the field of science education is not an exception. There are various ways through which information and communication technologies with digital tools can help in learning science. Websites prove to be a viable resource, and spreadsheets help in data collection and analysis.
The use of simulations helps in proving hypotheses and experimentation. Furthermore, several other applications assist in documentation, building models, visualization, justification, and discourse. It is evident that science teaching is increasingly being linked to the development of appropriate and useful digital skills (NRC, 2012). Within this tendency, the field of Science Technology Engineering Arts and Mathematics, or STEAM, education has become wider as a cross-curricular subject, since it combines science, technology, engineering, arts, and mathematics. This innovative field is associated with problem-solving activities through an inquiry-based approach (Allina, 2018; Quigley & Herro, 2016).

**Bibliometric Analysis Around the Impact of COVID-19 on Teaching**

The impact of COVID-19 on teaching has attracted the interest of bibliometricians. In the first year of the outbreak, Rodrigues et al. (2020) examined the disruption caused in educational institutions and found 93 articles related to the topic. Their analysis showed that the topics that concern the researchers can be classified into three clusters. The first relates to online learning that was imposed due to the COVID-19 pandemic, in relation to tools, resources, and educational outcomes. The second addressed managerial issues and appropriate teacher training. Finally, the third demonstrated the manner in which the pandemic impacted health, education, and other aspects of people's daily lives.

Ekin (2022) aimed to identify research trends around the results of the COVID-19 pandemic in education research. The author employed the Scopus database and collected 3039 articles that were published between January 2020 and May 2021. Most articles originated from the USA, the United Kingdom, China, Australia, Canada, Ireland, Italy, New Zealand, and Germany. The main topics that concerned the researchers included health issues, such as COVID-19 and the pandemic. Moreover, researchers were also interested in the students and the learning and teaching processes since they focused on topics such as e-learning and distance education.

Cretu and Ho (2023) carried out an overview of education research papers with respect to COVID-19. Through the Web of Science, the authors collected 2612 articles published during the years 2020 and 2021. Most of the papers included articles published in journals that are focused on research around education, science education, medical education, and computer education. The countries with the largest number of contributions included the USA, the United Kingdom, China, Australia, Canada, Germany, Spain, and Italy. The main topics of the articles, as revealed by the keywords, were related to teaching management, curriculum, assessment online teaching, especially in higher education, and the mental health of students.

Su et al. (2022) assessed the trends regarding the effects of the COVID-19 pandemic on early childhood education. The authors collected 507 articles from Scopus that were published between 2020 and 2022. The countries with the largest number of publications, as well as the ones that are the most cited, included the USA, China, Canada, Germany, Australia, and the United Kingdom. The majority of publications originated mainly from the areas of education, health, and medicine, with frequent contributions from areas such as environmental science, psychology, and social sciences. The keyword analysis demonstrated that researchers focused mainly on topics such as health, the pandemic, students, and education functions.

Lastly, Al Husaeni et al. (2023) conducted a bibliometric study on research trends in the field of education from 2017 until 2021. Although their study was not restricted to the period of the COVID-19 outbreak, the global pandemic proved to be a challenge in their analysis. With the help of a reference manager, the authors collected 993 documents. They found the rate of publications to rise over the years, and the most important topics examined in these publications were studies, student performance, higher education, effects and impact, practices, learning, professional development, teaching approaches, and quality of education. The topics of COVID, the pandemic, health, and online and distance education were also observed to occur in these studies.

In summary, bibliometric studies reveal that there is interest in the impact of COVID-19 on teaching as the number of publications that examine this issue is currently on the rise. From the analysis of keywords and citations, these studies depicted that there was an emphasis on certain topics, such as students. The studies have focused on examining students' mental health, performance, and the effects of online teaching and lockdown. A few studies also emphasized investigating COVID-19 through the prism of social side effects, the phenomenon of the pandemic, and the general health crisis (Al Husaeni et al., 2023; Cretu & Ho, 2023; Ekin, 2022). Another topic included teaching management and implementation, which involved examining the appropriate tools, professional development, curriculum, pedagogies, practices, and approaches (Al Husaeni et al., 2023; Cretu & Ho, 2023; Rodrigues et al., 2020). Furthermore, technology and the internet were also studied, specifically in terms of new modes of education such as e-learning, online learning, and its technical aspects (Cretu & Ho, 2023; Ekin, 2022; Rodrigues et al., 2020). The countries with the most contributions included the USA, China, Germany, Spain, Australia, and the United Kingdom. The researchers of these articles originated from various locations, and articles were published in journals that address issues in education, social sciences, sciences, computer science, engineering, environmental studies, health sciences, and psychology (Al Husaeni et al., 2023; Cretu & Ho, 2023; Ekin, 2022; Rodrigues et al., 2020; Su et al., 2022).
Bibliometric Analysis of Science Teaching

Bibliometric research has been conducted around science teaching in recent years. Wirzal et al. (2022) conducted an analysis of publications on scientific literacy between 2018 and 2022. In their search query in the Scopus database, the authors focused on articles that contained the terms 'scientific literacy' or 'science teaching' that were published during the specified period. The database provided them with 451 documents, which were published in journals of science education, education studies, or sustainability. As revealed from the publication rates and citation analysis, scientific literacy proved to be an imperative topic for the researchers. Most of the publications originated from universities in English-speaking countries, such as the USA, Australia, the United Kingdom, and Canada. However, non-English-speaking countries also contributed to research on these topics, including Spain, Germany, Indonesia, China, Turkey, and Taiwan. The keyword analysis demonstrated that the topics that interested the researchers usually involved the concept of scientific literacy, teacher education, learning efficacy, and the nature of science.

Wang et al. (2023) performed bibliometric research on the development of science education publications from 2001 to 2020. Their search found 6278 articles from 2321 institutions from 104 countries. The publication numbers and citations reveal a growing interest in science teaching. Most of the institutions that contributed to the research were universities. The majority of articles originated from English-speaking countries, such as the USA, England, Australia, and Canada. However, other countries, such as Turkey, Taiwan, Germany, Sweden, China, Israel, and the Netherlands, also contributed to the literature on these topics. The articles from these countries also received the most citations. The authors classified the keywords into seven clusters. The first was related to misconceptions, conceptual change, and the appropriate models. The second cluster addressed gender, motivation, and achievement in STEAM teaching. The third was about socio-scientific issues, such as the concept of science literacy, argumentation, and the nature of science. The fourth cluster showed professional development and teacher education. The fifth cluster was about learning, inquiry-based approaches, and discovery learning, and the sixth showed keywords about evolution in science. Finally, the seventh cluster demonstrated keywords related to peer review, activity, and social action in science teaching.

Abdullah (2022) examined the publication trends in biology education for a period of 63 years with the help of bibliometrics. The search was executed in the Scopus database and returned 1028 publications from 1957 to 2020. The number of publications demonstrated a rising pace, which accelerated significantly during the decade of 2000. Most publications emerged from journals that focused specifically on science or biology education, although articles were also present from journals on other areas of education studies, engineering, or social sciences. The most pertinent areas included social sciences, biological sciences, physics and astronomy, computers and engineering, and education and health sciences. The analysis of keywords revealed that the focus of researchers was on teaching factors, efficient learning, and curriculum. However, it has been shown that biology is treated as a cross-disciplinary area, which can be combined with the nature of science, environment, and evolution. The most influential countries in their study were the USA, Indonesia, Germany, Turkey, the United Kingdom, Australia, the Netherlands, Canada, Israel, and Brazil.

There have been a number of bibliometric studies around specific aspects of science teaching. Pratiwi et al. (2022) investigated trends around discovery learning in science teaching from the period of 1976 to 2022. Fifty-six articles were collected and analyzed in their study. These articles were published in journals oriented toward education studies, social sciences, computer sciences, and sciences. The countries with the most contributions included the USA, Indonesia, Spain, Germany, Malaysia, Australia, Greece, India, Japan, and Oman. In regard to the topics and keywords, five clusters were classified. The first addressed discovery learning and its features, whereas the second was related to the public understanding of science and discovery learning. The third cluster showed learning systems, such as e-learning, critical thinking, and learning models. The fourth cluster emphasized high school chemistry, while the last cluster showed a constructivist approach.

Al Husaeni and Munir (2023) completed a bibliometric mapping analysis around the philosophy of science and technology education between the years 2018 and 2022. Through a search in the Scopus database, the authors collected 184 articles. The main finding of the study demonstrated that some researchers investigate the relationship between the philosophy of science and science teaching, whereas others examine the relationship between the philosophy of science and technology teaching.

Maryanti et al. (2022) published a bibliometric analysis around sustainable development goals in science teaching. The research was done on the Scopus platform for the period 2012 to 2022. The findings depicted an increase in the publications, which summed up to 752 articles. The topics of the publications, as reflected by the keywords, addressed issues in education, environment, social issues, and technology.

In short, bibliometric studies in terms of science teaching and science education have demonstrated concern of researchers, as over the last few decades, the number of publications addressing these topics is generally rising. Moreover, the publications appear to acquire a sufficient number of citations (Abdullah, 2022; Wang et al., 2023; Wirzal et al., 2022). The researchers of these studies belong to various fields, such as education sciences, social sciences, engineering, computer sciences, and sciences. Occasionally, a few articles also belong to the areas of environmental or health sciences (Abdullah, 2022; Pratiwi et al., 2022; Wirzal et al., 2022). The countries with the greatest contributions are the USA, Taiwan, Germany, Turkey, Indonesia, Japan, the United Kingdom, and Australia (Abdullah, 2022; Pratiwi et
The keywords of the publications led to the conclusion that various topics have gained the interest of authors, such as the topic of science teaching in relation to the appropriate practices and models (Abdullah, 2022; Maryanti et al., 2022; Wang et al., 2023), and science teaching, such as the nature, or the philosophy, of science (Al Husaeni & Munir, 2023; Wirzal et al., 2022). In addition, the topic of teacher education and professional development has also been discussed (Wang et al., 2023; Wirzal et al., 2022). Lastly, technology in science teaching has also garnered attention (Abdullah, 2022; Al Husaeni & Munir, 2023; Maryanti et al., 2022; Pratiwi et al., 2022).

**Literature review summary**

In short, science teaching focuses on the development of scientific literacy. This complex concept has to do with the ability to implement scientific knowledge and processes in contexts and challenges in order to understand, explain and make decisions whenever this is required (Laugksch, 2000; OECD, 2003, 2019). Contemporary literature emphasizes the importance of promoting scientific literacy through inquiry-based pedagogies, which helps learners construct knowledge by actively engaging in actual activities based on real-life situations. This way, they can appreciate knowledge, skills and attitudes developed much better than just passively memorizing scientific information send by the teacher (NRC, 2000; OECD, 2003, 2019). Additionally, the role of technology is considered important in the delivery of science knowledge (NRC, 2012). This is associated with the development of STEAM as a new interdisciplinary approach to science teaching (Allina, 2018; Quigley & Herro, 2016). Science teaching is thought to be influenced by the COVID-19 pandemic (Mahdiannur et al., 2024; O’Brien, 2021; Rogayan & D antic, 2021).

Bibliometricians have tried to shed light on the trends regarding research around the effects of COVID-19 in teaching. There were studies around the impact on students’ health, motivation, performance and adaptability to online teaching and new modes of learning (Al Husaeni et al., 2023; Cretu & Ho, 2023; Ekin, 2022). Apart from that, there were studies around dimensions of teaching, such as strategies, pedagogies, teaching materials, curricula, professional development, management and implementation (Al Husaeni et al., 2023; Cretu & Ho, 2023; Rodrigues et al., 2020). There were also studies around the role of technologies specifically with regards to teaching (Cretu & Ho, 2023; Ekin, 2022; Rodrigues et al., 2020).

Science teaching has also grabbed the attention of bibliometricians. It has been concluded that researchers have investigated the relationship between science teaching and other fields of study, such as social sciences, information and communication technologies (ICT), environmental science as well as health (Abdullah, 2022; Pratiwi et al., 2022; Wirzal et al., 2022).

**Methodology**

The recent bibliometric studies that have focused individually on the impact of COVID-19 on education and science teaching appear to have several commonalities. First, in both topics, researchers pay attention to the teaching factor and the conditions that can help in effective teaching and learning outcomes. This may relate to teaching approaches, tools, curricula, and professional development (Al Husaeni et al., 2023; Cretu & Ho, 2023; Rodrigues et al., 2020). These features, specifically in science, may focus on models such as inquiry-based teaching (Abdullah, 2022; Maryanti et al., 2022; Wang et al., 2023; Wirzal et al., 2022).

Second, in both topics, researchers focus on technology and the internet. This may be related to the implementation of new learning institutions, such as online learning, and its requirements (Cretu & Ho, 2023; Ekin, 2022; Rodrigues et al., 2020). Specifically, in science, it may include a general approach to how technology can assist learning, or the focus on STEAM and other innovative cross-disciplinary subjects (Abdullah, 2022; Al Husaeni & Munir, 2023; Maryanti et al., 2022; Pratiwi et al., 2022; Wang et al., 2023).

Third, the countries with the greatest contributions in terms of the number of articles and cited articles were approximately the same, including the USA, China, Spain, Germany, Australia, and the United Kingdom. Fourth, the research interests and fields of the researchers were similar and varied, respectively, such as education, computer science, social science, sciences, and engineering, both in terms of the impact of COVID-19 (Al Husaeni et al., 2023; Cretu & Ho, 2023; Ekin, 2022; Rodrigues et al., 2020; Su et al., 2022), as well as science teaching (Abdullah, 2022; Maryanti et al., 2022; Wang et al., 2023).

The common points of the two topics can lead to the hypothesis that the COVID-19 pandemic may have influenced research trends, specifically in science teaching, in terms of teaching, students, and technologies. However, there seems to be limited bibliometric research examining the impact of the COVID-19 pandemic, specifically on the trends in science teaching. This study aims to address this research gap. Therefore, a search was performed on Scopus, which is a frequently used platform for bibliometric research. The search is highly dependent on employing the appropriate terms to form a relevant search string. A carefully designed string can lead to accurate, credible, and valid outcomes (Donthu et al., 2021; Lim & Kumar, 2024).

For the specific search query, the terms were selected based on literature on the impact of COVID-19 and science teaching. The search was expanded in all parameters, including abstracts, titles, authors, and keywords. This search was restricted
to the period during or after the pandemic, i.e., the years 2020 to 2023. Therefore, the search string was formed as follows:

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\text{ALL (science AND teaching, OR science AND education, OR science AND literacy, OR scientific AND literacy, OR physics AND teaching, OR physics AND education, OR chemistry AND teaching, OR chemistry AND education, OR biology AND teaching, OR biology AND education, OR elementary AND science AND teaching, OR elementary AND science AND education) AND ALL (covid19, OR coronavirus, OR pandemic, OR lockdown, OR quarantine) AND PUBYEAR > 2019 AND PUBYEAR < 2025).}
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The specific string generated 12,840 results. The analysis of research trends with the help of these documents can be achieved through certain parameters. The first parameter is the number of publications and citations. A growing number of publications revealed an increasing interest of the researchers. The second parameter included the areas of study, which were revealed by considering the resources and the journals where the collected research documents were submitted and published. The third includes the themes, in other words the issues that concern the researchers, which were assessed through an analysis of the keywords. Finally, the fourth included the identification of countries and affiliations with the greatest contributions to literature. These parameters, altogether, helped in providing a clear picture of the research trends. Each of them can be converted into a research question (Donthu et al., 2021). Considering the above discussion, the research questions were formulated as follows:

1. What was the combined publication output of the impact of the COVID-19 pandemic on teaching, particularly science teaching, from 2020 onwards?
2. What areas of study tend to combine these two concepts in their research?
3. What are the common themes between the two concepts?
4. Where do most of these publications originate?

The common points between trends on the impact of COVID-19 in teaching and trends in science teaching proved to be a hypothesis of potential responses to the research questions. All data were collected and analyzed with the help of Scopus and Microsoft Excel. In certain cases, data were displayed with the help of Scopus and VOS viewer. Scopus can help gathering and analyzing number of publications per year, area of study, country and affiliation. VOS viewer, can help visualization of keywords, based on their frequency. It can also help the development of keyword clusters, based on the frequency of co-occurrence, which shows how keywords and themes develop over time. This analysis is usually done in bibliometric studies (Donthu et al., 2021; Lim & Kumar, 2024).

Findings/Results

In general, the findings of this study demonstrated an apparent impact of COVID-19 on publication trends in the context of science teaching.

In what concerns the first research question, figure 1 shows that the publication rate is high and maintains an upward trend. The initial number of 590 publications in the year 2020 increased by almost five times in 2021 at 2951 publications, which further significantly increased to 5241 publications in 2022. This trend is likely to keep rising, as within the first eight months of 2023, 3860 studies have already been published. Therefore, it can be concluded that the rate of publications per year is considerable.
As seen in Figure 2, the majority of these publications include articles in research journals and comprise more than 70 percent of the total number of publications. The rest of the publications include a non-negligible number of conference papers, book chapters, reviews, and books.

In what concerns the second research question, Figure 3 shows that the articles focusing on the effects of COVID-19 on science teaching emerge from various fields of study. One-third of the total articles have been published in the area of social sciences, particularly education, schooling, training, and teaching. A smaller yet significant part of the publications originated from researchers who work in the area of computer science. This accounts for approximately one-sixth of the total number of publications. The contributions from the areas of social sciences and computer science combined comprise almost half of the total number of publications. In addition, a considerable number of articles were submitted by researchers in health professions, including medicine and psychology, arts and humanities, mathematics, engineering, environmental science and sustainability, and energy.

The rising tendency specified in the question around the publication output appears to be apparent in all areas of study or publication resources, as seen in Figure 4. In other words, the number of documents addressing the impact of COVID-
19 on science teaching is increasing regardless of the background of the researchers. This is apparent in journals with a high number of contributions, especially those that focus on the fields of education, technology, sustainability, and health studies.

In what concerns the third research question, the themes that emerged from the analysis of keywords can be classified into five clusters presented in Figure 5. In the first cluster, the most common keywords appear to be associated with the study contexts and education conditions. Such keywords include students, pedagogy, learning systems, artificial intelligence, inquiry, inquiry-based teaching, higher education, distance learning, online teaching, and learning systems.

In the second cluster, the most frequent keywords are associated with healthcare and clinical issues. These keywords are mental health, pandemic, depression, clinical studies, prevention and control, psychology, epidemiology, anxiety, mental stress, quality of life, SARS-CoV-2 vaccine, health behavior, attitude to health, and communicable disease control. In the third cluster, the most frequent keywords seem to be associated with medical education, including health care literacy, health promotion, health education, health care policy, health care access, health care delivery, tertiary education,
nursing, nursing education, medical education, medical learning environment, telehealth, tele-education, human experiment, and clinical practice. In the fourth cluster, the most frequent keywords are associated with teaching. Such keywords include teachers, academic achievement, preschool child, primary school, activity, parents, reading, literacy, competence, and literacy. Finally, in the fifth cluster, the most frequent keywords were associated with technologically oriented modes of teaching, such as distance education, STEAM, and computer-assisted instruction.

Finaly, in what concerns the fourth research question, in regard to the countries with the greatest number of contributions, Figure 6 shows a clear dominance of the United States with 2751 publications. The documents published in the US are twice in number than the documents published in Indonesia (1302), accounting for approximately one-fifth of the total number of articles. Other countries with a considerable number of contributions of approximately 400 and more include the United Kingdom, Australia, Canada, China, Spain, Malaysia, Germany, and India.

The affiliations with the greatest number of contributions, as shown in Figure 7, include Indonesian universities, which confirms the considerable number of publications from this country. Moreover, top affiliations include universities from Australia, the United Kingdom, China, and Hong Kong.
Discussion

Regarding the topic of the study, which was to point out the research trends regarding the impact of COVID-19 on science teaching, the findings have illustrated that there is a growing interest of researchers who wish to identify the outcomes of the COVID-19 pandemic in the context of science teaching. The influence of the COVID-19 pandemic on science teaching, which was approached by researchers (Mahdiannur et al., 2024; O’Brien, 2021; Rogayan & Dantic, 2021), is proved through bibliometric research. Therefore, the initial hypothesis is justified (Donthu et al., 2021; Lim & Kumar, 2024).

Presumably, researchers believe that the pandemic led to changes and development in the area of science teaching (Al Husaeni et al., 2023; Cretu & Ho, 2023; Rodrigues et al., 2020). This is in line with the theoretical perspective, wherein it is considered that the context within which science teaching takes place is significant, and if affected, it can impact the teaching of science along with its delivery and learning outcomes (NRC, 2000; OECD, 2003, 2019).

The trends shown in these findings reveal that there is a general interest in the results of COVID-19 and the quarantine on science education and teaching. The fields of study of researchers have been found to be similar to those investigating science teaching (Abdullah, 2022; Pratiwi et al., 2022; Wirzal et al., 2022) as well as post-COVID-19 teaching (Al Husaeni et al., 2023; Cretu & Ho, 2023; Ekin, 2022; Rodrigues et al., 2020; Su et al., 2022). An interest in the teaching and learning factor is evident (Al Husaeni et al., 2023; Cretu & Ho, 2023; Rodrigues et al., 2020). The significant percentage of contributions from computer science researchers can be explained by the use of ICT and online learning during the pandemic and its aftermath (Al Husaeni et al., 2023; Cretu & Ho, 2023; Rodrigues et al., 2020).

The findings may relate to the general influence of the social context in science teaching. Any effort to implement appropriate pedagogies in teaching is related to the conditions under which the schools operate, as well as the challenges of everyday life faced by members of the education community (Laugksch, 2000; OECD, 2003, 2019). Another issue is the influence or association of technological development in science teaching. The general social circumstances, in relation to the tendencies in education and pedagogy, might call for the development of appropriate skills for the learners, including digital skills. In short, the interest of social scientists and computer scientists in the topic may be explained by the fact that schools, in light of the pandemic, were required to implement varying pedagogies, relying on e-learning, distance education, and appropriate preparation of teachers and learners, particularly in science teaching (Laugksch, 2000; NRC, 2012).

The major themes are students, health care, health education, teaching, and technologically assisted education. The emphasis on the first and fourth clusters can be associated with the tendency in science teaching to emphasize the student, the learner, and the student-centered approaches, such as inquiry-based teaching (NRC, 2000; OECD, 2003, 2019), which frequently emerged as a keyword. Presumably, in light of new modes of learning, this approach was considered to be compatible and appropriate. Therefore, educators and researchers decided to further promote and adopt this approach through new means, such as distance education. This might be related to the general finding around bibliometric trends in science teaching, which points out that there is a continuous effort to point out the most suitable model of learning and teaching, bearing in mind the social context and general development (Abdullah, 2022; Maryanti et al., 2022; Wang et al., 2023). The emphasis on the second cluster can be associated with the tendency of researchers in science teaching to focus on topics related to health issues (Abdullah, 2022; Pratiwi et al., 2022; Wirzal et al., 2022). This was further stimulated by the spread of COVID-19 and its impact on the general social context, which impacted education patterns (Ratten, 2023). Hence, it is justified that science teaching practitioners and researchers tend to base their teaching on challenges and problems that are derived from everyday life (Laugksch, 2000; OECD, 2003, 2019).
Finally, the emphasis on the fifth cluster can be associated with the general tendency to examine the influence of technological developments in science teaching (Abdullah, 2022; Al Husaeni & Munir, 2023; Maryanti et al., 2022; Pratiwi et al., 2022). Finally, the education of STEAM, which emerged as a keyword, is a crucial point in contemporary science teaching theory (Allina, 2018; Quigley & Herro, 2016).

The findings concerning the countries of most publications, are relatively compatible with the contemporary publication trends around post-COVID-19 teaching (Al Husaeni et al., 2023; Cretu & Ho, 2023; Ekin, 2022; Rodrigues et al., 2020; Su et al., 2022) and science teaching (Abdullah, 2022; Pratiwi et al., 2022; Wang et al., 2023; Wirzal et al., 2022).

Lastly, the findings concerning affiliations confirm that universities are the most apparent sources of publications, especially in regard to research trends around science teaching. However, the contributions of different countries can be attributed to probable frequent cooperation between countries and institutions (Wang et al., 2023; Wirzal et al., 2022).

Conclusions

The aim of this study was to examine the way research trends around science teaching changed after the COVID-19 outbreak through bibliometric research. There is little bibliometric research that specifically examines the influence of the COVID-19 pandemic on science teaching. This research gap became the rationale of this bibliometric study. It was assumed that the trends indicated by such a study would be similar to the common trends of these two topics. With this hypothesis in mind, a bibliometric study was carried out through the Scopus platform, which is commonly used for relevant bibliometric research studies (Donthu et al., 2021; Lim & Kumar, 2024). The search aimed to gather all published documents that involved research on science teaching and COVID-19. A total number of 12,840 documents published between 2020 and 2023 were collected and analyzed.

The analysis of the findings demonstrated that the hypothesis was justified. It was found that a large number of publications examined the influence of the COVID-19 pandemic on science teaching. The output of publications is increasing annually. This finding can be attributed to an interest of researchers around this topic, as the pandemic has influenced the social context within which science teaching takes place. This context has been widely studied by researchers (Al Husaeni et al., 2023; Bergman, 2022; Cretu & Ho, 2023; Dillon & Avraamidou, 2020; Macias et al., 2022; NRC, 2000; OECD, 2003, 2019; Rodrigues et al., 2020).

The researchers belonged to various fields of study, with a majority working in the field of social sciences. Other researchers worked in fields of computing, engineering, mathematics, sciences, arts, environmental and health studies. This finding helps us conclude that the impact of COVID-19 on science teaching is a complex topic and can be approached through various fields and perspectives (Donthu et al., 2021; Lim & Kumar, 2024). This is because the topic has several dimensions, such as educational, technical, social, or those related to the health, safety, and well-being of members of the educational community (Al Husaeni et al., 2023; Cretu & Ho, 2023; Rodrigues et al., 2020).

The themes emerging from the articles varied. It was found that researchers focus on the learning and teaching process, health issues and well-being, and medical education, as well as the influence of technological progress and development, indicating appropriate teaching paradigms (Abdullah, 2022; Maryanti et al., 2022; Wang et al., 2023). Moreover, health matters, either as a body of knowledge or issues with respect to the pandemic conditions and safety, were also under heavy consideration (Abdullah, 2022; Pratiwi et al., 2022; Wirzal et al., 2022). Furthermore, researchers were also keen to assess the influence of the internet as well as information and communication technologies for teaching (Abdullah, 2022; Al Husaeni & Munir, 2023; Maryanti et al., 2022; Pratiwi et al., 2022). These trends can be associated with the available contemporary literature around science teaching (NRC, 2000; OECD, 2003, 2019).

The countries with the most contributions to the literature include the USA, Indonesia, China, United Kingdom, Spain, Australia, Malaysia, Germany, Canada and India. There appears to be a strong cooperation between institutions from various countries around teaching after the COVID-19 pandemic, which proves its significance for the researchers (Donthu et al., 2021; Lim & Kumar, 2024).

Recommendations

In the future, more similar bibliometric research should be conducted to describe the long-lasting effects of COVID-19 on the teaching of science. This can be done by specializing in certain dimensions of science teaching. For example, there may be research on the impact of COVID-19 specifically on the content of science teaching or its’ impact on technological development. Furthermore, researchers may benefit from studies investigating the impact of COVID-19 in science teaching compared to the impact on the teaching of other subjects such as mathematics, too. Moreover, bibliometric analysis can focus on other factors, such as co-authorship (Donthu et al., 2021). Aside from that, it might be useful to approach this topic with other research methods, such as interviews with researchers or teachers who focus on delivery of science subjects. After all, interviews of researchers and teachers have been used in investigating the general impact of COVID-19 on education (Reshi et al., 2023; Robinson et al., 2023; Sidi et al., 2023).
Limitations
This research has limitations as it made use of only one search engine and considered a period of only three years following the COVID-19 outbreak.

Ethics Statement
No human beings or animals were involved as subjects in the research. The resources came from journal articles, collected via platforms.

Acknowledgments
At this stage, I would like to thank the Faculty of Humanities at the University of the Aegean for their support.

Conflict of Interest
The researcher(s) declare no conflicts of interest in this study.

Funding
No funding was received for this research.

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