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Research Article

# Bibliometric Analysis of STEM Education Integration in Physical Sciences: Global Trends and Future Directions

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**Abstract.** Based on a corpus of 127 scientific papers indexed in the Scopus database between 2020 and 2024, this article gives a focused bibliometric analysis on the incorporation of the STEM method in physical science education. The major goal is to present a thorough and organized summary of the scientific development in this area, which is still understudied despite its strategic significance in modern educational systems. Using a strict quantitative approach based on the PRISMA protocol, this

study finds the most important publications, the most prestigious journals, the top authors and organizations, and the most popular keywords. According to the data, scientific production has significantly increased since 2023, with contributions from nations like the US, Turkey, and Mexico accounting for a large portion of this growth. The social sciences, engineering, and educational technology make up the majority of the disciplines concerned. This study's unique emphasis on the physical sciences a field that is frequently underrepresented in more general STEM analyses adds value. It improves comprehension of research dynamics, reveals unexplored regions, and suggests strategic directions for future research, teacher preparation, and the creation of evidence-based educational policy by offering an accurate and current mapping of the domain.

**Keywords**: STEM education, Physical sciences, Teaching in the 21st century, Bibliometric analysis

## INTRODUCTION

STEM education (science, technology, engineering, and mathematics), a crucial element of contemporary educational systems, addresses the urgent need for transdisciplinary learning to prepare students for the challenges of the twenty-first century **[1].** By bridging theoretical understanding with practical applications, STEM education equips students to navigate a technologically advanced global culture. Its foundation lies in promoting problem-solving, collaboration, and critical thinking. Over the past four years, researchers have increasingly focused on integrating STEM concepts into the teaching of physical sciences due to their essential importance in fostering the development of technical and analytical skills **[2].**

Global interest in incorporating the STEM paradigm into science education has significantly increased in recent years, especially after the COVID-19 epidemic. New pedagogical approaches, digital education, and the need for education to be more grounded in real-world situations are all strongly related to this evolution **[3, 4].** However, most existing
studies adopt a general view of STEM education, without specifically addressing the unique features of **physical sciences**, which require tailored didactic, epistemological, and instrumental considerations.

By providing a bibliometric analysis of STEM education's integration into the physical sciences and combining information from 127 peer-reviewed publications published between 2020 and 2024, this study seeks to close these gaps. Building on approaches like those used by Majd El Meraoui et al. (2024) **[5]**, who proposed a plan to design a training framework based on the STEM approach, aimed at helping learners overcome difficulties and obstacles in physical sciences. This study finds worldwide patterns, identifies key figures, and investigates new topics in the field. Employing the PRISMA protocol and a refined search strategy, this research provides a structured mapping of the field.

The main objective is to:

- Identify recent publication trends (2020 - 2024) ;
- Highlight the most active countries, institutions, authors, and journals;
- Uncover emerging keywords and conceptual themes;
- Offer a strategic reference framework for researchers, curriculum developers,

and policymakers.

This work is notable for its international scope, its unprecedented disciplinary focus on the physical sciences and its use of quantitative methodology, which is still little used in this field. It helps to fill a twofold scientific void: firstly, the lack of an overview of STEM research applied to the physical sciences; secondly, the need for decision-making tools based on structured, objective data.

## METHODS

In this section we will discuss about the methods applied in this paper.Moorover PRISMA FREMWORK was ultizedas the manfremwork for this study **[6]**.

### Identification

This review took place on Decembre 22$^{th}$, 2024, using Scopus database. This review aimed to investigate the relationship between STEM education in physics.

Two main keywords were used for instance, STEM education and in physics, and the query used for this is TITLE-ABS-KEY ( stem AND education AND in AND physics ). This search has been conducted for the last four years, as this query was used AND PUBYEAR > 2019 AND PUBYEAR <2025. A set of inclusion and exclusion criteria were used on this review. Table 1 shows the inclusion and exclusion criteria.

**Table 1** .inclusion and exclusion criteria

| **Inclusion criteria** | **Exclusion criteria** |
|---|---|
| STEM education AND in AND Physics | Any other keywords. |
| Articles from 2020 - 2024 | Any research before 2020 was excluded. |
| Only articles in english language | Any other languages |
| Only articles | Conference papers, books ; thesis |
| Social Science, Physics and Astronomy, Psychology, Engineeering, Chemistry, Decision Sciences and Arts and Humanities | Any other field. |

### Screening

The initial search resulted 1250 documents in the scopus database. After applying the set of inclusion and exclsuin criteria this review included only 127 documents, whereas 1123 were excluded fron the search.

### Eligebilty

Only articles in the field of Social Science, Physics and Astronomy, Psychology, Engineeering, Chemistry, Decision Sciences and Arts and Humanities were included in this search, following the query AND ( LIMIT-TO ( SUBJAREA , "SOCI" ) OR LIMIT-TO ( SUBJAREA , "CHEM" ) OR LIMIT-TO ( SUBJAREA , "PSYC" ) OR LIMIT-TO ( SUBJAREA , "ENGI" ) OR LIMIT-TO ( SUBJAREA , "PHYS" ) OR LIMIT-TO ( SUBJAREA , "DECI" ) OR LIMIT-TO ( SUBJAREA , "ARTS" ) ). Moreover, only articles were included AND ( LIMIT-TO ( DOCTYPE , "ar" ) ). A set of "exact keywords" were used to provide more precise results as follow, "STEM Education, Physics Education,

Physics Teaching, Physics, Chemistry Education, as follow; AND ( LIMIT-TO ( EXACTKEYWORD
, "STEM Education" ) OR LIMIT-TO ( EXACTKEYWORD , "Physics Education" ) OR LIMIT-TO ( EXACTKEYWORD , "Physics Teaching" ) OR LIMIT-TO ( EXACTKEYWORD , "Physics" ) OR LIMIT-TO ( EXACTKEYWORD , "Chemistry Education" ) ) lastly, only articles in English language were included as follow; AND ( LIMIT-TO ( LANGUAGE , "English" ) ). Figure 1 PRISMA framework is the main framework for this study **[6]**.

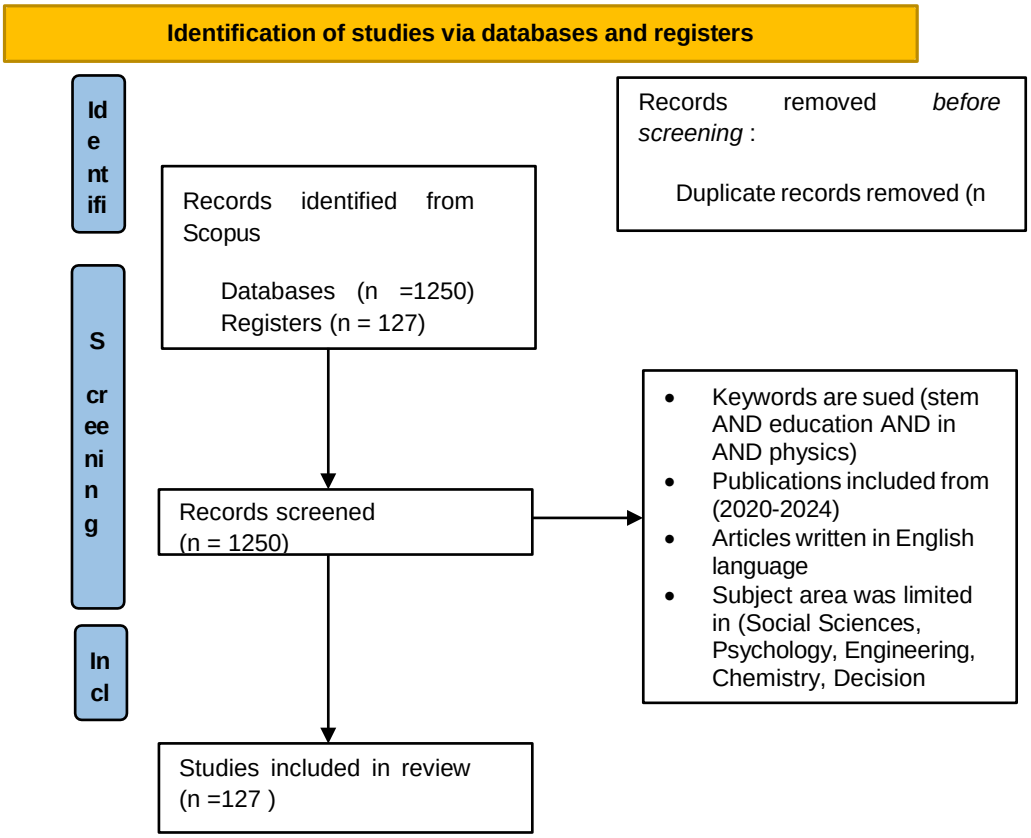


**Figure 1 .** PRISMA Framework for this review **[6].**

## RESULTS

This section presents the results of a bibliometric analysis of the integration of STEM education into physical science teaching. Our study provides in-depth information on various aspects of this constantly evolving field and covers several years of research. It covers important areas of research, publication trends, major countries and journals, key academic institutions, prolific authors and key search terms. The aim of this synthesis is to delineate the evolution of research on the integration of STEM education especially in the physical sciences, to identify the fundamental components that propel academic investigations and to provide a global perspective on global efforts to understand the impact of the STEM approach on the development of learners' competences and especially to transform science teaching, promoting

practical and interdisciplinary learning adapted to the challenges of the XXI[e] century [5].

**The distribution by years** .

This section addresses the following research question: "What is the distribution of integration of STEM education in physics sciences in the years 2020 and 2024?" By analyzing the data provided, we can answer the first study question about the distribution of integration STEM education in physics sciences from 2020 to 2024(figure 2).

The statistics show a marked increase in the number of publications in 2023 (34 publications) and 2024 (32 publications), following fairly constant figures in previous years. Indeed, 2020 saw the registration of 24 publications, followed by a marked fall in 2021 and 2022, with 18 and 19 publications respectively.

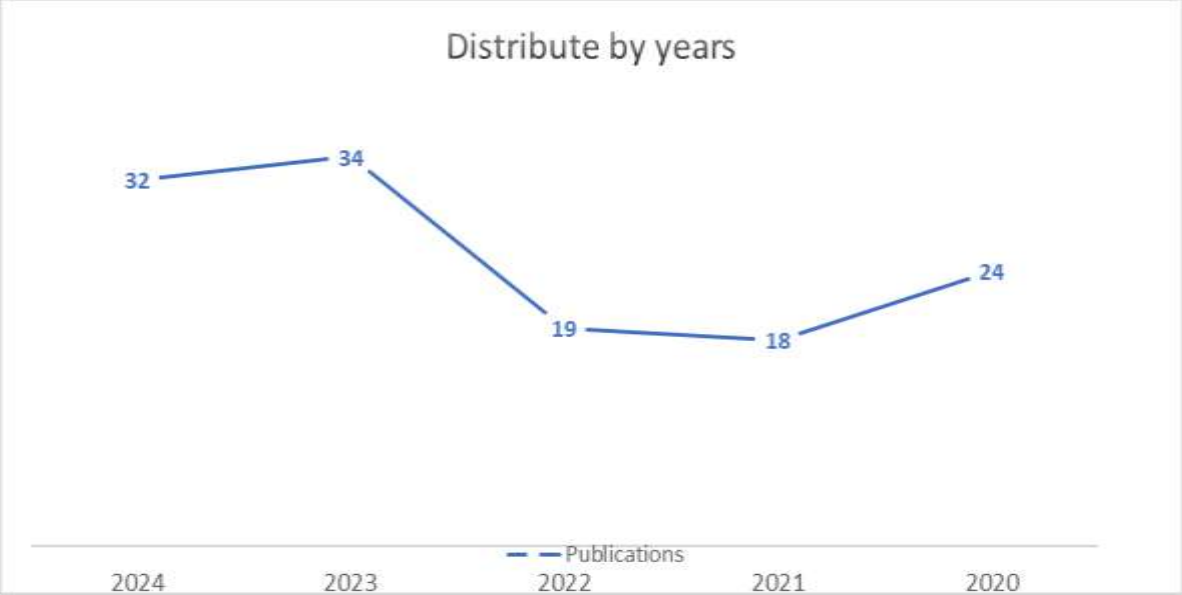


**Figure 2.** The distribution by years

This development highlights the growing value of STEM teaching in the physical sciences as a crucial component in preparing learners for the challenges of the 21st century.

**The most relevant journals**

With regard to the second research question, which academic publications are most relevant to the study of the integration of the STEM approach in physical sciences education? Table 2 shows a wide range of publications that make substantial contributions to this topic, based on data provided for the years 2020 to 2023.

**Table 2.** The Top 10 journals in STEM education in physics research

| **Journal** | **TP* (2020 - 2023)** | **TC* (2020 - 2023)** | **te score (2023)** | **Most cited article** | **Times cited** | **Publisher** |
|---|---|---|---|---|---|---|
| Eurasia Journal of Mathematics, Science and Technology Education | 553 | 2354 | 4.3 | Secondary school mathematics teachers' views on e-learning implementation barriers during the COVID-19 pandemic: The case of Indonesia **[7].** | 360 | Modestum LTD |
| International Journal of Science Education | 471 | 2177 | 4.6 | Forms of inquiry-based science instruction and their relations with learning outcomes: evidence from high and low-performing education systems **[8].** | 81 | Taylor & Francis |
| European Journal of Physics | 768 | 1327 | 1.7 | Hermione and the Secretary: How gendered task division in introductory physics labs can disrupt equitable learning **[9].** | 69 | Institute of Physics Publishing |
| International Journal of Engineering Pedagogy | 229 | 1268 | 5.5 | Remote knowledge acquisition and assessment during the covid-19 pandemic **[10].** | 85 | International Federation of Engineering Education Societies (IFEES) |
| International Journal of Innovation in Science and Mathematics Education | 74 | 85 | 1.1 | Self-Regulated Learning in Undergraduate Science **[11].** | 15 | University of Sydney |
| Journal for STEM Education Research | 69 | 273 | 4.0 | Computational Thinking Is More about Thinking than Computing **[12].** | 107 | Springer Nature |
| Journal of Science Education and Technology | 237 | 2229 | 9.4 | Examining Science Education in ChatGPT: An Exploratory Study of Generative Artificial Intelligence **[13].** | 459 | Springer Nature |
| Jurnal Pendidikan IPA Indonesia | 239 | 847 | 3.5 | Ethno-stem project-based learning: Its impact to critical and creative thinking skills **[14].** | 79 | Universitas Negeri Semarang |
| PRIMUS | 277 | 451 | 1.6 | Online Mathematics Tutoring During the COVID-19 Pandemic: Recommendations for Best Practices **[15].** | 37 | Taylor & Francis |

| | | | | | | |
|---|---|---|---|---|---|---|
| Qubahan Academic Journal | 94 | 556 | 5.9 | IoT and Cloud Computing Issues, Challenges and Opportunities: A Review **[16].** | 293 | Qubahan |

**TP***= Total publications **TC*** = Total Citations

The reviews most relevant to the topic of integrating the STEM approach into physical science teaching are presented in Table 2. The data spanning from 2020 to 2023 un-derscores a number of significant articles. "Eurasia Journal of Mathematics, Science and Technology Education " a scholarly journal distributed by Modestum LTD, distinguishes itself via its remarkable total of 553 arti-cles and 2354 citations.The article that receives the most citations, 360, pertains to the Obstacles to the implementation of e-learning during the COVID-19 pandemic, and a cite score of 4.3. In the STEM education in physics sciences, the "International Journal of Science Education," published by the Taylor & Francis, demonstrates a significant impact with a total of 471 articles, 2177 citations, and a cite score of 4.6. With 81 citations, its renowned paper on Forms of inquiry-based science instruction and their relations with learning outcomes: evidence from high and low-performing education systems. The journal "European Journal of Physics," which is published by Institute of Physics Publishing, is distinguished by its 768 articles, 1327 citations, and 1.6 cite score. Likewise, "International Journal of Engineering Pedagogy," an officThe journals that are most pertinent to the subject of student performance in e-learning platforms are shown in Table 2. The data spanning from 2020 to 2023 un-derscores a number of significant articles. "Eurasia Journal of Mathematics, Science and Technology Education " a scholarly journal distributed by Modestum LTD, distinguishes itself via its remarkable total of 553 arti-cles and 2354 citations.The article that receives the most citations, 360, pertains to the Obstacles to the implementation of e-learning during the COVID-19 pandemic, and a cite score of 4.3. In the STEM education in physics sciences, the "International Journal of Science Education," published by the Taylor & Francis, demonstrates a significant impact with a total of 471 articles, 2177 citations, and a cite score of 4.6. With 81 citations, its renowned paper on Forms of inquiry-based science instruction and their relations with learning outcomes: evidence from high and low-performing education systems. The journal "European Journal of Physics," which is published by Institute of Physics Publishing, is distinguished by its 768 articles, 1327 citations, and 1.7 cite score. Likewise, "International Journal of Engineering Pedagogy," has an impressive compilation of 229 publications and a remarkable 1268 total citations, accompanied with a cite score of 5.5. "International Journal of Innovation in Science and Mathematics Education" by University of Sydney makes a scholarly contribution of 74 articles, 85 citations, and a cite score of 1.1. With a cite score of 4.0, the "Journal for STEM Education Research," publish in Springer Nature, catalogues 69 articles and 273 citations. Finally, With the highest number of score, 9.4, the 'Journal of Science Education and Technology', another Springer Nature publication, lists 237 articles and 2229 citations.

This result allows us to promote the journals with the highest number of publications, as well as presenting the citation score for each journal to make it easier

for researchers to find the most relevant journals.

**The most significant countries**

In order to examine the third study inquiry, which nations have the most impact on integration STEM education in sciences physics? An analysis of the data presented reveals a heterogeneous worldwide impact, as seen in Figure 3. Dis-tribution of publications by nation.

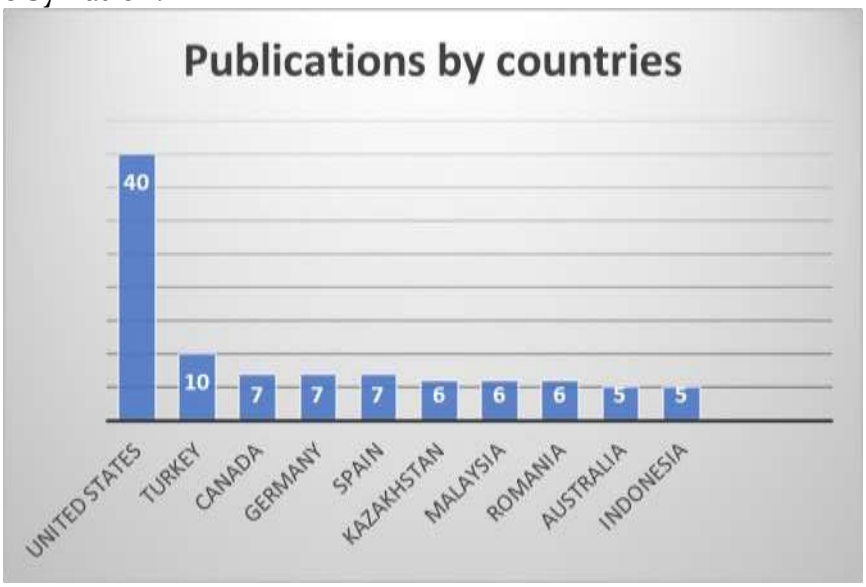


**Figure3.** Publications by countries

A study of the countries involved in research into STEM teaching in physics, as shown in Figure 3, reveals notable differences in the production of articles. With 40 publications, the United States is clearly in first place, demonstrating its predominance in research in this professional field. With 10 publications, Turkey ranks second, illustrating a significant contribution to the international body of research, albeit considerably less than that of the United States. Countries such as Canada, Germany and Spain each have 7 publications, demonstrating a significant if less conspicuous involvement in STEM physics education research. Kazakhstan, Malaysia and Romania each participate with 6 publications, indicating a permanent if modest presence in this field of research. Finally, Australia and Indonesia each have 5 publications, highlighting their relatively less important but nonetheless perceptible influence on STEM education in physics.

In general, the information reveals that the United States is the main player in research in this field, while other countries such as Turkey, Canada, Germany and Spain also play an important role, although they publish less research, and Figure 4 shows the geographical distribution of their publications on the world map.

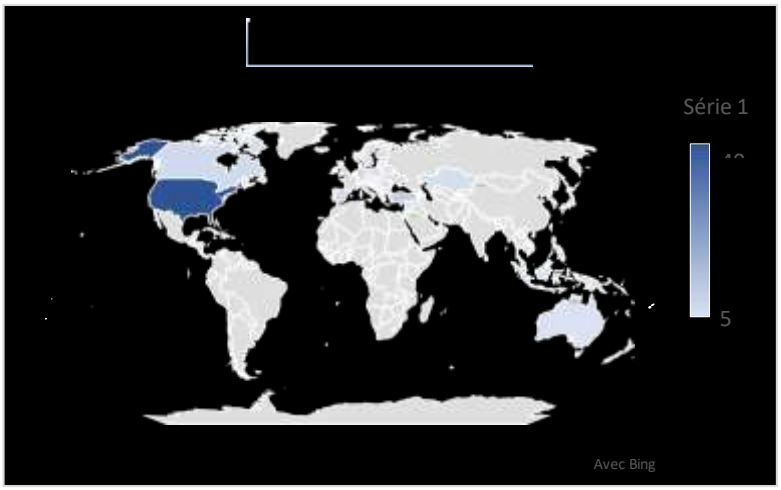


**Figure 4.** Geographical distribution of publications on a global scale.

**The most significant educational institutions**

The data presented in answer to the fourth research question "Which educational institutions have made the most notable contributions to the study of integration STEM education in physical sciences?" emphasizes a number of such institutions. As seen in Table 3, and Figure 5.

**Table 3.** The most significant educational institutions in student's

| **educational institution** | **TP*** | **Country** |
|---|---|---|
| Université Yeditepe | 7 | Turkey |
| Université de Dokuz Eylül | 4 | Turkey |
| Université Andrés Bello | 3 | Chile |
| Technologique de Monterrey | 3 | Mexico |
| Université Tufts | 3 | United States |
| Université internationale kazakhe-turque Khoja Akhmet Yassawi | 3 | Kazakhstan |
| Université du Colorado à Boulder | 2 | United States |
| Université de Hradec Králové | 2 | Czech Republic |
| Université de l'Illinois à Urbana-Champaign | 2 | United States |
| Université Western Michigan | 2 | United States |

**TP***= Total publications

Yeditepe University in Turkey generated the highest number of publications (TP), 7 (see Table 3), which testifies to its dedication to research into the incorporation

of STEM into physical science teaching. The four papers from Dokuz Eylül University, also located in Turkey, highlight the country's involvement in research on this topic.

In addition, three publications were made by each of the following universities: Universidad Andrés Bello in Chile, Universidad Tecnológica de Monterrey in Mexico, Tufts University in the United States and Khoja Akhmet Yassawi Kazakh-Turkish International University in Kazakhstan. Finally, universities with two publications include the University of Colorado at Boulder, the University of Illinois at Urbana-Champaign and Western Michigan University, all three based in the United States, as well as the University of Hradec Králové in the Czech Republic.

Institutions such as Yeditepe University and Université de Dokuz Eylül in Turkey stand out for their significant contributions. Their commitment underlines the dynamic role of universities in advancing STEM education. The growing importance attached to STEM education in the teaching of the physical sciences is highlighted by the variety of institutions present on various continents. The regional breakdown of publications is shown in Figure 5.

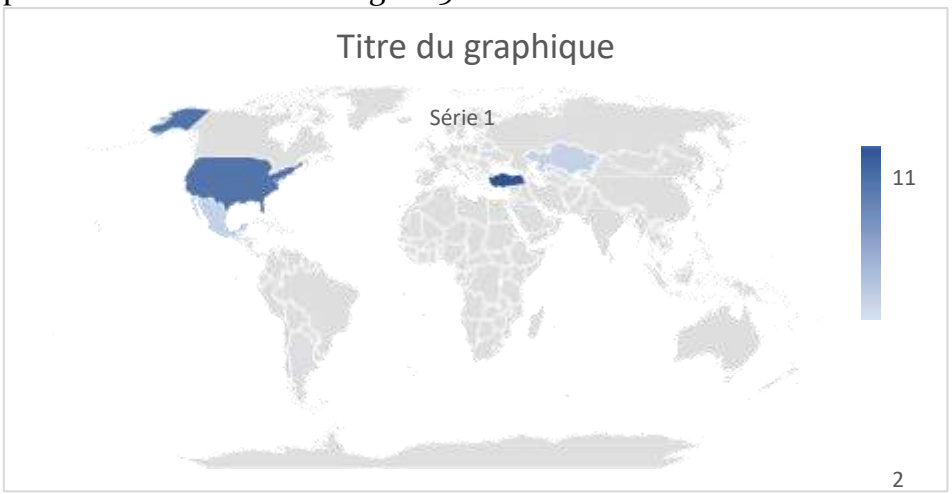


**Figure 5 .** Geographical distribution of the top ten institutions worldwide.

Turkey confirms its dominant position in this field of study, with a total of eleven publications divided between two Turkish universities: Yeditepe University, with 7, and Dokuz Eylul University, with 4. The United States ranks second in the world with 9 publications, from four universities: Tufts University (3 publications), the University of Colorado at Boulder, the University of Illinois at Urbana-Champaign and Western Michigan University, each with 2 publications. Mexico, Chile and Kazakhstan are all in third place worldwide, with each country having published 3 articles. Finally, the Czech Republic came fourth with two publications.

These findings underline the fact that Turkey and the United States lead this sector, confirming their dominant position in STEM physics research and education.

**The most prolific authors**

Regarding the fifth research question, "Which authors have made the most substantial contributions to the field of integrating the STEM approach into physical science education?" The data in Table 4 highlights several authors who have made remarkable contributions in this area.

**Table 4.** top 10 authors in the field of STEM education in physics

| **Author** | **Year of first publication** | **TP*** | **TC*** | **H- index** | **Current affiliation** | **Country** |
|---|---|---|---|---|---|---|
| Çoban, Atakan | 2019 | 16 | 73 | 5 | Ludwig-Maximilians-Universität München | Germany |
| Caspari-Gnann, Ira | 2022 | 8 | 61 | 4 | Tufts University | United States |
| Erol, Mustafa | 1996 | 30 | 192 | 8 | Dokuz Eylül Üniversitesi | Turkey |
| Zavala, Genaro | 1995 | 109 | 1 285 | 16 | Tecnológico de Monterrey | Mexico |
| Barniol, Pablo | 2009 | 34 | 374 | 12 | Tecnológico de Monterrey | Mexico |
| Bezak, Eva | 1996 | 196 | 2606 | 27 | University of South Australia | Australia |
| Calvo-Iglesias, Encina | 1996 | 28 | 760 | 16 | Universidade de Santiago de Compostela | Spain |
| Chiriacescu, Bogdan | 2019 | 16 | 84 | 4 | Universitatea din Bucuresti | Romania |
| Chiriacescu, Fabiola Sanda | 2019 | 16 | 84 | 4 | Universitatea din Bucuresti | Romania |
| Çoban, Atakan | 2019 | 16 | 73 | 5 | Ludwig-Maximilians-Universität München | Germany |

**TP***= Total publications **TC*** = Total Citations

The most prolific authors are shown in Table 4. For example, Çoban, Atakan, who published his first work in 2019, has accumulated a remarkable 16 publications and an h- index of 5, which translates to 73 citations. Çoban, who is now associated with the Ludwig- Maximilians-Universität München in Germany, has established

himself as a preeminent authority in the subject via his substantial body of research. Since Caspari-Gnann, Ira her academic career in 2022, he has amassed 8 articles to date, garnering 61 citations and an h- index of 4. Her affiliation with Tufts University in United States her increasing prominence in the field of study in question. Since his first publication in 1996, Erol, Mustafa has accumulated a total of 30 articles and now has an h-index of 8. The 192 citations he has accumulated and his association with Dokuz Eylül Üniversitesi in Turky testifies to his lasting and influential reputation in the area. Zavala, Genarohas accumulated a significant h-index of 16, 109 articles, and 1285 citations since his inception in 1995. His affiliation with Tecnológico de Monterrey in Mexico underscores the con-siderable advancements that the country has achieved in the domain of STEM Eeducation in Physical sciences. 34 of Barniol, Pablo papers have been cited 374 times and have earned him an h-index of 12 since her first publication in 2009. This author is also affiliated with the same university as Zavala, Genaro. Bezak, Eva has accumulated an h-index of 27 since her first publication in 1996, 196 articles, and 2206 citations. Her affiliation with University of South Australia in Australia con-tributes to the elevation of the country's standing in the field of STEM Eeducation in Physical sciences.

Calvo-Iglesias, Encina, who started his scholarly pursuits in 1996, has produced a total of 28 publications. These works have received 760 citations and have an h-index of 16. His association with the Universidade de Santiago de Compostela in Spain indicates that he has made a substantial contribution to the area. Since 2019, Chiriacescu, Bogdan, who has amassed 84 citations and an h-index of 4, has published 16 papers. His association with the Universitatea din Bucuresti in Romania. 16 publications authored by Chiriacescu, Fabiola Sanda have received 84 citations and an h-index of 4 since 2019. This demonstrates Universitatea din Bucuresti in Romania dedication to the field of STEM education in physical sciences Since her first publication in 2019, Çoban, Atakan has accumulated Seventy-three citations and Sixteenth articles, which is reflected in her h-index of five. Ludwig- Maximilians-Universität München in Germany is with which she is intellectually affiliated. The integration of STEM education in physical sciences have been profoundly influenced by the authors' copious research and publications. The geographic and institutional diversity among the authors reflects a collaborative and international effort to advance STEM education.

**The primary research keywords and trends**

In response to the sixth inquiry, "Over the last four years, what have been the most prominent research terms concerning STEM education in physical sciences?" The figure 6 illustrates the principal research terms and their frequency of occurrence, as shown by the information presented in the picture

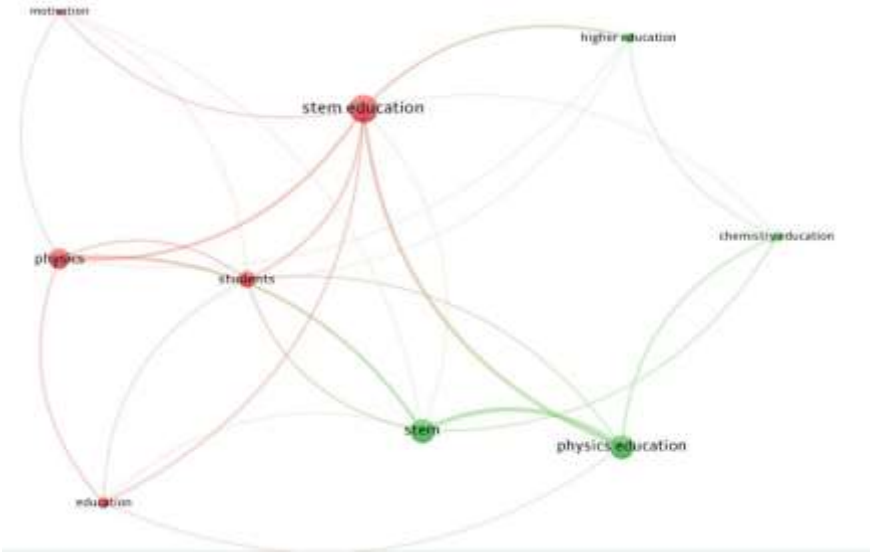


**Figure 6.** The primary research keywords and their occurrences

The occurrences of the core research terms are shown in Figure 6. Over the last four years, there has been a diverse array of main research keywords pertaining to STEM education in physical sciences, which reflects the broad spectrum of interests that exist in this sector and especially in STEM education research in general. The term "STEM education" surfaced as the most frequent keyword, ap-pearing 72 times, indicating its critical significance in the field of educational re-search. The term "Physics education" was also often occurring, being used 40 times, which emphasises the primary emphasis of the research. The terms "Physics" and "STEM" which appear 21 and 29 times, respectively, underscore the considerable attention given to science, technology, engineering and mathematics to train learners in the physicl sciences. The terms "students" and "higher education" are frequently used, reflecting a strong research interest in higher education and students within the context of this STEM approach.

The study places significant im-portance on the outcomes of "STEM education" and "in physics" which underscore the overarching objective of comprehending and improving the learning process based on the STEM education in physical sciences.

**The most important subject area**

In order to investigate the seventh research inquiry, which topic area is the most critical in terms of application for STEM education in phicical sciences? Based on the facts pre- sented, social sciences as the preeminent field of study, with a substantial collection of 111 articles. The social sciences top the distribution as seen in Figure 7, reflecting a strong interest in pedagogical methods, education and the human dimensions of teaching. This emphasis reflects a growing awareness of the importance of the social sciences in understanding and optimising teaching and learning methods in STEM fields.

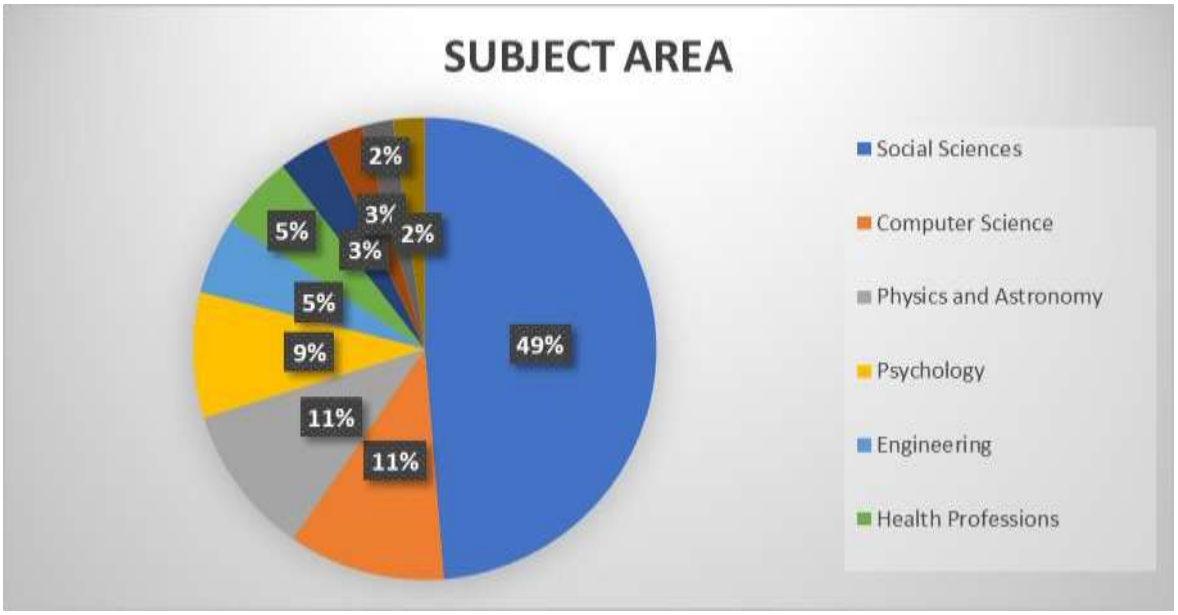


**Figure 7.** The most important subject area

Computer science, which has been the subject of 25 articles, is another significant area of interest, since it involves the use of technology concepts in the development and improvement of Courses based on the STEM approach, whether delivered online or in-person. Even if some issue areas may not be as prevalent as others, they nevertheless make substantial contributions to the field. With a combined total of 24 and 20 papers, the Physics and Astronomy and Psychology, respectively, provide significant Even if some issue areas may not be as prevalent as others, they nevertheless make substantial contributions to the field. Contributions to the body of knowledge about the use of STEM education in physical sciences. Engineering, with 12 publications, represents another important area of interest, as it involves the application of engineering concepts in the development and improvement of solutions to various types of problems.

On the other hand, there are other interesting fields such as "Health Professions", "Mathematics", "Business, Management and Accounting", "Arts and Humanities", and "Biochemistry, Genetics and Molecular Biology", which have 12, 8, 6, 5, and 5 publications respectively.These fields, despite belonging to various sectors, enrich STEM education in physical sciences by offering interdisciplinary perspectives that integrate scientific, technological, mathematical, and creative concepts crucial for solving complex problems and fostering pedagogical innovation.

## DISCUSSION

In the dynamic context of STEM education and its impact on the excellence of learners in physical sciences, this article presents an in-depth bibliometric study that offers a holistic perspective on the progression and development of research in this field between 2020 and 2024. The research indicates that this expansion is characterized by a variety of contributions from different countries and organizations, as well as a growing interest from researchers.

**Publication Trends and Temporal Analysis**

Publications on the integration of STEM education in the physical sciences have steadily increased between 2020 and 2024, reaching a high in 2023. This pattern supports the rising demand for creative and multidisciplinary methods in scientific instruction. This conclusion is consistent with the findings of Honey and Hilton (2011), who had previously highlighted the necessity of including STEM fields to better equip students for the realities of the twenty-first century **[17].** According to Bozkurt & Sharma's (2020) study on new pedagogical paradigms in distance education, the COVID-19 epidemic sped up this shift by requiring the use of digital technologies and hybrid techniques **[18].**

**Central role of major scientific journals**

The journals included in this study, including the International Journal of Science Education, the Eurasia Journal of Mathematics, and Science and Technology Education, attest to their prominent position in sharing research on STEM integration. As previously mentioned by other studies, including Li et al. (2020), these publications are essential to the development of research on interdisciplinary learning environments in science. These publications frequently examine topics of particular interest, such as project-based learning, scientific reasoning, and inquiry-based teaching **[19].**

**Geographical and Institutional Contributions: Towards a Democratization of STEM Research**

The United States and Turkey's dominance in the identified literature confirms earlier findings (Margot & Kettler, 2019) that both nations have educational policies that supported the incorporation of the STEM approach beginning at the secondary level **[20]**. Nonetheless, there is a clear trend toward the democratization of STEM research indicated by the increasing involvement of institutions from nations like Kazakhstan, Romania, and Indonesia. Bybee (2013) underlined that both local adaptation and coordinated worldwide efforts are necessary for educational change, and this is in line with his vision **[21].**

**Influential Authors and Collaborative Dynamics**

Research in this discipline depends on important individuals who are actively involved in numerous international joint projects, as evidenced by the identification of prolific authors like Mustafa Erol and Genaro Zavala. According to Kelley & Knowles (2016), a common
understanding of competency-based learning and inter-institutional research networks are essential for the STEM method to succeed **[22]**. By demonstrating how research endeavors are based on solid collaborative foundations, our study supports that theory.

**Emerging Keywords and Research Orientation**

A shift in research focus toward the learner and higher education contexts is reflected in the most commonly occurring keywords ("STEM education," "physics

education," "higher education," and "students"). This approach is in accordance with Moore et al. (2014), who stress that in order to increase students' interest and engagement, STEM subjects must be related to real-world problems they face **[23]**.

**Interdisciplinarity and Openness to the Humanities**

Lastly, the approach promoted by Larson & al (2011), which maintains that the integration of transversal abilities, such as communication, ethics, and creativity, is essential to the success of STEM education, is supported by the substantial representation of social sciences (49%) in the evaluated publications **[24].** In keeping with a STEAM education perspective (where the "A" stands for "Arts"), as suggested by Yakman (2008), the study also finds new and understudied fields, like the arts and humanities **[25].**

**Summary of the results of this review**

With a focus on its impact on student performance, the following table offers a comprehensive overview taken from this research study that thoroughly examines the origins, effects, and possible future advancements of STEM education in the physical sciences. The information is categorised into important areas, such as discoveries, implications, trends, and future plans. These categories offer a thorough grasp of the subject-specific emphasis, regional distribution, primary authors, and scholarly attention in the field of online learning. As shown in Table 5, the goal of the study is to outline the current situation and predict future directions in this rapidly developing field.

**Table 5.** A Thorough Examination of STEM education in physical sciences and Its Influence on Academic performance: Principal Discoveries and Prospects for the Future

| Aspect | Findings | Implications | Tends | Future Agenda |
|---|---|---|---|---|
| **Publications** | Peak publications in 2023 (34) followed by 2024 (32). Stable publications before 2023, with a dip in 2021 (18). | Growing interest in the integration of STEM education into physical sciences to address the challenges of the 21st century **[4].** | Post-pandemic rebound with a significant increase in research on interdisciplinary approaches. | Continue exploring the impact of STEM integration on learners' skills and their adaptability to the global market. |
| **Journals** | " Eurasia Journal of Mathematics, Science and Technology | These journals play a key role in disseminating innovative approaches to | Focus on the barriers and opportunities of e-learning platforms and | Publishing in multidisciplinary journals to increase the reach and impact |

| | | | | |
|---|---|---|---|---|
| | Education, “, “International Journal of Science Education,” and “European Journal of Physics ” are all significant periodicals. | science education. | their global adoption. | of STEM research. |
| **Countries** | The United States leads, followed by Turkey, with Canada, Germany, and Spain tied for third place. | A testament to the diverse range of educational and cultural contexts and the global nature of STEM education in the physical sciences comme le Kazakhstan et la Malaisie. | increasing global contributions from a number of countries. | Foster international collaborations to share best practices and resources. |
| **Educational Institutions** | Université Yeditepe and Université de Dokuz Eylül are notable donors to this cause | Key institutions in the research and dissemination of STEM approaches in physical sciences. | Emergence of institutions in developing countries in the field of STEM education, especially in relation to the teaching of physical sciences. | Encouraging the participation of institutions from underrepresented regions to diversify teaching approaches. |
| **Authors** | The fact that prominent authors like Mustafa Erol, Genaro Zavala, and Pablo Barniol contributed to the | Significant contributions of established and emerging researchers to STEM education in physical sciences. | International collaborations are increasing , enriching the field with diverse perspectives. | Supporting the research of young researchers while leveraging the work of established experts. |

| | | | | |
|---|---|---|---|---|
| | writing in the domaine indicates that there is a mix of established and | | | |
| | up-and-coming experts in the field. | | | |
| **Keywords** | "STEM education" and "physics education" are among the most common terms, along with words like "students" and "higher education." | Emphasizes the importance of learner-centered approaches in STEM educational environments. | Terms related to technology and engineering are gaining prominence in research. | New keywords are emerging to improve STEM learning methods. |
| **Subject Areas** | The social sciences, computer science, physics, astronomy, and psychology are the most important topic areas in terms of significance. | Interdisciplinary approaches combining pedagogy, science, and technology to address educational challenges. | Underrepresented disciplines such as the arts show untapped potential. | Strengthening the integration of disciplines to enrich learning experiences and foster innovation. |

The significant rise in scientific contributions since 2023 is indicative of both a greater awareness of the STEM approach's capacity to address current educational issues, especially those exacerbated by the COVID-19 pandemic, and a growing interest in it. This pattern confirms the findings of Maisano et al. (2024), who stress that the STEM approach is more pertinent than ever in international educational systems because of the post-pandemic era's increased use of digital and hybrid pedagogical solutions **[26].**

One important sign of the STEM approach's development is its collaborative and interdisciplinary nature. A growing body of research highlights the value of international partnerships in promoting creative and contextually appropriate teaching methods (e.g., Dominguez et al., 2023) **[27].** The increasing number of collaborations between academic institutions, research centers, and universities that seek to combine their knowledge of engineering, didactics, digital technology, and learning psychology is indicative of this.

## CONCLUSION

The research's bibliometric analysis provides a comprehensive and inclusive look at the dynamic relationship between students' academic performance and the STEM approach's integration, as well as the growth of their transversal skills, which are essential for their entry into the workforce. It draws attention to a notable rise in scholarly study in this area, highlighting the growing significance of integrating STEM into modern education.

The popularity of specific subjects and keywords, as well as the variety of contributing nations and institutions, demonstrate the global scope of research on integrating the STEM approach. International cooperation between researchers, technologists, and academics has not only shed light on the field's current status but also set the stage for future research. At a time when transversal skills are critical for successful integration into the workforce, ongoing research is key to improving student learning experiences and forming educational approaches.

Despite the large number of publications, this research shows several major shortcomings in the existing literature on the integration of the STEM approach, in particular an overly general and poorly contextualised view of the physical sciences. Few works evaluate pedagogical models in depth or take into account the specificities of higher education, which limits the effectiveness of their implementation in university courses.

Three major perspectives emerge: (1) further qualitative analysis of the real impact of STEM devices; (2) design integration models adapted to the experimental and analytical nature of the physical sciences; (3) propose a new model for STEM integration at university, based on interdisciplinarity, problem-solving and pedagogical innovation.

This work represents a solid basis for researchers, particularly those who will be integrating the STEM approach into the physical sciences.

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