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Mapping the Research of Technical Teachers' Pedagogical Beliefs about Science Technology Engineering and Mathematics (STEM) Education

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Science, technology, engineering, and mathematics (STEM) education have become increasingly popular among educators in recent times. Research on STEM education has been shaped by a great number of articles published across the world. This study attempts to objectively examine the STEM education literature on technical teachers' pedagogical beliefs by analysing the bibliometric data extracted from the two popular scientific databases known as SCOPUS and Web of Science core collection. This paper highlights the current research trends in this domain by identifying the most impactful documents, topics, contributing authors, journals, and countries. A bibliometric review method has been employed to analyse the scientific research published on teachers' pedagogical beliefs in STEM education. The findings reveal that this field of research is relatively new and began to publish in 1990. Recent trend shows a gradual increase in publications on the domain of teachers' pedagogical beliefs in STEM education. Online pedagogy such as blended learning and its relevant pedagogical approach i.e., gamification etc. are found to be dominant research themes related to technical teachers' pedagogical beliefs in STEM education. Also, technology integration, self-efficacy, gender issue etc. are the key research areas that were explored and studied in this domain of research. Developed countries appeared to be the dominating contributors in STEM education research. The findings of this study give insights and quantitatively synthesise the research development on teachers' pedagogical beliefs in STEM education.

Keywords: STEM education, bibliometric review, technical teachers, pedagogical belief, co-citation analysis

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INTRODUCTION

Making scientific and engineering methods available to students has become critical for countries seeking to improve their technological development and socioeconomic growth (Özkaya, 2019). Therefore, many countries emphasize the importance of teaching science, technology, engineering, and mathematics together, which is widely known as STEM education, into their curriculum (Bagiati et al., 2015; Furner & Kumar, 2007; Özkaya, 2019; Stinson, et al., 2009). The goal of STEM education is to blend engineering and technology-oriented application into the curriculum to assist students in making connections between engineering and science disciplines. It also helps the student to develop competent skills through the practice of interconnected disciplines. The blending of arithmetic and science skills among the graduates is considered the driving component for the upcoming industrial revolution (Berisha & Vula, 2021).

STEM education was built in the early 1990s and is regarded as an interdisciplinary curriculum approach in which basic learning concepts are combined with real-world applications (Ha et al., 2020). STEM education allows students to apply their understanding of science, technology, engineering, and mathematics in real-world situations to compete in the new global economy (Hsu & Yeh, 2019). It positively impacts the learning outcomes and skills of students (Batdi, Talan, & Semerci, 2019). STEM education is directly influencing the financial, ecological, and social development of a nation (Kelley, T. R., & Knowles, 2016). Thus, educators are incorporating STEM skills into the curriculum to compete with the global market on a continuous premise.

Lately, STEM education drew a lot of attention among the researchers, educators, and policymakers of technical education because of its relevance to the global economy and industrial revolution (Kanadlı, 2019). In this regard, the field of technical education is trying to incorporate STEM subjects into its curricula to meet the expectation of the global market (Shafi, et al., 2021; Khairutdinov, et al., 2019). However, there is a lack of research to uncover the current state of affairs of STEM education in this field. Thus, this study attempts to study the current situation of STEM education in the context of technical education. Specifically, technical teachers' pedagogical beliefs and the characteristics of STEM education literature from 1990 to 2021 have been quantitatively mapped through the bibliometric review method.

Teachers' Pedagogical Beliefs in Stem Education

Teaching STEM subjects poses a genuine challenge to teachers as the discipline is constantly upgrading with the advancement of technology and innovations in the industry (Assefa & Rorissa, 2013; Siekmann, 2016). Research suggests that pedagogy and content knowledge are the key ingredients for effective teaching in STEM education. Özden, (2008) defines pedagogy as "the science of teaching, instruction, and training" whereas content knowledge is "the concepts, principles, relationships, processes, and applications a student should know within a given academic subject" (p.634). Additionally, knowledge of technology also plays a key role to teach STEM subjects (Chai, 2019).

Pedagogical knowledge, being the most crucial skill of a teacher, concentrates on the actual implementation of the teaching strategy in the instructional setup (Berisha & Vula, 2021). The pedagogy involves educators' thoughts, convictions, perspectives, information, and comprehension about the educational plan, instruction, and learning measure which influence their teaching practices (Kaluyu, 2020). DeCoito & Myszkal (2018) suggested that teachers' beliefs influence their ability to teach sciences and mathematics subjects confidently whereas it also indicated that teachers' self-efficacy and beliefs impact the implementation of the inquiry-based practices in the process of teaching-learning.

Teachers' pedagogical beliefs represent the individual perceptions and practice of teaching in classroom situations. According to Pajares (1992), beliefs stimulate the way knowledge is observed. According to Chen, Huang, & Wu, (2020) "Teachers' pedagogical beliefs is often defined as a holistic conception related to several dimensions, such as teaching, curricula, and the teaching profession in general" (p.138). A teacher's pedagogical beliefs will influence their academic targets, teaching values, and performance of the students' behaviour towards achieving the learning outcomes (Khader, 2012). Diverse pedagogical beliefs might have critical effects on teaching (Lim & Chai, 2008). Kanadli (2019) in his research findings indicated the contribution of STEM education to the science curriculum and also reflect the views of teachers and students participating in STEM education in the process of teaching-learning.

In recent years, several review studies have been carried out to examine the teachers' pedagogical beliefs on STEM education. For example, Tondeur et al. (2017) suggest that teachers' pedagogical beliefs and technology use in education are interconnected. Ndiku & Kaluyu (2020) argued that it is important to adopt the new pedagogical approach for better student learning through the integration of new technology to teach STEM subjects. Assefa & Rorissa (2013) critically analysed and examined the domain of the STEM teachers' pedagogical beliefs and focused on the development of a suitable educational program and policy for teaching. The limitations of these papers are that they have qualitatively analysed the textual data in the field of STEM literature which cannot be generalized. Razali (2021) research findings influenced the students towards the STEM career for the economic development of the country and also be professionally developed in the field of Science, Technology, Engineering, and Mathematics. McDonald (2016) revealed the contribution of four disciplines of STEM education and effective pedagogical practices of the teachers that influence student engagement in STEM education.

In their review, Martín-Páez, et al., (2019) have given special attention to analysing those educational interventions referred to as STEM education and the important attributes that make those educational interventions successful. In doing so, the analysis of the selected educational experiences points to the existence of multiple ideas on what STEM education is and how to implement it. Further, Martín-Páez, et al., (2019) criticize that no explicit connection has been established between the different contents and the STEM disciplines in the educational interventions, thus the understanding of how these are integrated become difficult to comprehend.

In their review, Winberg et al., (2019) argue that appropriate pedagogies are the key factor contributing to student achievement, yet we think less about how teachers can obtain the pedagogical ability. There is little spotlight on this pedagogical issue in STEM disciplines. Most of the studies focus on what makes the STEM disciplines hard to teach or learn but how the instructors will overcome these pedagogical challenges are mostly unanswered.

Despite demonstrating the effectiveness of the pedagogical beliefs on STEM education, previously published review papers have some methodological limitations. To begin with, the majority of the research has been reviewed qualitatively the STEM education literature overlooking the quantitative synthesis of the STEM discipline and the trends in this field. Second, the sample size is limited due to the qualitative nature of the review articles. Third, earlier papers come up short on the objectivity to represent the status quo of teachers' pedagogical beliefs on STEM education. Thus, very little research in STEM education has been carried out that objectively mapped the STEM education literature on teachers' pedagogical beliefs.

The goal of this study is to conduct a bibliometric analysis of scientific investigations published in STEM education to determine the overall layout of the scientific knowledge and structure of the field by objectively synthesizing the bibliometric data. As a result, the advancement of research in the field of STEM education may be predicted. Thus, this study would like to investigate the following research questions.

RQ1: What is the current status of the research articles published in the domain of teachers' pedagogical beliefs in STEM education?

RQ2: What are the key research themes and developmental trends that have been observed in recent STEM education research on technical teachers' pedagogical beliefs?

METHOD

This study adopted a bibliometric review methodology to examine the research trends in teachers' pedagogical beliefs in STEM education. The bibliometric approach quantitatively analyses the scientific research data in a given field (Özkaya, 2019). It mainly focuses on mapping the scientometric data such as author names, keywords, methods used, citations, etc. to display the structure and dynamics of the researched areas. Thus, the bibliometric study yields a variety of results about the contribution of authors, countries, and the research trends about the given topic (AL, U., & Coştur, 2007). The bibliometric method also uses the co-reference strategy to bring up the connection between articles and themes and the development of a subject area.

In doing the analysis, this study employed five phases of bibliometric analysis, such as *i)* study design, *ii)* data collection, *iii)* data analysis, *iv)* data visualization and *v)* interpretation (Borner, et al., 2005; Zupic & Čater, 2015). The data set has been drawn upon from Web of Sciences (WoS) and Scopus- the two most popular indexing databases covering most of the scientific articles published in the research field (Maditati, et al., 2018; Piñeiro-Chousa, et al., 2020). After rigorous searching, screening, and filtering process, this study finally selected 144 articles that were published between the years 1990 and 2021. While searching in the databases, the entire

range of the years (1900-2021) and "all documents" were selected to include all the important records. The article selection procedures and review methodology of this study have been presented in the following schematic diagram (Figure 1).

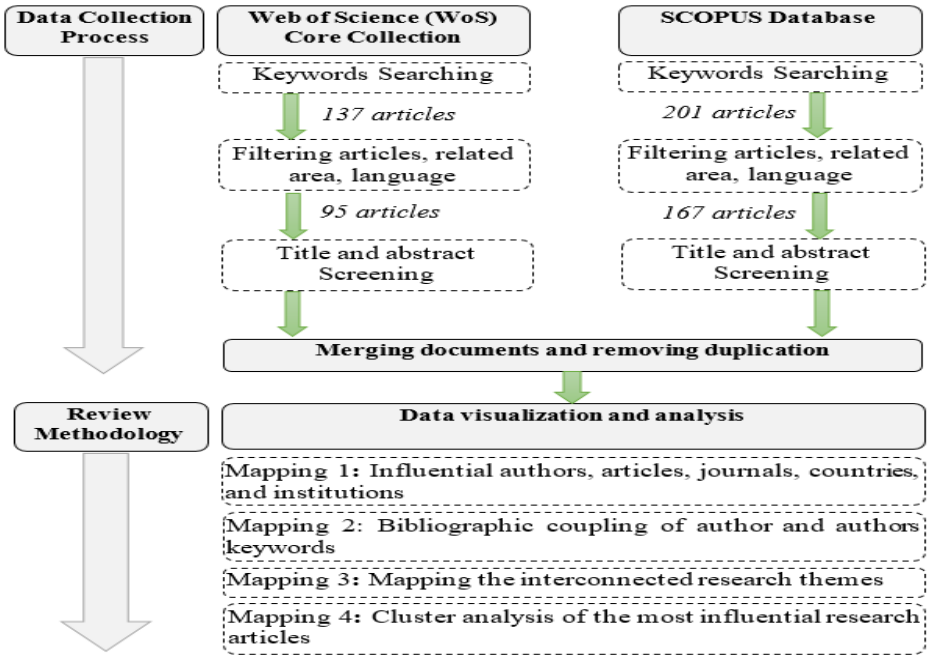

Figure 1
The bibliometric review process of data collection and analysis of STEM education research (adapted from, Al Mamun et al., 2021)

The data collection phase comprises article searching, data filtering, and data screening process to select the relevant articles for this study. The author team performed a search in the Scopus database and Web of Science core collection with advanced search options to ensure search terms and Boolean operators matched the syntax of the search tool. The searching keywords are categorized into three different themes to capture all the relevant articles. The keywords for the first theme include 'Pedagogical beliefs', 'Teaching/Teachers beliefs, perception, conception', 'Instructional beliefs', 'Educational beliefs', 'Pedagogical practice', and 'Instructional Practice'. The second theme includes the keywords- 'STEM', 'Science Education', 'Science, technology, engineering and mathematics, 'Science, technology, engineering, and math' and 'Mathematics education'. The third theme comprises the keywords- 'Technical education', 'Career education', 'Professional education', 'Technology education', 'Vocational education', 'Occupational education', 'Further education', 'Technical', and 'Vocational'.

In the document filtering process, only the journal articles and conference papers are selected for this study. Also, documents written in the English language have been

selected as default in the article selection process. We carefully screened and scrutinized the titles, keywords, and abstracts of all the articles to eliminate the irrelevant documents that were not connected to STEM education. After screening, scrutinizing, and removing duplication from both databases, we finally included 144 articles (Journal paper and conference paper) in the data repository for bibliometric review.

In the analysis phase, we first look at the scientometric data of all the selected documents to examine the number of publications, citations per year, types of publications, co-citation network, country collaborations, publishing trends, the most prolific journals, authors, and organizations. We also look for collaboration among the most prolific nations in this research field through examining the cross-country co-authoring network.

During the data visualization stage, we employed the bibliometric package in R (Aria, M., & Cuccurullo, 2017) and VOSviewer (van Eck & Waltman, 2010). Furthermore, Microsoft Excel was utilized to summarize data at various phases. We also utilised the default web application available in both Scopus and Web of Science core collection database to examine the various statistics related to author, article, country, institution, and citations about the teachers' pedagogical beliefs in STEM education.

BIBLIOMETRIC ANALYSIS AND DISCUSSION

In this segment, more detailed insights have been given into the data repository of the selected articles. The general overview of the selected documents between the years 1990 and 2021 has been shown in Table 1.

Table 1
Main information Related to the STEM Education

Description	Results
Documents	144
Sources (Journals, conference proceedings, etc)	92
Keywords Plus (ID)	472
Author's Keywords (DE)	391
Timespan	1990:2021
Average citations per document	6.89
Authors	419
Author Appearances	453
Average years from publication	6.44
Authors of single-authored documents	32
Authors of multi-authored documents	387
Average citations per year per doc	0.75
Single-authored documents	32
Documents per Author	0.34
Authors per Document	2.91
Co-Authors per Documents	3.15
Collaboration Index	3.46
h-index	108
References	4718
article	110
Conference paper	34

As revealed, Table 1 indicates that an aggregate of 144 documents consists of 110 articles and 34 conference papers have been published between the years 1990 and 2021 in 92 different sources. A total of 419 authors wrote these articles. The average citations per year per document is 0.75 and the average citations per document are 6.889. The h-index of all the selected articles is 108. Moreover, with a collaboration index of 3.46, there are 32 single-authored documents and on average 3 co-authors per document have been reported.

Annual Production and Citations of the Document

Figure 2 represents the annual scientific production and the total citations received by the selected 144 documents as of March 2021. It showed that the publication related to the teachers' pedagogical beliefs on STEM education was started to publish in 1990 (with 2 documents) and increased gradually until the year 2020 (21 documents).

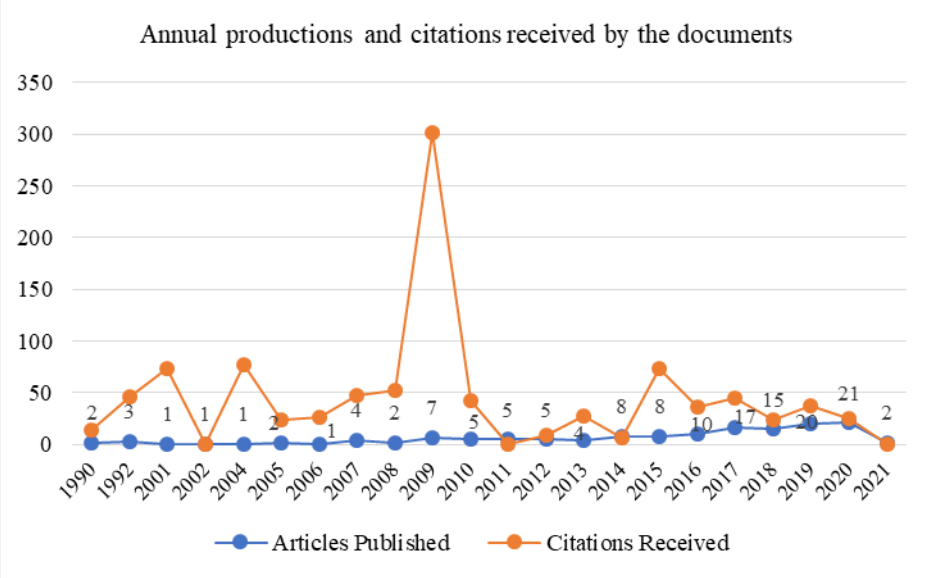

Figure 2
Annual scientific production

The citation line shows ups and down patterns throughout the period between 1990 to 2021. However, documents published in 2009 (7 documents) became standout as their citations showed a rapid increase (301) compared to other documents. This rapid increase in citations indicates that these are the core documents published in STEM education focusing on the teachers' pedagogical beliefs. As these documents were published a bit earlier in the year 2009, they drew attention to other researchers to read and cite their contributions.

Authors' Productivity

Figure 3 has been drawn with the help of Lotka's law (Lotka, 1926) to illustrate the authors' productivity pattern on teachers' pedagogical beliefs in STEM education. It clarifies the recurrence of the authors' publications on a particular topic in a given period. The solid line with the blue shaded region outlines the '% of authors' who wrote their document in this field.

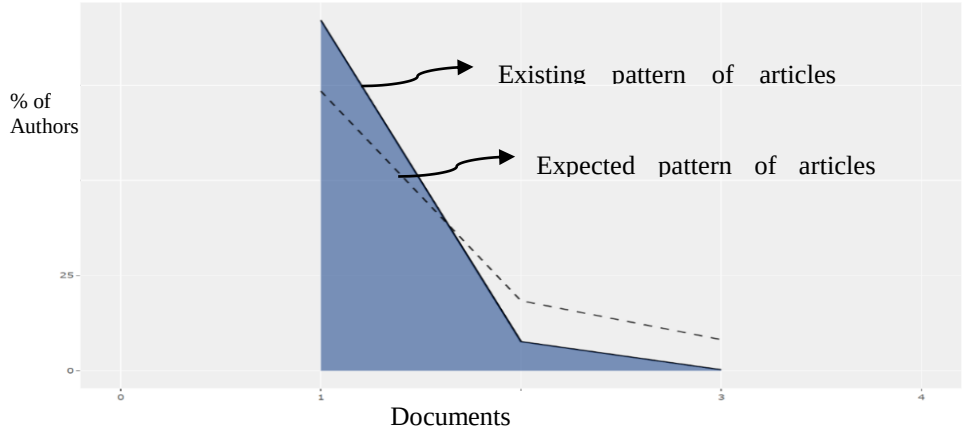

Figure 3
Lotka's Law shows the authors' productivity pattern

The solid line shows that the '% of authors' declines with the growth of the number of documents. The dashed line implies the ideal pattern of the '% of authors' who should publish the number of articles in STEM education. As revealed, a maximum portion (about 95%) of the authors have published just one document which is higher than the ideal case scenario (75%). On the contrary, 7.8 % of the authors wrote two documents and just 0.5% of authors wrote three documents to contribute to this research field. This is much lower than the ideal pattern of the '% of authors' and published document ratio which should be 20% for the two documents and 10% for the three documents. This suggests two things: first, though numerous authors did publish only one document in this field they did not consider it as their main research stream and thus did not engage with any further research in this field. Second, as per Lotka's law, this field of research did not reach maturity yet. Therefore, there is a possibility that some of the researchers might continue to work and publish more articles in this field in future.

Top authors' production over time

Figure 4 shows the top 20 authors' article production on teachers' pedagogical beliefs in STEM education with at least two documents. As revealed authors' production has rapidly increased after the year 2014. The two authors namely Canty D and Hunag K have continuously worked in this domain since 2014. Atwood A is the only other author who published two articles in 2009 and 2010. Also, Clark A, Ernst J, Hogue B, and Lari N published two articles in 2011.

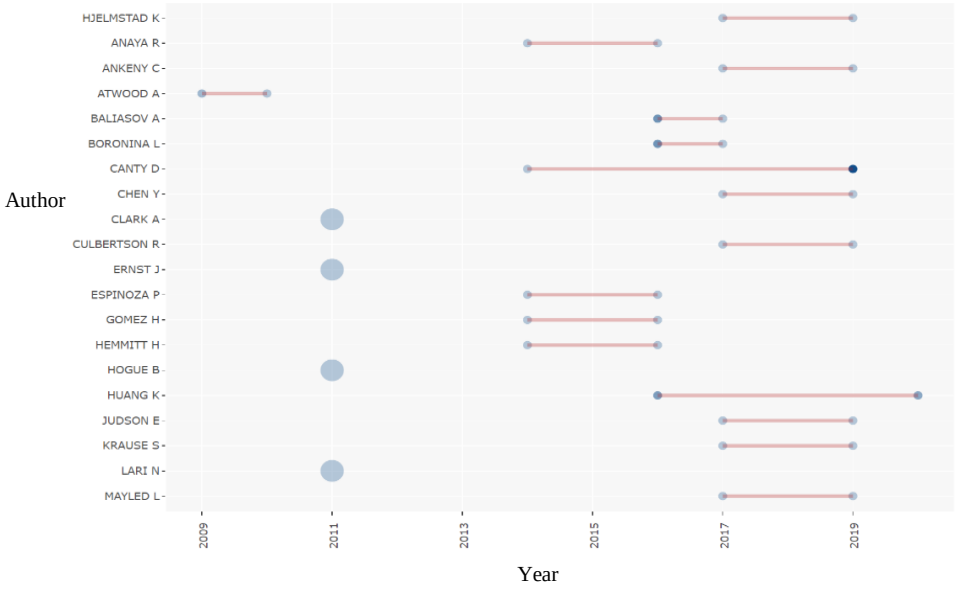

Figure 4
The 20 most productive authors on teachers' pedagogical belief in STEM education

Most Impactful Documents, Authors, Institutions, and Countries

Table 2 indicates that the most influential article is produced by Mayo J. (2009) and published in the Journal of *Science*. Compared to the other publications, this article became the most cited document in the domain of STEM education. In fact, among the top four cited documents Mayo J. (2009) has the highest citation *(223),* followed by 77 citations by McCormick R. (2004)*;* 73 citations by Cajas, F. (2001), and 53 citations by Stone, Alfeld, & Pearson (2008). Besides, out of five top-cited articles, the *International Journal of Technology and Design Education* published two of them. Furthermore, table 2 also revealed that Mayo J. (2009) tops the list with a total citation per year (17.153) and normalized total citation (5.186).

Table 2
Most impactful documents

Paper	*TC	TC per Year	Normalized TC
Mayo J. (2009), *Science*	223	17.15	5.18
McCormick R. (2004), *International Journal of Technology and Design Education*	77	4.27	1.00
Cajas, F. (2001), *Journal of Research in Science Teaching*	73	3.47	1.00
Stone, Alfeld, & Pearson (2008), *American Educational Research Journal*	53	3.78	2.00
Ritz & Fan (2015), *International Journal of Technology and Design Education*	42	6.00	4.54
Shea, Ertelt, Gmeiner, & Ameri (2010), *Advanced Engineering Informatics*	39	3.25	4.53
Özden (2007), *Eurasia Journal of Mathematics, Science and Technology Education*	36	2.40	3.00
Tala (2009), *Science and Education*	34	2.61	0.79
Carr, A. J. M. (1992), *Research in Science Education*	30	1.00	1.95
Vazquez, A. (2009), *BMC Systems Biology*	28	2.15	0.65
Dow W. (2006), *International Journal of Technology Design Education*	27	1.68	1.00
Hudson P. (2012), *International Journal of Science Education*	19	1.11	1.58
Rogers & Twidle (2013), *Research in Science & Technological Education*	17	1.88	2.42
Acm, Bastarrica, & Perovich (2017), *IEEE/ACM 39th International Conference on Software Engineering: Software Engineering Education and Training Track*	16	3.20	6.04
Niyazi Erdogan (2015), *International Journal of Education in Mathematics, Science and Technology*	16	2.28	1.72
Battaglia, D. M., & Kaya (2015), *International Journal of Engineering Education*	13	1.85	1.40
Hardy T. (1990), *Research in Science Education*	13	0.40	2.00
Fuentes, D. S., Warnick, G. M., Jesiek, B. K., & Davies (2016), *ASEE Annual Conference and Exposition, Conference Proceedings*	12	2.00	3.33
Markley et al. (2009), *Journal of Geoscience Education*	11	0.84	0.25
Aubusson & Webb (1992), *Research in Science Education*	11	0.36	0.71

**TC= Total Citations*

Table 3 shows the most prolific author in STEM education research regarding the teachers' pedagogical beliefs. As revealed Hjelmstad K is the most impactful author with the highest 3 publications. The rest of the authors following him have 2 publications each contributing to this field of knowledge.

Table 3
20 most impactful authors, institutions, and countries

Authors	NP	Institutions	NP	Countries	NP
Hjelmstad K	3	*University of Wisconsin*	10	*USA*	69
Anaya R	2	*North Carolina State University*	9	*Spain*	12
Ankeny C	2	*University of Toledo*	5	*UK*	12
Atwood A	2	*Old Dominion University*	4	*Turkey*	11
Baliasov A	2	*Purdue University*	4	*Brazil*	8
Boronina L	2	*Arizona State University*	3	*Indonesia*	8
Canty D	2	*California State University*	3	*China*	6
Chen Y	2	*Florida Atlantic University*	3	*Germany*	6
Clark A	2	*Georgia Institute of Technology*	3	*Australia*	5
Culbertson R	2	*Humboldt State University*	3	*Ukraine*	5
Ernst J	2	*Texas A and M University*	3	*Ireland*	4
Espinoza P	2	*University La Rioja*	3	*Italy*	4
Gomezh	2	*Universitat Politcnica De Catalunya (UPC)*	3	*Russia*	4
Hemmitt	2	*University of Louisville*	3	*South Africa*	4
Hogue B	2	*University of The West of England*	3	*Latvia*	2
Huang K	2	*Ural Fed University*	3	*New Zealand*	2
Judson	2	*Arizona State University*	2	*Singapore*	2
Krauses	2	Hong Kong Polytechnic University	2	Austria	1
Lari N	2	Natl Chiayi University	2	Belgium	1
Mayled L	2	Natl Tech University Ukraine	2	Canada	1

NP = Number of Publications

Among the top 20 institutes, the University of Wisconsin ranked first with 10 publications, following North Carolina State University (9 publications) and the University of Toledo (5 publications). At the country level, the USA ranked the top position with 69 publications by a far distance compared to other countries in the list. Spain (12 documents), UK (12 documents), and Turkey (11 documents) are the three most contributing countries following USA.

Most Relevant Sources

Table 4 reveals that *ASEE Annual Conference and Exposition Conference Proceedings* is the most contributing source in STEM education research with the highest 21 publications. *The International Journal of Technology and Design Education*, *International Journal of Engineering Education* and *Research in Science Education* are the other most contributing journals with 9, 5, and 5 publications respectively.

Table 4
10 Most impactful sources in STEM education

Sources	NP	IF (2020)	SJR	H-index	Quartile
ASEE Annual Conference and Exposition Conference Proceedings	21	-	-	31	-
International Journal of Technology and Design Education	9	2.177	0.82	40	Q1
International Journal of Engineering Education	5	-	0.55	50	Q1
Research in Science Education	5	5.439	1.21	53	Q1
African Journal of Research in Mathematics Science and Technology Education	4	-	0.34	15	Q2
International Journal of Science Education	3	2.241	1.09	108	Q1
International Conference of Education Research and Innovation	2	-	-	-	-
Chemistry Education Research and Practice	2	2.959	0.76	45	Q1
Computers in Education Journal	2	0.20	0.14	13	Q4
EduLearn proceedings	2	-	-	-	-

NP= Number of publications; IF = Impact Factor; SJR = SCImago Journal Rank Indicator

In terms of impact factor and SJR indicator, the journal of *Research in Science Education* is the most reputable source in publishing documents on teachers' pedagogical beliefs in STEM education. This journal also has the second-highest h-index (53) following the *International Journal of Science Education* (h-index =108). Another noteworthy finding is that most of the sources positioned themselves among the top 25% (Q1) in the journal ranking.

Source Dynamics with Regards to the Contribution over Time

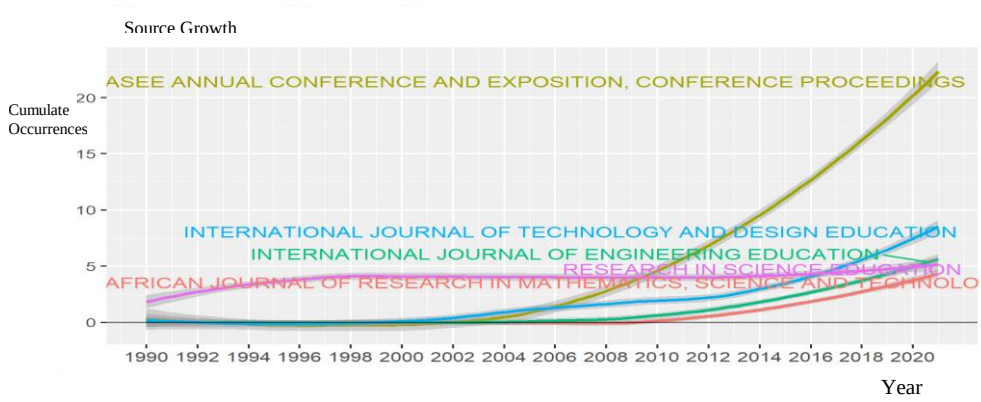

Figure 5
Source dynamics with regards to the contribution over time

Figure 5 shows that the contribution of the *ASEE Annual conference and exposition* in this field began in 2004. Since then, it has drastically increased its contribution (with 21 publications) to the field of teachers' pedagogical beliefs in STEM education. In 2020, the journal contribution reached a distant height compared to the other sources. In contrast, the Journal of *Research in Science Education* has almost constantly contributed to this field since 1990 up until 2021. Besides, *the International Journal of*

technology and design education and *the International Journal of Engineering Education* recently showed a steady rise in the publications after the year 2013.

Three Field Plots: Relation between Authors, Themes, and Countries

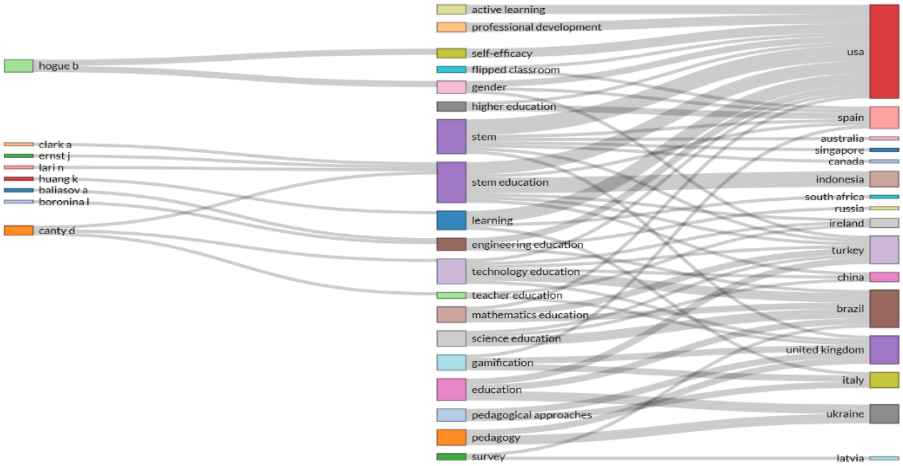

Figure 6
Three field plots of author-keywords-country based on the Sankey diagram

Figure 6 shows that Canty D contributed to more research themes such as 'stem education', 'teacher education' and 'technology education'; whereas Huge B has given more focus on gender issues and self-efficacy in the domain of STEM education. Baliasov A and Boronina I are the two notable authors who worked on Engineering education within the domain of STEM education. As stand out, 'STEM education' is the most used keyword following mathematics education, technology education, and gender. Among the country, the USA contributed to the most research streams of STEM education following Brazil, UK, Turkey, and Spain. Also, researchers from Ukraine and Italy have focused more on pedagogy, education, and gamification concept related to this field.

Co-Occurrences of Author Keywords

Analysis of keyword co-occurrences turns into a critical methodology in bibliometric research to show the mapping of the related research themes (Cheng, et al., 2018; Radhakrishnan, et al., 2017). Figure 7 shows the most connected research keywords in the topic of teachers' pedagogical beliefs towards STEM education. To map the co-occurrences of the author keywords, the minimum occurrence of a keyword is set to 2. Out of the 366 keywords, only 40 meet the threshold. The clusters created by the most related keywords are determined by the colour of the nodes. The frequency of occurrences of a keyword determines the size of the node for that keyword. The distance between two nodes indicates the strength of the association among the keywords. As a result, the stronger the association between the keywords has been observed the closer the two nodes are.

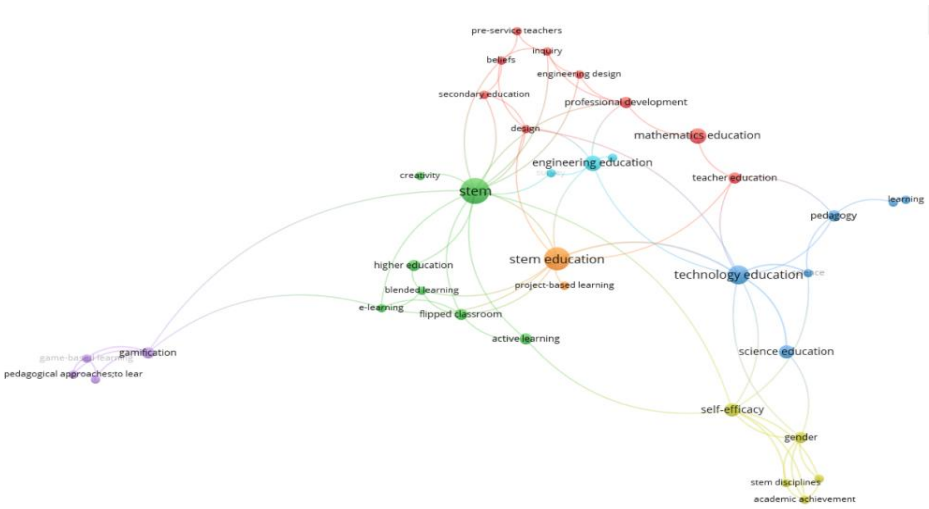

Figure 7
The 40 most indicative keywords' co-occurrence

Figure 7 demonstrates six clusters of author keywords. These clusters show the predominant research themes about the technical teachers' pedagogical beliefs. The green cluster highlights the STEM education research stream related to online pedagogy such as flipped learning, blended learning, active learning, and so on. Further, the green cluster clarifies a learning environment that requires teachers to consider a student-centred pedagogical approach in the context of e-learning. In a similar vein, the purple cluster focuses on pedagogical approaches related to gamification and game-based learning that provide students with an active learning environment. The orange cluster highlights project-based learning which also focuses student-centred approach with an active learning environment. The blue and red coloured clusters focus on technology education, science education, engineering education, teacher education, mathematics education, professional development, engineering design, and teachers' beliefs to highlight the broader perspectives of STEM education research in recent times.

Table 5
20 most co-occurring author keywords

Keyword	Occurrences	*TLS	Keyword	Occurrences	TLS
Stem Education	22	26	Game-Based Learning	2	6
Technology Education	7	13	Pedagogical Approaches to Learning	2	6
Self-Efficacy	4	12	Stem Teaching	2	6
Gender	3	10	Beliefs	2	5
Academic Achievement	2	8	E-Learning	2	5
Gamification	3	8	Flipped Classroom	3	5
Stem Disciplines	2	8	Inquiry	2	5
Vocational Aspirations	2	8	Professional Development	3	5
Design	2	6	Blended Learning	2	4
Engineering Education	5	6	Pedagogy	3	4

**TLS = Total Link Strength*

Corresponding to Figure 7, Table 5 indicates the total link strength explaining the magnitude of individual connection associated with the keywords. As portrayed, stem education, technology education, self-efficacy, gender, and academic achievement are the five most frequently occurring author keywords in the topic of teachers' pedagogical beliefs in STEM education research with the highest total link strength.

Country collaboration network

In bibliometric research, social network analysis is used to investigate scientific collaboration and co-author relationships among the countries and institutions. It allows mapping the key countries in the given study field. The collaboration and network between countries and institutions are playing a significant role in understanding the emerging research fields. Also, this collaboration among the scientific community drives the development and improvement of that research field (Al Mamun et al., 2021). The collaboration network shows the academic relationship among the research networks in various institutions and nations (Donthu, et al., 2020).

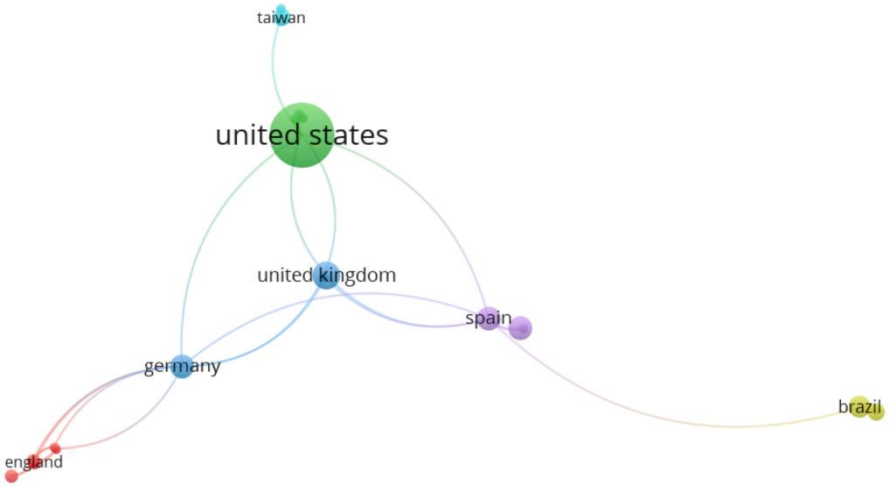

Figure 8
Mapping and visualizing the authorship co-occurrences between the countries

Figure 8 depicts such collaborative networks between the nations in the research of technical teachers' pedagogical beliefs in STEM education. The width of the lines indicates the degree of cooperation between the two countries (Liao et al., 2018). The size of the nodes represents the number of documents collaboratively published by the respective country. The larger node indicates a greater number of publications with that country. Several important collaborative networks commenced in STEM education research led by the United States, United Kingdom, Germany, and Spain. Particularly, the degree of collaboration among the United Kingdom, Germany, and Spain are much higher compared to other countries. In terms of the number of publications, the United States is the most contributing country (47 documents) in this field (Table 6). In brief,

all the countries illustrated in the collaboration network (Figure 8) are the most impactful nations in STEM Education that drive the research and development in this field.

Table 6
Top 20 countries in the collaboration network

Country	NP	TC	TLS	Country	NP	TC	TLS
Germany	6	34	8	Indonesia	2	4	2
United states	47	138	8	Italy	2	10	2
Argentina	1	53	4	Sweden	2	29	2
Brazil	5	5	4	Ukraine	2	6	2
Serbia	1	5	4	Ireland	2	6	1
Singapore	1	1	4	Israel	1	0	1
United Kingdom	8	0	4	Kazakhstan	1	1	1
Australia	5	0	3	Lithuania	1	1	1
Spain	6	14	3	Netherlands	1	1	1
Ecuador	1	16	2	New Zealand	2	5	1

NP = Number of publications, TC= Total Citations, TLS = Total Link Strength

Further, to comprehend the joint effort and strength between the nations, **Table 6** shows the total link strength of the individual countries. The width of lines and the gap between the nodes show the coordinated effort and strength associated with the countries.

IMPLICATIONS AND LIMITATIONS

This study has various implications for researchers and academicians in the field of STEM education. Results from this study may help for future research development and growth in STEM education. It is particularly significant for decision-makers for future planning and implementation of STEM education into the curriculum. It also helps policymakers to understand how the advancement of STEM education research is happening currently to meet the global demand of STEM graduates (Hsu & Yeh, 2019).

Nonetheless, this investigation experiences a few constraints. For example, this study only includes the Web of Science core collection and the Scopus database for the analysis. Future research may include other popular indexing services like Google Scholar, PubMed, EBSCO, DOAJ and so on. Also, this study includes only journals and conference proceedings and filtering the other types of documents. Finally, we acknowledge a methodological limitation of this study by utilising only quantitative data to analyse the trend and research font of the technical teachers' belief in STEM education. A more rigorous analysis by utilizing both quantitative and qualitative data might be conducted in the future for exploring the research front in this field.

CONCLUSION

This study offers a comprehensive mapping of the research on technical teachers' pedagogical beliefs in STEM education by synthesizing the quantitative data extracted from SCOPUS and Web of Science core collection database. The researchers adopted a bibliometric review methodology to know the recent research trends in the research of teachers' pedagogical beliefs in STEM education. This study distinguishes the most

impactful authors, institutions, sources, and countries associated with STEM education research. As revealed, the STEM education research has drawn considerable attention from different nations, especially those from technologically progressed nations, such as USA, UK, Germany, Turkey, and Spain. Specifically, USA is the most prominent country in this field by publishing a greater number of documents, receiving the highest number of citations, and having the highest total link strength in the country collaboration network. The keyword co-occurrence network revealed various bunches of STEM education research such as technology education, teacher education, engineering education, pedagogical beliefs, educational design, self-efficacy, gender issues etc. that have been emerged as the trending research front in recent times. Thus, the research findings indicate that educators should focus on STEM teachers' training to facilitate teachers' 'pedagogical beliefs' and 'practice' within the instructional settings. It also focuses on the recent development of STEM education related to the technical education field. Furthermore, the researchers recommended that the recent development of a blended learning environment also needs to be considered and should offer the necessary training to enhance teachers' ability to deliver the STEM subjects within the blended learning environment.

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