

The Synthesis for Research Trends in Identity Studies in STEM Education: A Bibliometric Analysis of the STEM Literature

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ABSTRACT

This review aims to analyze trends in identity studies research in peer-reviewed articles in STEM education indexed in the Web of Science database from first mention through the end of 2024. This study used bibliometric analysis for the evolutionary examination of large amounts of meta-data. Performance analysis and science mapping analysis were performed. For performance analysis, metrics-related to publications and citations-related metrics are used. For science mapping analysis, citation analysis, bibliographic coupling analysis, and co-word analysis of documents for prevailing themes and emerging areas of interest, and relationships between identity topics in STEM education are presented. This study found that the number of identity studies in STEM education and citations to these studies have been steadily increasing. Identity research in STEM education is mostly conducted in the United States of America. Teacher education and professional identity are the prevailing themes while STEM identity, mathematics identity, science identity, belonging, inclusivity, gender, and COVID-19 are emerging areas of interest. Science, professional, physical, online, and physics identities are predominantly studied. However, more research is needed on specific identity types. This review sheds light on the present state of identity studies and research gaps in STEM education and offers important implications and recommendations.

KEY WORDS: Engineering identity, mathematics identity, science identity, STEM identity, technology identity

INTRODUCTION

Recent studies have shown that identity has been an emerging area of interest in the past two decades of science education (Li, 2024). As a person acts and interacts, others perceive that person as acting and interacting as a particular kind of person or even as multiple different kinds at the same time. Identity is seen as an important tool for understanding schools and society. Identity is a more dynamic approach than race, class, and gender, which are seen as static variables, but are related to how someone is recognized as someone in a given context and can change over time and in different contexts through interaction (Gee, 2000). As Lave and Wenger (1991) noted, learning is a social practice that contributes to the recognition and development of an individual's identity. Learning environments enable individuals to discover who they are as a result of their exploration of identity. According to the definition of Gee (2000), disciplinary identity can be conceptualized as the perception of a person in the corresponding discipline. STEM identities have been a focus of educational research for examining disciplinary identities and the pursuit and understanding of science (Kim et al., 2018).

Although many studies revealed that identity affects career interest (e.g., Zhao et al., 2024), career choice (e.g., Godwin et al., 2013), career aspirations (e.g., Sheldrake, 2018), self-efficacy (e.g., Brändle et al., 2018), experience (e.g.,

Dou et al., 2019), participation (e.g., Allie et al., 2009), engagement (e.g., Murphy and Kelp, 2023), and achievement (e.g., Miller-Cotto and Byrnes, 2016), a few bibliometric studies focused on identity in different STEM subjects. The studies were either on a specific topic, such as a bibliometric study of factors influencing students' integrated STEM choices and success (Maphosa et al., 2022), or on a specific grade level or year range, such as two decades of STEM education research in middle school (Le Thi Thu et al., 2021). However, no bibliometric review study was found to identify identity research trends in STEM education or more than one STEM discipline. Therefore, this study aims to fill this literature gap by reviewing identity studies in the STEM education literature. This study reviewed the studies that addressed disciplinary identity in the four STEM disciplines separately, as well as studies that addressed integrated STEM identity, to gain a comprehensive understanding of STEM identity.

Aim and Research Question

This review aims to analyze trends in identity studies in peer-reviewed articles in STEM education indexed in the Web of Science (WoS) database from the first mention through the end of 2024. The following research question is addressed in the present research: "How is identity research addressed in STEM education from the first mention to the end of 2024 using bibliometric analysis?"

LITERATURE REVIEW

Identity Studies in STEM Education

Identity is a malleable construct because it has the potential to change and evolve through social interaction and real-world experiences. Identity in STEM education research has historically evolved from developmental perspectives (e.g., Erikson, 1950; 1968; Marcia, 1966) to sociocultural identity (e.g., Gee, 2000; Wenger, 1998) and discipline-specific perspectives (e.g., Carlone and Johnson, 2007; Hazari et al., 2010).

Historically, the first studies date back to Erikson's (1950; 1968) psychosocial identity theory. According to psychosocial developmental theory, adolescents' difficulty in defining their identity is a polar result of identity versus role confusion resulting from psychosocial crisis. Although adolescents have difficulty defining their identity, they need to create a stable identity. For this reason, Erikson (1968) points to the influence of psychological and physiological factors on identity development, as well as environmental factors. Marcia (1966), on the other hand, presented the Identity Status Theory and further developed Erikson's theory of identity formation, arguing that the formation of ego identity is effective in the formation of stable identity by individuals. According to Marcia's (1966) Identity Status Theory, during adolescence, individuals form their identity and sense of self by achieving certain stages, such as identity achievement, identity moratorium, identity foreclosure, and identity diffusion, respectively. In Marcia's (1966) study, the social context is located in social interactions and practices based on developmental foundations.

Lave and Wenger (1991) introduced the concepts of legitimate peripheral participation and communities of practice into the literature, arguing that learning emerges from relationships with social communities and is constructed through social interaction. According to the communities of practice framework, learners inevitably participate in the sociocultural practices of the community. Through legitimate peripheral participation, they can develop relationships with new learners and provide a pathway into communities of knowledge and practice through the construction of identities. Thus, learning is not only about the transfer of knowledge, but identities are constructed through the process of participating in the sociocultural practices of the community. Similar to Lave and Wenger's (1991) approach, Gee (2000) considers identity in a social context. Gee (2000) argues that identity is constructed in a social context through the processes of a state, a position, an individual trait, and experiences by presenting it in a four-additive structure as nature identity, institution identity, discourse identity, and affinity identity. These studies provide a solid foundation for STEM identity research by pointing to the importance of identity in its psychological underpinnings and understanding how students develop their identities through participation in a STEM learning community. It is important for students to identify with science, as their science identity

can be influenced by various social constructs, such as ethnicity and gender (Archer et al., 2010; Carlone and Johnson, 2007).

The concept of identity plays a central role in the development of an individual's sense of self through continuous interaction with the social environment. Some researchers define scientific identity as an intrinsic quality of the individual, while others consider it a dynamic process shaped by social relationships and interactions (e.g., Jiang and Wei, 2023). STEM identity has been theorized by researchers, such as Carlone and Johnson, (2007) and Hazari et al. (2010). Carlone and Johnson's (2007) model of science identity is based on Gee's identity theory and the three dimensions of science identity, namely, competence, performance, and recognition. Carlone and Johnson (2007) defined the performance dimension as making one's scientific practices visible to others, the recognition dimension as recognizing oneself and others as a scientist, and the competence dimension as understanding the content of science. Potvin and Hazari (2013) further extended the model in the context of physics education, building on Carlone and Johnson's (2007) science identity model. Potvin and Hazari (2013) proposed a physics identity framework that predicts students' affinity for physics and their physics-related career choices. This framework consists of the following dimensions: performance beliefs, competence beliefs, recognition beliefs, and interest. This framework differs from Carlone and Johnson's (2007) framework in two ways. While the population in Carlone and Johnson's (2007) framework was scientists, the population in Potvin and Hazari's (2013) framework was students. Unlike Carlone and Johnson (2007), Potvin and Hazari (2013) added the interest factor to their framework because scientists, unlike students, already have an established interest in science. In addition, while Carlone and Johnson (2007) conceptualized self-knowledge to include being recognized by others, Potvin and Hazari (2013) conceptualized self-knowledge as a key feature of having a scientific identity. Thus, throughout history, studies of science identity have focused on individuals belonging to science and developing their science identity in a social setting through dynamic interactions with educators in learning environments (e.g., Ulu and Yerdelen-Damar, 2024; Carlone and Johnson, 2007; Hazari et al., 2013).

The science identity model, developed by Carlone and Johnson (2007), is a widely used theory in science education and STEM education. It has been employed across various levels of science education (Archer et al., 2010; Avraamidou, 2018) and referenced in numerous studies (e.g., Hazari et al., 2013; Salehjee and Watts, 2018). A STEM identity is a multidimensional construct that one's sense of belonging to a STEM field, others' recognition of one as a STEM professional, and one's becoming part of a STEM community shape (Gee, 2000; Carlone and Johnson, 2007). Participation in this community requires shared values, knowledge, skills, and practices, all of which are essential for success. Numerous studies demonstrate that STEM identity is a more significant predictor of persistence than demographic factors (Chemers

et al., 2011; Dou and Cian, 2022). In this context, an individual's self-perception regarding their competence in developing a STEM identity, their capability in performing tasks in the field, and the acknowledgment they receive from their surroundings play a pivotal role in shaping their sense of belonging and motivation within the field. Consequently, the relationships between STEM identity, self-efficacy beliefs, and sense of belonging have become a point of interest for researchers.

METHODS

Research Methods

Bibliometric analysis, mainly a quantitative method, is used to identify trends in specific fields of study using large amounts of data that are too big for reviewing manually (Donthu et al., 2021; Verma and Gustafsson, 2020). Bibliometric studies are valuable in visualizing foundational and emerging themes in the field of study, providing a solid foundation for researchers to identify research gaps. As the analyzed data are enormous, the scope of bibliometric analysis is broad rather than specific, which prevents analyzing the field at a deep level, unlike systematic literature review methods (Donthu et al., 2021).

Data Collection

In this study, the WoS Core Collection database was used as the data collection source. As Zhu and Liu (2020) pointed out, WoS is a world-leading and prestigious database containing high-quality research. Compared with the Scopus database, the WoS database is old and holds a dominant role in research. Therefore, WoS is postulated as a suitable database for authoritative and old database. The framework of this study is based on the Preferred Reporting Items for Systematic reviews and Meta-Analyses (PRISMA) guideline, or Preferred Reporting Items for Systematic Reviews and Meta-Analyses. PRISMA guideline provides rigorous checklist items for review studies.

Inclusion and Exclusion criteria

Inclusion and exclusion criteria are determined by the researcher for the transparency of the review process (Moher et al., 2009). The following inclusion and exclusion criteria were considered in this study:

1. Studies were included if they were from the Education and Educational Research (E&ER) category, and studies outside this category were excluded
2. Studies were included if they were articles, review articles, or early access documents, and studies outside these document types were excluded
3. Studies were included if they were in English and excluded if they were not.

This bibliometric review was conducted in four stages, following the PRISMA flow diagram, to determine the articles included in this study. These stages were identification, screening, eligibility, and inclusion. Figure 1 shows each step of the article selection process for identity studies in STEM education in the WoS database using the PRISMA bibliometric

analysis flow diagram and the number of articles included and excluded in each step (Moher et al., 2009).

Identification

For the bibliometric analysis in this study, the researchers first identified the following keywords in the abstract section of the articles in the WoS database:

(scien* identity OR math* identity OR engineering identity OR techno* identity OR STEM identity OR physic* identity OR chemistry identity OR biology identity)

This keyword search was intentionally chosen to be as comprehensive as possible in documenting identity studies in STEM education. In this study, no year range was specified in the filtering process. Because the researchers' institutes offer open access to the WoS database, this study included all articles, both with and without open access. To conduct a comprehensive analysis, all articles from the first mention of identity in the WoS database to the end of 2024 were included in the analysis process. As a result of this process, 82,499 articles were identified.

Screening

Based on the purposes of this study, the research filtered the articles as the Education and Educational Research (E & ER) category under the WoS Core Collection in the WoS database. As a result of this process, the total number of articles decreased to 6,099.

Eligibility

Articles, review articles, and early access categories were filtered for document type. This filtering process is used to analyze empirical studies and trend studies first-hand using empirical study bibliometric data. The reason for selecting early access studies is to provide the most comprehensive literature review possible by including publications accepted for publication. As a result of this filtering process, the total number of articles was reduced to 4,798.

Included

The publication language of the studies was filtered as English. In this study, 450 non-English articles were identified, and these articles were excluded. As a result, for this study's bibliometric analysis 4,185 articles from the E & ER research category that were articles or review articles written in English were eligible and included. The filtering process for this phase was completed on November 16, 2024.

Validity and Reliability of the Study

The present study took several steps to ensure reliability by using well-established, widely recognized quantitative bibliometric techniques. First, the bibliometric analysis is widely considered a reliable method because it employs a transparent, consistent, unbiased, and reproducible quantitative review process (Bretas and Alon, 2021; Van Raan, 2014). Second, the bibliometric metadata was obtained from the WoS database. This database is a world leader in providing access to high-quality, peer-reviewed articles (Zhang et al.,

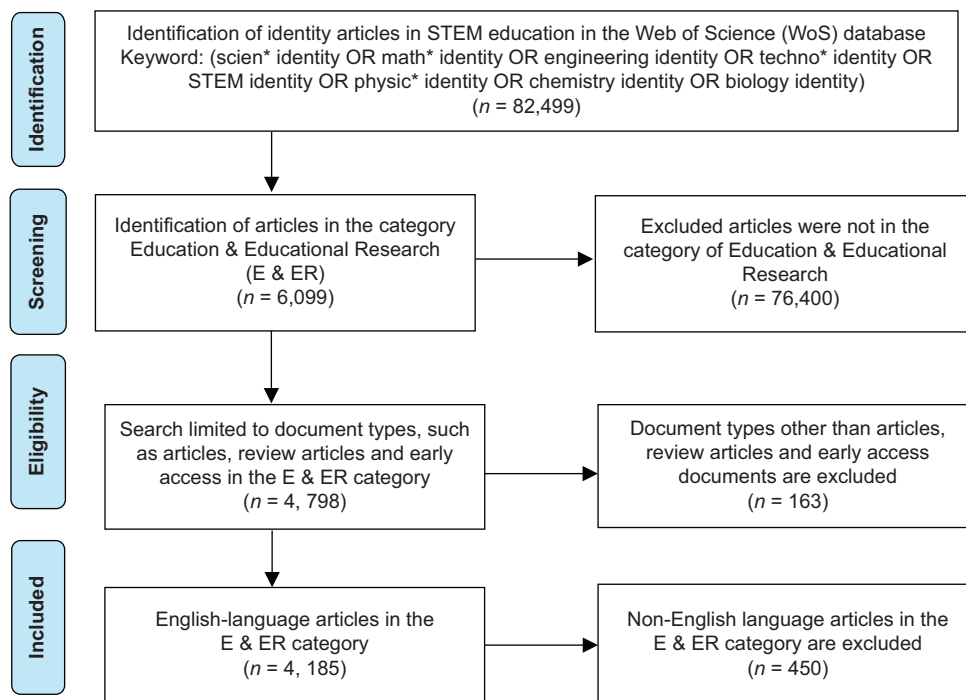


Figure 1: Article selection process on identity studies in STEM education using PRISMA flow diagram for bibliometric analysis (Moher et al., 2009)

2023; Zhu and Liu, 2020). Third, this study uses the PRISMA flow diagram, a widely used, internationally recognized, and reliable reporting tool for bibliometric studies that ensures reliability and transparency. It increases the reproducibility and transparency of the study by showing how the articles were selected according to the inclusion and exclusion criteria (Moher et al., 2009). Fourth, bibliometric analyses require meticulous data cleaning because data in bibliometric datasets may be documented differently (Donthu et al., 2021; Van Eck and Waltman, 2023). When creating scientific maps, the names of authors, institutions, countries, and document titles may vary from one publication to the next. Eliminating such inconsistencies through data cleaning is essential for an accurate and reliable representation of the data (Van Eck and Waltman, 2023). For example, for the emerging area of interest, author keywords are examined. Although “pre-service teachers” and “pre-service teachers” refer to the same concept, the program may perceive this word differently because of the hyphen and report a low frequency. Therefore, the thesaurus files for each analysis were carefully prepared to avoid erroneous entries and duplicates. Fifth, the primary author conducted the analyses and the secondary author-verified all resulting findings. Any discrepancies between the two researchers were addressed until a precise consensus was reached.

Data Analysis

A bibliometric review of articles indexed in the WoS database from the first mention through the end of 2024 was conducted to analyze the studies on identities in STEM education. Bibliometric analyses provide great value in summarizing large data sets that cannot be analyzed manually and in visualizing

emerging trends in the literature (Donthu et al., 2021). In this study, conducting a bibliometric analysis in the first phase was deemed appropriate to provide as comprehensive an overview as possible. A total of 4,185 articles selected for bibliometric screening in the WoS database were downloaded as plain text files. All files were uploaded to VOSviewer (Van Eck and Waltman, 2023) for bibliometric analysis.

First, the number of publications and number of citations of identity in STEM education studies by year in the WoS database were created from the Citation Report category in the WoS database to reveal trends in the number of publications and number of citations. Bibliometric analyses are divided into: performance analysis and science mapping analysis. For performance analysis, metrics related to publications and citations and the results of the most influential documents by total number of citations are presented. For science mapping analysis, the results of research networks of studies by citations, most influential documents by total number of citations, bibliographic coupling analysis and co-word analysis of documents for prevailing themes and emerging areas of interest, and relationships between identity topics in STEM education are presented.

RESULTS

Research Publication Trends by Years

Figure 2 shows the publication and citation trend of articles in the WoS database in science, mathematics, engineering, technology, STEM, physics, chemistry, and biology. The graph in Figure 2 was generated from the WoS database. The 4,185 articles included in this review were cited a total of

73,653 times. The first studies of identity in STEM education date back to 1992. As shown in Figure 2, the number of studies generally increases over the years, and the number of citations to these studies has increased steadily.

Most Prolific Authors

Prolific authors are the backbone forces that lead the development of scientific knowledge in a particular field. Prolific authors are evaluated according to the number of publications and citations (Wang et al., 2023). A total of 4,185 articles included in this review were contributed by 9,110 authors. Authors who published 10 or more studies on identities are listed in Table 1. Lousi Archer and Zahra Hazari are the most prolific authors in identity studies in STEM education in terms of the total number of publications. The number of articles published by prominent authors accounts for 3.65% ($n = 153$) of the total number of articles ($n = 4,185$). In addition, the number of citations of articles published by prominent authors accounts for 9.40% ($n = 6,913$) of the total number of citations ($n = 73,653$).

Most Influential Documents

In the VOSviewer program, the analysis type was selected as “citation” and the unit of analysis as “document.” 177 of the 41,185 articles with 100 or more citations were visualized. Figure 3 shows the most influential studies on identity in STEM education according to the number of citations. Carlone and Johnson (2007), Hunter et al. (2007), Allender et al. (2006), Greenhow et al. (2009), Hazari et al. (2010), Beijaard et al. (2000) were found to be the most influential documents.

These studies were found to be related to science identity (Carlone and Johnson, 2007), professional identity (Beijaard et al., 2000; Hunter et al., 2007), physical identity (Allender et al., 2006), online identity (Greenhow et al., 2009), and physics identity (Hazari et al., 2010). Table 2 shows the article title, journal title, number of citations, and average number of citations per year for these influential documents in identity research in STEM education.

Prevailing Themes and Emerging Areas of Interest in Identity Studies STEM Education

Analysis of emerging areas of interest is valuable in identifying gaps in research areas and guiding future research. This study used bibliographic coupling analysis to create thematic clusters based on cited publications. This method visualizes the evolution of identity studies in STEM education. Recent publications can gain visibility by conducting bibliographic coupling analysis (Donthu et al., 2021).

Figure 4 shows a network visualization of documents for prevailing themes in identity research in STEM education with 30 or more citations. In the network visualization shown in Figure 4, items are represented by labels and, by default, a circle. The size of the label and circle is determined by the weight of the item. The weight determines how prominently the items are displayed on the map, and the larger the weight of the item, the larger the label and the larger the circle (Van Eck and Waltman, 2023). The lines between the items represent the

Table 1: Authors who have published 10 or more studies on identities

Prolific authors	Total number of publications	Total number of citations
Archer, Louise	17	890
Hazari, Zahra	16	1,329
Avraamidou, Lucy	13	451
Barton, Angela Calabrese	13	1,107
Dewitt, Jennifer	11	814
Heyd-Metzuyanin, Einat	11	248
Madsen, Lene Moller	11	303
Singh, Chandralekha	11	255
Black, Laura	10	254
Godec, Spela	10	151
Olitsky, Stacy	10	183
Williams, Julian	10	234
Wong, Billy	10	694
Total	153	6,913

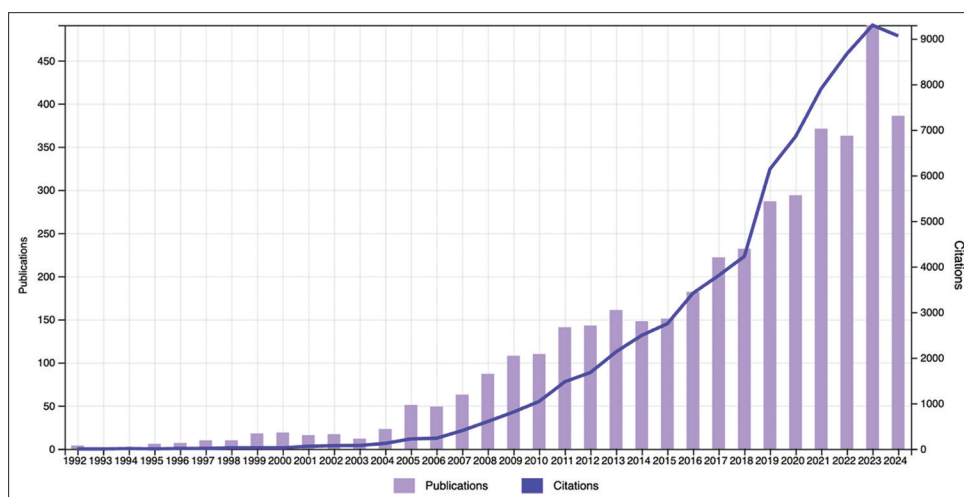


Figure 2: Annual publication and citation trends in identity research in STEM education (WoS database, 2024, last accessed: 16 December 2024)

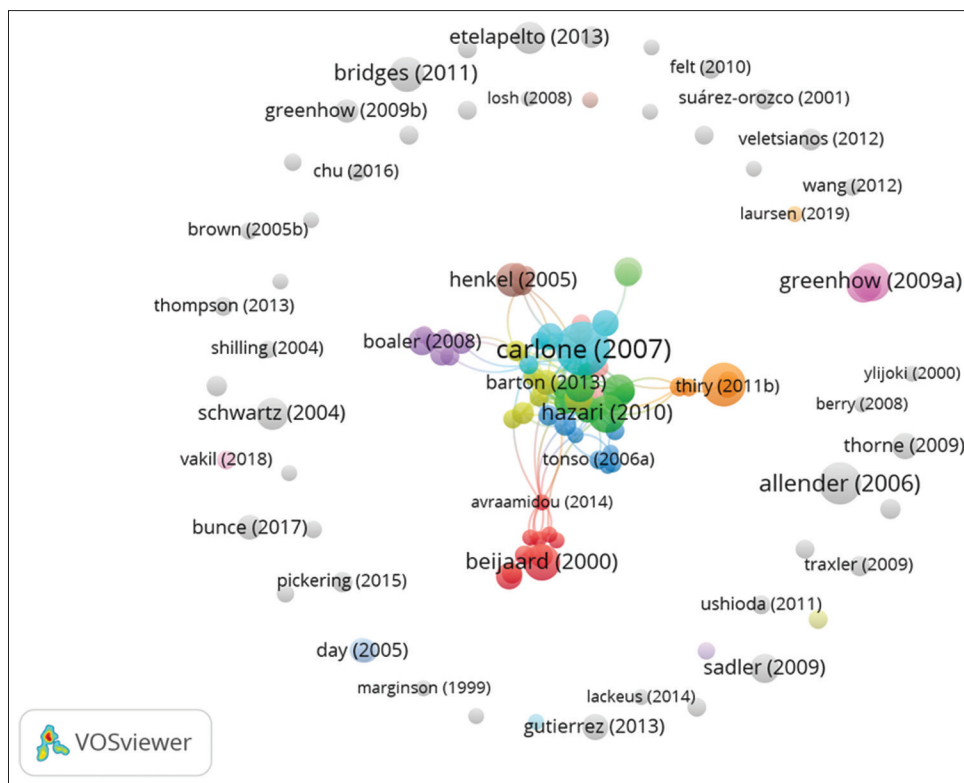


Figure 3: Identity research in STEM education networks with 100 or more citations

Table 2: The top most influential identity studies have more than 500 total citations

Article title	Reference	Journal title	Number of citations	Average citations per year
Understanding the science experiences of successful women of color: Science identity as an analytic lens	Carlone and Johnson, 2007	Journal of Research in Science Teaching	1,145	63.61
Becoming a scientist: The role of undergraduate research in students' cognitive, personal, and professional development	Hunter et al., 2007	Science Education	743	41.28
Understanding participation in sport and physical activity among children and adults: A review of qualitative studies	Allender et al., 2006	Health Education Research	717	37.74
Learning, teaching, and scholarship in a digital age: Web 2.0 and classroom research: What path should We take now?	Greenhow et al., 2009	Educational Researcher	575	35.94
Connecting high school physics experiences, outcome expectations, physics identity, and physics career choice: A gender study	Hazari et al., 2010	Journal of Research in Science Teaching	573	38.2
Teachers' perceptions of professional identity: An exploratory study from a personal knowledge perspective	Beijaard et al., 2000	Teaching and Teacher Education	520	20.8

connections between the items. Science identity (e.g., Archer et al., 2010; Carlone, 2004; Carlone and Johnson, 2007), physics identity (e.g., Hazari et al., 2010), professional identity (e.g., Beijaard et al., 2000; Henkel, 2005; Hunter et al., 2007), discursive identity (Brown, 2004) have been predominantly studied.

Figure 5 shows an overlay visualization of documents for prevailing themes in identity research in STEM education with 30 or more citations. Except for the different coloring of the elements, the overlay visualization is identical to the network visualization. In the overlay visualization, the change in subjects studied by year is shown in accordance with the color coding shown in a color bar in the lower right corner

(Van Eck and Waltman, 2023). It is seen that science identity (e.g., Atkins et al., 2020; Avraamidou, 2020; Fisher et al., 2020; Kim et al., 2018) and physics identity (e.g., Kalender et al., 2019) themes continued to be explored, and in addition, STEM identity (e.g., Dou et al., 2019; Starr et al., 2020) themes emerged as an area of interest.

Co-word analysis was also used to analyze trends in identity research in STEM education more comprehensively. Co-word analysis is used to analyze existing or future relationships between topics in a research area based on author keywords (Donthu et al., 2021). As shown in Figure 6, research on identity in STEM education is clustered into five groups. The bubble with each keyword changes according to the frequency

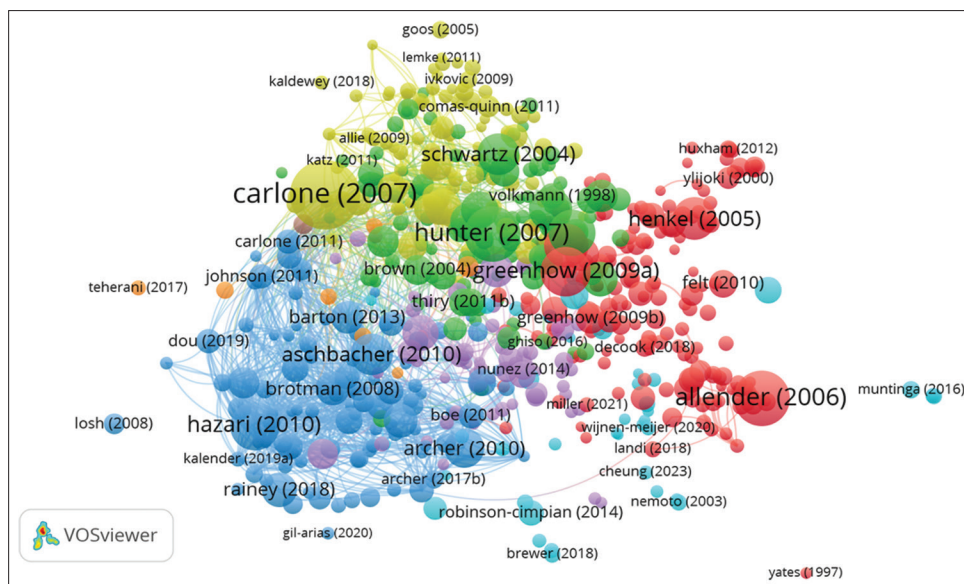


Figure 4: Network visualization of documents for prevailing themes in identity research in STEM education

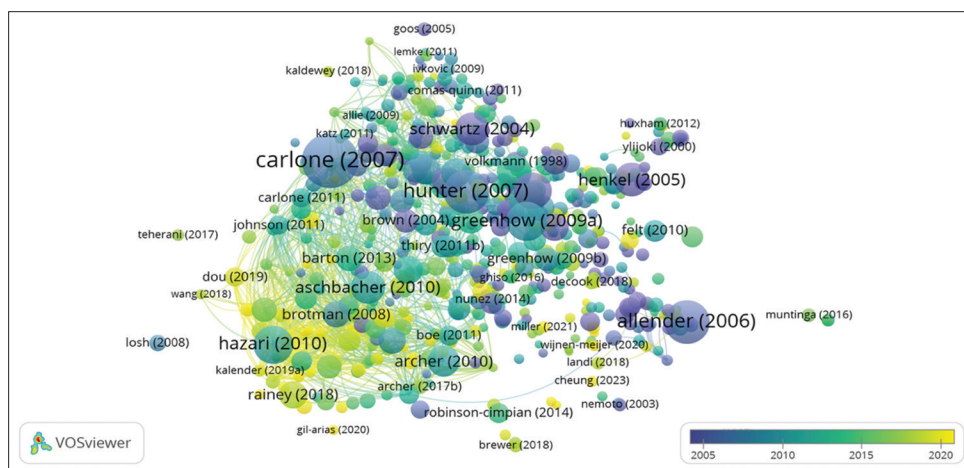


Figure 5: Overlay visualization of documents for emergent area of interest in identity research in STEM education

of use of the author's keyword. In Figure 6, the main word is identity, and the dominant words in each group are as follows: teacher education, professional identity, STEM, gender, and technology. Table 3 illustrates prevailing identity themes and author keywords in identity research in STEM education.

Figure 7 shows the emerging areas of interest in identity research in STEM education over the years. Although teacher education and professional identity are the prevailing themes, it can be seen that in recent years there has been an emerging trend in studies related to STEM, mathematics identity, science identity, belonging, inclusion, gender, and COVID-19.

Leading Countries

One hundred four countries contributed 4,185 articles included in this review. Out of 104 countries, the top 10 host countries with the highest number of identity studies in STEM education are shown in Table 4. There are eight host countries where more than 100 studies have been published. The United States

of America (USA) was the dominant country with the highest number of identity studies in STEM education. Authors in the USA published 1,797 studies, representing 43% of the total studies included in this review ($n = 4,185$). After the USA, authors in the UK and Australia were in the top three countries in terms of the number of articles, with a total of over 300 studies. The contribution of the top 10 leading countries to identity studies in STEM education ($n = 3,554$) is 85% of all published articles selected for this review ($n = 4,185$).

The 4,185 articles included in this review were cited 73,653 times. When comparing countries in terms of total citations, the USA is a leader in the number of citations received by authors for their published work. The number of citations received by the works of authors from the USA ($n = 39,905$) accounts for 54% of the total number of citations received by the works included in this review study ($n = 73,653$). After the USA, authors from the United Kingdom (UK) ranked second in terms of citations, publishing papers with more than 10,000

Social Interaction among Authors in Identity Research in STEM Education

It is important to examine the social interactions between authors as they can influence the development of the research field (Donthu et al., 2021). Of the 9,110 authors, 87 have a minimum of five documents. Figure 9 illustrates the social interaction among identity research authors in STEM education. Among the prominent authors by number of publications, Louise Archer, Zahra Hazari, Julian Williams and, Lene Moller Madsen are the most collaborative authors. It was found that Louise Archer established collaboration with Heidi Carlone, Jennifer Dewitt, Billy Wong, and Justin Dillon and worked on science identity. Zahra Hazari worked with Remy Dou, Geoff Potvin, and Gerhard Sonnert on physics and STEM identities. Julian Williams and Lene Moller Madsen also collaborated on STEM identity. Furthermore, while small groups do collaborate, they tend to be weakly connected, and their collaborations seem to occur between specific groups.

DISCUSSION

The purpose of this review was to analyze trends in identity studies research in peer-reviewed articles in STEM education indexed in the WoS database from the first mention through the end of 2024. To present the studies on identity in STEM education from a broader perspective, this study conducted bibliometric analysis to paint a holistic picture of the field.

This study has provided empirical evidence and critical recommendations to the literature in many respects.

This study has shown that annual publication and citation trends in identity research in STEM education tend to increase over the years. In particular, the number of studies and citations peaked post-COVID. Although identity studies in education are growing (Shaby and Vedder-Weiss, 2020), it is evident from this study that more research is needed to provide evidence on particularly emerging trends, such as STEM, gender, and belonging in the identity literature in STEM education. As revealed in this study, Archer, Louise and Hazari, and Zahra were found to be the most prolific authors in identity research in STEM education. Thus, these authors have made significant contributions to the advancement of the field by contributing to identity studies. Based on the total number of citations, the article *Understanding the science experiences of successful women of color: Science identity as an analytical lens*, in which Carlone and Johnson (2007) developed the science identity model, was found to be the most influential article. This finding supports Kim et al. (2018) finding that the science identity model proposed by Carlone and Johnson (2007) has been used as a framework in science identity research in recent years. The reason this study is most influential may be that it is the first study to develop an identity framework in the science literature and may have influenced and guided other studies.

This study provides empirical evidence that while physics identity, teacher education, and professional identity

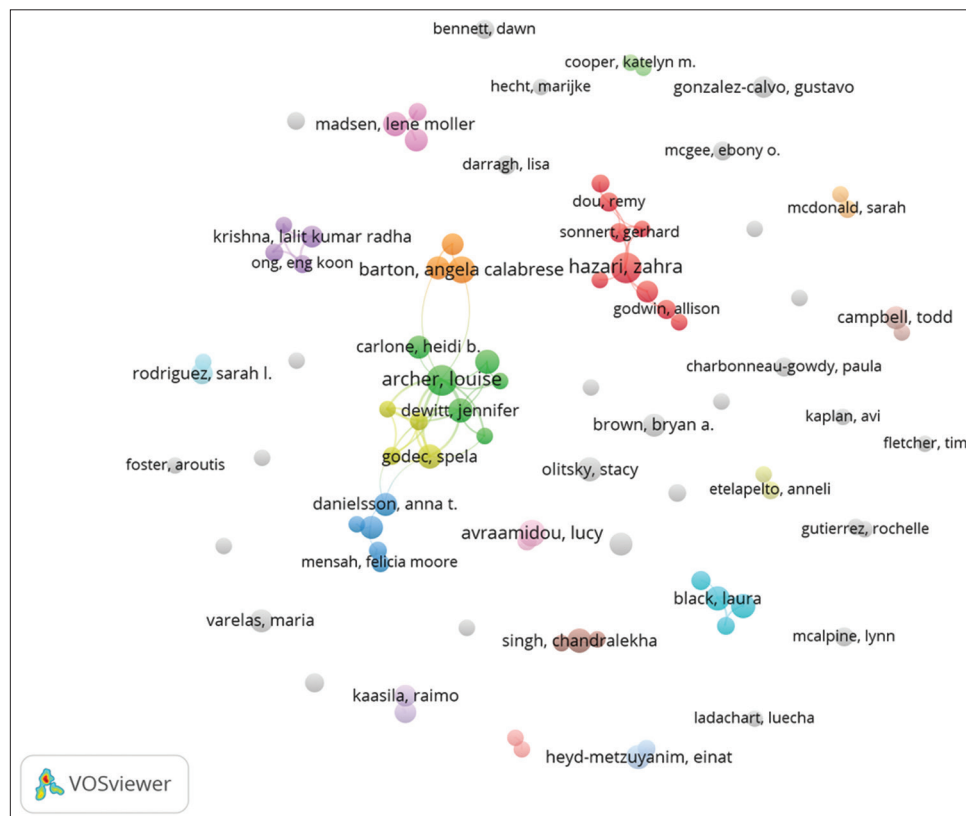


Figure 9: Social interaction among identity research authors in STEM education

are prevailing themes, STEM, STEM identity, gender and technology, mathematics identity, science identity, belonging, inclusivity, gender, and COVID-19 are emerging areas of interest in identity research in STEM education. This finding supports Zhang and Wang's (2022) bibliometric analysis that professional identity has continued to be studied over the past two decades. This finding also provides further evidence of the growing interest in identity research in STEM education (Li et al., 2022). Although many studies address students' identity formation, the female underrepresentation across specific STEM fields, such as physics, computer science, and engineering is still an issue (Kim et al., 2018). Understanding the development of female identity in science offers a flexible science culture for those outside certain norms of the science environment (Eren, 2021). Therefore, more research is needed to understand why the underrepresentation of certain groups, including women, in STEM fields is a persistent challenge to overcome and the main limitations of the present policies approaching that challenge. Moreover, since COVID-19 is an emerging area of interest, it is quite reasonable for researchers to investigate the impact of COVID-19 on science identity, which has a high impact on the whole world and deeply affects social life. Breakwell and Jaspal (2021) examined the identity processes that shape individuals' responses to COVID-19 and found that trust in science is positively related to the risk of COVID-19, which could be an example. Especially in the post-COVID-19 period, with the increase in the number of studies on identity in STEM education, the focus on factors, such as belonging, inclusion, and gender may be due to a lack of knowledge in these areas and a desire to examine the effects of COVID-19 on identity.

This study found that almost half of the identity studies (43%) were conducted by researchers in the USA. After the U.S., it was seen that there were efforts to make significant contributions to the literature from the UK and Australia. This finding can be attributed that these countries have done a significant amount of work on identity may be due to the funding they receive, the research areas of the researchers, and their multicultural backgrounds. However, to increase our collective understanding of identity studies in STEM education, we recommend, based on this empirical evidence that other countries should work specifically on identity.

The United States is the most collaborative country, collaborating with 45 different countries, with Canada, the United Kingdom, and the People's Republic of China being the most collaborative countries. Australia, Canada, Sweden, and the People's Republic of China are the next most collaborating countries, followed by the USA. This study also found that the countries most collaborative are the USA, Canada, and the UK. These countries collaborate most with Northern Europe and least with Asian countries, and most collaborating countries are English-speaking countries. Therefore, collaboration with non-English speaking countries should be considered to increase diversity in identity research.

CONCLUSION

Research trends in STEM education research provide a bird's eye view of the evolution of research interests and allow them to see the research gaps under investigation. This study analyzed research trends in identity studies in peer-reviewed articles in STEM education indexed in the WoS database from first mention through the end of 2024. This study offers multiple empirical evidence and implications for multiple stakeholders in terms of research and practice.

This study has important implications for researchers as one of the stakeholders, and researchers should take these implications into consideration as they continue their work. The first implication of this study for researchers is that the shift in research trends toward STEM identity, mathematics identity, science identity, belonging, inclusivity, gender, and COVID-19 topics implies a need for more research on the sociocultural dimensions of identity in STEM education. In addition, emerging themes, such as the impact of the pandemic on online identity have significant potential for identity research. By examining these dynamics more closely, identity researchers can shed light on post-pandemic educational strategies and reveal how identity is reflected in digital learning environments. The second implication for research is that while science identities, professional identities, physical identities, online identities, and physics identities are predominantly studied, there are limited studies on specific identity types, and focusing on such identity types can contribute to deepening the field. The third implication is the need to increase cultural and geographical diversity in identity studies. The results of the bibliometric analysis revealed that the majority of identity research originates from the USA. This indicates the necessity of conducting more research on STEM identity development in various regions, either within each STEM field or regarding integrated STEM identity development. Researchers should conduct broader, comparative studies on a global scale that incorporate cultural and geographical diversity and inclusiveness.

This study has unique implications for teachers and teacher education programs as well as other stakeholders. First, there is a need to strengthen professional identity and sense of belonging in STEM fields. Developing teachers' STEM identities are essential for fostering student identity development and improving teaching quality. Therefore, teacher education programs in schools of education should help pre-service teachers explore and strengthen their identities. Second, inclusive pedagogical approaches should be used in STEM teacher education. In addition to developing pre-service teachers' STEM identities, adopting inclusive and diverse teaching strategies can positively impact the STEM identities of students from different cultural backgrounds. This will help reduce inequalities in STEM fields.

This study provides curriculum designers with practical applications and implications. First, there is a need for inclusive and diversity-oriented content development. The growing

body of identity research in STEM education is evidence that curricula should be designed not only to convey knowledge, but also to foster student identity development and create an inclusive learning environment. The growing number of studies on gender, belonging, and inclusion themes, in particular, reveals the need to adapt curriculum materials to different student profiles. The second implication is the need to emphasize integrating teacher identity and professional development into the curriculum. Given the central role of teachers' professional identities in successfully implementing STEM education, teacher education should be a focal point in curriculum design. Curriculum designers should create modules with rich content that support teachers' identity development. These modules should enable teachers to strengthen their professional and student identities. Another implication is the need to adapt to educational models that have been studied more since the pandemic. The prominence of both the pandemic and online identity in identity studies requires that the impact of online learning environments on student and teacher identity be considered in the curriculum. In this context, inclusive curriculum structures that support face-to-face and online learning models should be developed for students from different cultural backgrounds and with different needs.

This study has important implications for policymakers, enabling them to turn research results into policy and implement them in practice. First, there is a need to develop inclusive STEM policies. The increase in identity research in recent years highlights the importance of policies that focus on social justice, equity, gender, and inclusion in STEM education. Therefore, education policies must include concrete strategies that address the social and cultural diversity of students and eliminate all barriers to STEM education. Second, education policies should diversify professional development programs and provide financial support to strengthen teachers' STEM identities. Strengthening teachers' STEM identities will positively impact the formation and development of students' STEM identities. The final implication suggests that efforts should be made to develop culturally responsive educational policies. The geographical distribution of identity studies in the context of STEM education reveals marked inequality. The scarcity of identity studies outside the U.S. makes it difficult to develop universal policies. Education policymakers need multinational data and international collaborative studies to understand how identity is constructed in different cultural and socioeconomic contexts. Such collaborations allow for the wider sharing of effective teaching strategies. This enables identity studies to be conducted in different countries and allows for the development of more inclusive, context-sensitive STEM policies.

Although this review provides significant insights for research and practice, it has two major limitations. The first limitation is that the WoS database was chosen as the sole data source for this study. Therefore, the results of this study should be interpreted in the context of this database. For future studies to

be more comprehensive, we recommend that other databases, such as Scopus, be included in addition to WoS. The second limitation is that the language of all articles selected for this review is English. Therefore, the results of this article should be considered in the context of scientific studies published in English in the WoS database. In future studies, we recommend international collaborations to investigate the trends of studies in the area of identity in STEM education in different languages.

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The submission has not been previously published, nor is it before another journal for consideration.

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CONFLICT OF INTEREST DISCLOSURE

The authors report there are no conflict of interests to declare.

DATA AVAILABILITY STATEMENT

This study used publicly accessible data from the Web of Science (WoS) database. Therefore, no additional data is required for this study.

ETHICS APPROVAL

An ethics statement is not applicable because this study used publicly accessible data from the Web of Science (WoS) database.

CONSENT TO PARTICIPATE

Not applicable.

CONSENT FOR PUBLICATION

Not applicable.

AUTHORS' CONTRIBUTION STATEMENTS

All authors contributed to the conception and design of the study. The first author took a lead role in analyzing the data and writing the manuscript under the supervision of the second author. The second author provided feedback throughout the study to ensure its successful completion and contributed to the writing of the manuscript.

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