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Authorship and topic trends in STEM education research

Yeping Li* and Yu Xiao

Abstract

In this study, we reviewed publications in the *International Journal of STEM Education* from 2014 to 2021 to gain a glimpse of STEM education research trends in terms of authorship and topics. We analyzed publication quantities and types, authors' profession, research topics and school levels, and the top 10 most-cited publications over the years. The results provide some encouraging indications of the expanded engagement and dynamic development in publication authorship and topics in STEM education research worldwide.

Keywords: Authorship, Research review, School level, Status, STEM education research, Topic, Trends

Introduction

STEM (science, technology, engineering, and mathematics) education has experienced tremendous development over the past decade, evidenced clearly in the rapid growth of STEM education research publications (Li et al., 2020). Both STEM and STEM education are no longer just buzzwords in the United States and many other education systems. The public engagement, national priority initiatives in education, and research interest in STEM education have helped to turn it into an educational movement with ever-increasing enthusiasm and impact worldwide (see Li, 2018a). At the same time, we should acknowledge that STEM presents itself with multi-facets, including disciplinary, multidisciplinary, interdisciplinary, or transdisciplinary in STEM (Vasquez et al., 2013). The development trajectory of STEM education as a distinct field will continue to be vibrant and exciting with the contribution from numerous educators and researchers in various disciplines to address many different issues and questions. To gain a better understanding of STEM education scholarship development, we thus aimed to identify and examine possible trends in research publications to learn more about who engaged in and contributed to STEM education research and research topic evolution over time.

To identify possible trends in research publications, it would be ideal to conduct a large scope research review that covers a wide range of journals. However, this would go beyond the scope of this editorial. Instead, we planned to focus on what we can learn from the publications in the *International Journal of STEM Education* (IJSTEM). Although IJSTEM does not have a long publishing history, the journal has established itself as a leading journal in multidisciplinary STEM education research worldwide (see Li, 2021a). With the journal's leadership and its focus on STEM education research, reviewing the publications in IJSTEM can help provide some insights about research trends in STEM education.

Building upon previous reviews of publications in IJSTEM

Several editorials were published before to provide publication reviews both yearly (e.g., Li, 2018b, 2019, 2020, 2021a) and over a period of the journal's first 5 years (Li et al., 2019). The yearly reviews were based on the journal's publication cycle year (e.g., August 2020 to July 2021 as the 7th publication cycle year). The review over the journal's first 5-year period was based on the calendar years from 2014 to 2018. The counting by calendar year provided an opportunity to systematically collect and analyze the journal's performance data, such

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as publication downloads and citations (Li et al., 2019). Thus, in this editorial, we decided to review the journal's publications based on the calendar years from 2014 to 2021.

This editorial built upon the previous review of the journal's publications in its first 5-year period. In a way, we intended to expand the previous review to cover a longer period of time from 5 years to 8 years (2014–2021). Thus, some general aspects of the journal's performance were also reviewed and reported this time, including the number and type of publications each year, the main topics that have emerged in STEM education research based on the journal's publications, and highly cited publications in STEM education research.

At the same time, we aimed to gain some insights about who contributed to STEM education research. In the previous review (Li et al., 2019), we focused on the geographic distributions of the authors and readers of the journal's publications. We learned that the journal's publications were contributed by authors from a wide range of countries/regions and also accessed by readers worldwide. The result helped us to learn about the nationality/region of authors but not the profession of the authors. Learning about authors' profession will help us glimpse the scope of scholarly engagement in STEM education research from different professional fields.

In summary, this editorial used data from the first 8 years (2014–2021) to systematically analyze and report: (1) numbers and types of items published in IJSTEM, (2) professions of the authors of the journal's articles, (3) topic areas and school levels addressed by the articles and possible trends, and (4) the top 10 most-cited articles published in IJSTEM.

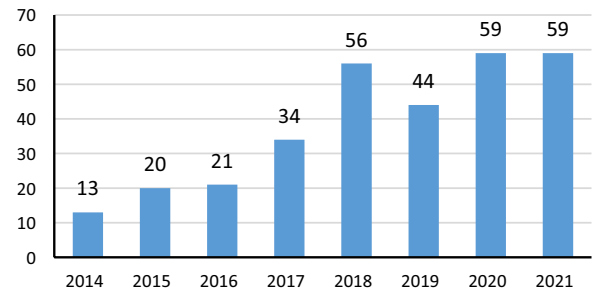

Fig. 1 Number of publications by year (Source: Journal website)

The journal's publications over the 8-year period, 2014–2021

The journal had published a total of 306 items by the end of 2021, thus averaging about 38 items per year. Figure 1 shows the number of items published for each calendar year, from 2014 to 2021. The figure shows the journal published more items since 2017 than in the first 3 years from 2014 to 2016. The result suggests that the growth in the number of the journal's publications reflects a growing interest in STEM education research.

Moreover, the steady increase in the journal's publications after 2019 suggests that the pandemic did not impact scholarly productivity in STEM education research, in contrast to what some researchers observed about research production decrease in other fields of study (see Marín-Marín, et al., 2021). The growing number of publications in STEM education was noted previously in the journal's yearly editorials (Li, 2020, 2021a), and also reported in the *Journal for STEM Education Research* (Li, 2021b).

Because the journal publishes several types of items, Table 1 shows the breakdown of these 306 publications by type and calendar year.

Table 1 shows that research articles have been the main type of publications each year and thus in total for the

Table 1 Number (percentage) of publications of each type by year

Year	Research articles	Research reviews	Short reports*	Commentaries	Other**
2014	11 (85%)			1 (8%)	1 (8%)
2015	15 (75%)	2[#] (10%)	3 (15%)		
2016	14 (67%)		3 (14%)	3 (14%)	1 (5%)
2017	28 (82%)		3 (9%)	1 (3%)	2 (6%)
2018	44 (79%)		5 (9%)	3 (5%)	4 (7%)
2019	32 (73%)	3 (7%)	2 (5%)	3 (7%)	4 (9%)
2020	46 (78%)	5[#] (8%)	3 (5%)	4 (7%)	1 (2%)
2021	49 (83%)	7[#] (12%)		2 (3%)	1 (2%)
Total	239 (78%)	17 (6%)	19 (6%)	17 (6%)	14 (5%)

* The journal stopped publishing "short reports" in 2021

** Including editorials, guest editorials, and errata

[#] Including articles that were submitted and published as "research" or "editorial", but are research reviews

8-year period, followed by short reports in total, and then research reviews and commentaries. Only 2 research reviews were published over the first 5-year period (Li, 2018b). The relatively short history of STEM education might be one reason for such a low number at that time. However, as research activities in STEM education research have moved forward quickly, Table 1 shows that the journal published an increasing number of research reviews every year since 2019.

Authorship of the journal's publications from 2014 to 2021

In addition to numbers and types of publications, analyzing authorship provides another perspective on scholarly contribution and trends in multidisciplinary STEM education research. As STEM education is not a well-defined field, specifying and classifying different professions of publication authorship require careful considerations. First, many publications in STEM education have joint authorship (Li et al., 2020). However, publications with joint authorship often contain very limited information about different co-authors beyond their names, nationality/region, and institutional affiliation. Thus, we decided to examine only the corresponding author's profession based on his/her first department/college/institution affiliation, if multiple department, college and/or institution affiliations are listed.

Second, there is no consensus about what fields can be included under the umbrella of STEM (see Li et al., 2020). The U.S. National Science Foundation once published a list of approved fields it considered under the umbrella of STEM. The list not only includes disciplines widely considered under the STEM tent (called "core" disciplines, such as physics, chemistry, and materials research), but also includes disciplines in psychology and social sciences (e.g., political science, economics). However, Gonzalez and Kuenzi (2012) noted that at least two other U.S. federal agencies, the Department of Homeland Security and Immigration and Customs Enforcement, used a narrower definition that excludes social sciences. Moreover, STEM education is also not a well-defined field. Given the complexity associated with the meanings of STEM and STEM education, it seems not productive to develop and use a detailed list of disciplines and/or fields to classify author's profession. Instead, we decided to use "education" and "STEM+" as two general categories to identify and specify a corresponding author's profession in education/educational research or disciplines and fields other than education. The category of STEM+ is broader than a collection of those disciplines or fields commonly considered under the STEM umbrella, including biology, design, engineering, library science, physics, social sciences, and psychology (not in education school/college). To determine the profession of a corresponding author, we thus checked and used the author's department or college or institution affiliation. For example, if an author is affiliated with educational studies department/college, the author's profession is classified as "education". If an author is in psychology department that is housed in College of Arts and Sciences, the author's profession is classified as "STEM+". If an author is affiliated with both engineering college (1st affiliation) and education college (2nd affiliation), the author's profession is classified as "STEM+".

Excluding errata from the publication counts in 2016 and 2018, we assigned each publication to one profession category of its corresponding author. Figure 2 shows that researchers from both education and STEM+ fields were the corresponding author of publications in IJSTEM over the years. However, researchers in education took the role of corresponding author in more publications than researchers in STEM+ fields every year from 2014 to 2020, reflecting the journal's emphasis in educational research in STEM. The balance altered in 2021 when there were more corresponding authors from STEM+ fields than from education/educational research. Although the results are limited to this journal's publications over 8 years from 2014 to 2021, they suggest an increasing trend of STEM education scholarship contribution from diverse STEM+ fields.

Topics as appeared in the journal's publications from 2014 to 2021

To examine research topics, we used the same list of topics from a previous review (Li et al., 2019). The list contains seven topic categories that were used to classify and examine the 304 items (excluding the two errata) published in this journal from 2014 to 2021.

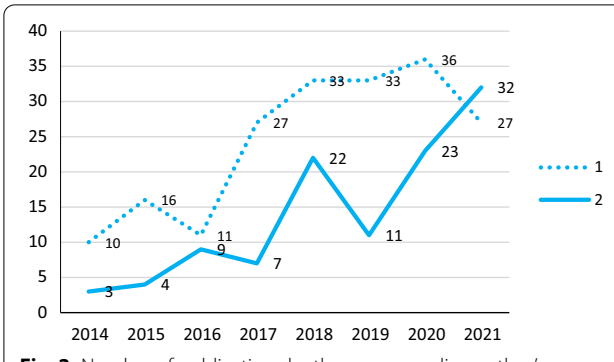

Fig. 2 Number of publications by the corresponding author's profession and year (Note: 1 = education, 2 = STEM+)

(1) Teaching, teacher, and teacher education in STEM (including both pre-service and in-service teacher education) in K-12 education;
(2) Teacher and teaching in STEM (including faculty development, etc.) at post-secondary level;
(3) STEM learner, learning, and learning environment in K-12 education;
(4) STEM learner, learning, and learning environments (excluding pre-service teacher education) at post-secondary level;
(5) Policy, curriculum, evaluation, and assessment in STEM (including literature review about a field in general);
(6) Culture, social, and gender issues in STEM education;
(7) History, epistemology, and perspectives about STEM and STEM education.

Consistent with the coding practice used in the previous review (Li et al., 2019), we assigned each publication to only one topic. When there were cases that more than one topic could have been used or with uncertainty, a decision was made after discussion.

Table 2 shows the annual number of publications in each of the seven topic categories from 2014 to 2021, with the bold numbers for those categories in top 3 ranks each year and in total. The topic of "policy, curriculum, evaluation and assessment" had the most publications every year and hence in total. On an annual basis, the topics with the second or third most publications varied over the 8-year period. However, we observed that topics in "K-12 STEM teaching, teacher, and teacher education" and "K-12 STEM learner, learning, and learning environment" had more publications before 2018, but not in 2020 and 2021. Instead, the number of publications in "post-secondary learners and learning in STEM education" and "culture, social, and gender issues" (e.g., STEM identity and students' career choices in STEM) notably increased. A growing interest in post-secondary STEM learning and teaching and "culture, social, and gender issues in STEM education" was pointed out in the previous review (Li et al., 2019), and this trend has continued in 2020 and 2021.

The topic trend measured by the number of publications may well connect to the school level, where researchers paid close attention to issues in STEM education. If reclassifying the journal's publications in terms of school level, we decided to use three categories: K-12, post-secondary, and general. In this classification, publications on pre-service teacher training were then placed into the category of post-secondary level as all pre-service teachers are college students, but not for publications on in-service teachers. Publications in topic areas 5, 6, and 7 (see Table 2) were also reclassified in terms of school level. The inclusion of "general" category is for those publications on questions or research work either pertinent to all school levels or across the boundary of K-12 school and college.

Figure 3 shows the distribution of publications by school level focus and year. It presents a fast-growing trend in publications on STEM education at the

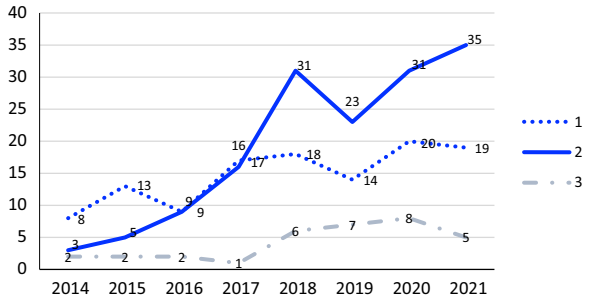

Fig. 3 Distribution of publications by school level focus and year (Note: 1 = K-12 school level, 2 = Post-secondary level, 3 = General)

Table 2 Frequencies of research topic distribution over the 8-year period

Research Topic	2014	2015	2016*	2017	2018*	2019	2020	2021	Total
(1) K-12 teacher and teaching	**2**[3]	**4**[3]	**4**[2]	3	4	**8**[2]	3	**9**[3]	**37**[3]
(2) Post-sec teacher and teaching	1	1	2	**6**[2]	3	**7**[3]	4	5	29
(3) K-12 learner and learning	**4**[1]	**5**[2]	1	1	**6**[3]	3	4	4	28
(4) Post-sec learner and learning	1	1	0	3	**8**[2]	**7**[3]	**12**[2]	**12**[2]	**44**[2]
(5) Policy, curri., and assessment	**4**[1]	**9**[1]	**10**[1]	**16**[1]	**25**[1]	**13**[1]	**16**[1]	**18**[1]	**111**[1]
(6) Culture, social, and gender	0	0	0	**4**[3]	**6**[3]	6	**12**[2]	8	36
(7) History, perspectives of STEM	1	0	**3**[3]	1	3	0	8	3	19
Total	13	20	20	34	55	44	59	59	304

[1] Number one topic, [2]Number two topic, [3]Number three topic

*Excluding errata from that year's publications

post-secondary level over the 8-year period, exceeding publications in other two categories from 2018.

Top 10 most-cited articles published in IJSTEM

With the data from Springer, we were able to identify the 10 publications with the highest total citation counts. Table 3 shows the top 10 most-cited articles published from 2014 to 2021. On average, there are 175 citations for each of these 10 articles, an indication of the high quality of these articles. The bold titles refer to those 5 articles that also made to the list of top 10 most-cited publications in the previous review (Li et al., 2019). Cumulatively, these 5 articles have 1110 citations which are 63.5% of the total citation counts of these top 10 most-cited articles. The result suggests the on-going high impact of these 5 articles in the international community.

If taking a closer look at these articles listed in Table 3, we found that these articles cover all the topics in the list used above, except topic 4 (STEM learner, learning, and learning environments at post-secondary level). The result suggests that articles on STEM education in many different topic areas have been highly cited, reflecting the existence of active and dynamic research interest on different topics in the field. More articles on STEM education at K-12 school level made to this top 10 most-cited list than articles at other two school categories (i.e., "post-secondary" and "general").

Moreover, we noticed that seven articles have the corresponding author from the U.S., two with the corresponding author from Australia and one from the U.K. If taking a further look at the corresponding author's profession, we found that six are in education/educational research and four are in the STEM+ category. The results suggest a limited diversity in the corresponding author's nationality/region of these top 10 most-cited articles, a result consistent with what we learned before (Li et al., 2019, 2020). Moreover, educational researchers might cite more from publications in this journal as an educational research journal over the 8-year period.

To explore possible trends in research interest development in the field, we decided to examine recent publications that have been highly cited. Table 4 shows the top 10 most-cited articles published in 2021. There are an average of more than 12 citations per article for the list. As these articles were published about a year ago, the citation count provides a clear indication of these articles' impact.

We noticed that these 10 articles cover all seven topic categories. The result suggests that articles on STEM education in all different topic areas have been highly cited, confirming the active and dynamic research interest on different topics in the field. Moreover, there are now two articles on topic 4 (STEM learner, learning, and learning environments at post-secondary level) that is not covered by articles listed in Table 3. A notable increase in scholarly interest in post-secondary STEM education is evident as the list includes 5 articles at the post-secondary level, 3 at K-12 school level, and 2 in the "general" category.

By examining the authorship of these articles from Table 4, we observed that while the U.S. researchers continued to be the corresponding author for 6 out of the top 10 articles, there are an increasing number of researchers from other countries/regions to contribute to those highly cited articles (i.e., 1 from Canada, 1 from Hong Kong, 1 from Spain, 1 from Taiwan for a total of 4). Moreover, out of these top 10 articles, there are equal numbers of articles with researchers in education or

Table 3 Top 10 most-cited articles published from 2014 to 2021

Title (year of publication)	Author (country/region*)	Citation counts**
A conceptual framework for integrated STEM education (2016)	Kelley & Knowles (USA)	487
STEM education K-12: perspectives on integration (2016)	English (Australia)	313
Teachers' perception of STEM integration and education: a systematic literature review (2019)	Margot & Kettler (USA)	189
Race and gender differences in how sense of belonging influences decisions to major in STEM (2018)	Rainey et al. (USA)	163
STEM learning through engineering design: fourth-grade students' investigations in aerospace (2015)	English & King (Australia)	120
Assessing teacher education and professional development needs for the implementation of integrated approaches to STEM education (2017)	Shernoff et al. (USA)	109
The importance of context: an exploration of factors influencing the adoption of student-centered teaching among chemistry, biology, and physics faculty (2015)	Lund & Stains (USA)	101
Strategies to mitigate student resistance to active learning (2018)	Tharayil et al. (USA)	90
Research trends on argumentation in science education: a journal content analysis from 1998 to 2014 (2015)	Erduran et al. (UK)	89
Research and trends in STEM education: a systematic review of journal publications (2020)	Li et al. (USA)	87

*Country/region refers to where the corresponding author's research organization or institution was located at the time of publication

**Citation counts retrieved from Springer Nature Insights/Dimensions on August 31st, 2022. (Source: Springer)

Table 4 Top 10 most-cited articles published in 2021

Title (school level)	Author (country/region*)	Citation counts**
Effects of infusing the engineering design process into STEM project-based learning to develop preservice technology teachers' engineering design thinking (post-secondary)	Lin et al. (Taiwan)	18
STEAM in education: a bibliometric analysis of performance and co-words in Web of Science (general)	Marin-Marin et al. (Spain)	17
Understanding coherence and integration in integrated STEM curriculum (K-12 school)	Roehrig et al. (USA)	15
Using design thinking to cultivate the next generation of female STEAM thinkers (K-12 school)	Kijima et al. (Canada)	14
STEM stereotypes predict students' STEM career interest via self-efficacy and outcome expectations (K-12 school)	Luo et al. (Hong Kong)	12
A scoping review of literature assessing the impact of the learning assistant model (post-secondary)	Barrasso & Spilios (USA)	10
Active learning through flipped classroom in mechanical engineering: improving students' perception of learning and performance (post-secondary)	Cho et al. (USA)	10
The influence of expressive and instrumental social capital from parents on women and underrepresented minority students' declaration and persistence in engineering majors (post-secondary)	Puccia et al. (USA)	10
Instructor strategies to aid implementation of active learning: a systematic literature review (post-secondary)	Nguyen et al. (USA)	9
NGSS-based teacher professional development to implement engineering practices in STEM instruction (general)	Christian et al. (USA)	8

*Country/region refers to where the corresponding author's research organization or institution was located at the time of publication

**Citation counts retrieved from Springer Nature Insights/Dimensions on August 31st, 2022. (Source: Springer)

STEM+ fields as the corresponding author. The results suggest an increasing diversity in the corresponding authorship of these top 10 most-cited articles published in 2021.

If cross-examining these two lists of top 10 most-cited articles (Tables 3 and 4), we found some interesting development over the years. First, there is a notable increase in the number of articles at post-secondary level in the 2021 publication list, a result that is consistent with what we can learn from Table 2 and Fig. 3. Moreover, we noticed the increasing diversity in the authorship for these highly cited articles over the years, in terms of both nationality/region and profession. The increasing contribution of researchers from diverse STEM+ fields is an encouraging sign of broad scholarly engagement in STEM education, a field that does need extensive and cross-boundary collaborations. At the same time, it is important to point out that both lists cover a broad range of topics, an indication of on-going strong interest in diverse issues and questions in STEM education across different school levels.

Coda

The systematic analysis of publications in IJSTEM from 2014 to 2021 revealed some dynamic development in terms of publications, authorship, and topics. While there is an increasing trend of publication quantity, the evidence based on citations suggests the high quality of publications.

Analysis of publications in terms of research topics, albeit limited to this journal, shows some development of STEM education as a field over the past several years. Specifically, there are a growing number of publications on issues in STEM education at post-secondary level, especially over the past four years. The analyses of the top 10 most-cited publications over the 8-year period from 2014 to 2021 and those published in 2021 help uncover not only researchers' on-going strong interest in a broad range of topics, but also confirming evidence for the evolving trends in authorship and topics. Such information should be helpful to the international research community in learning about and reflecting on possible research development. At the same time, the results of this analysis also suggest the need and importance of analyzing publications in other journals to examine and document the status and trends in STEM education research in multiple aspects.

In some ways, the analysis shows trends with implication beyond this journal. For example, it is important to learn that the top 10 most-cited articles published in 2021 present an increased diversity in authorship in terms of both nationality/region and profession. The expanded participation and contribution from researchers with diverse disciplinary training and cultural background are encouraging signs for the dynamic development of STEM education in the future.

Last but not least, we want to take this opportunity to thank all authors, reviewers, researchers, and readers for their contributions and support. We are happy to learn from this review that the journal has drawn authors from many different STEM+ fields in addition to education, and the journal's high quality publications on a broad range of topics have been well received and cited. We

are confident that the journal will continue its growth to serve the broad and evolving research community in STEM education worldwide.

Abbreviations
IJSTEM: International Journal of STEM Education; K-12: Kindergarten-Grade 12; STEM: Science, Technology, Engineering, and Mathematics; STEM+: Disciplines or fields other than education, including those commonly considered under the STEM umbrella plus some others.

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YL conceptualized the review, coded and analyzed data, and wrote the manuscript. YX helped with data coding and reviewed manuscript drafts. Both authors read and approved the final manuscript.

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Declarations

Competing interests
The authors declare that they have no competing interests.

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