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Trends and Research Issues of STEM Education: A Review of Academic Publications from 2007 to 2017

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Trends and Research Issues of STEM Education: A Review of Academic Publications from 2007 to 2017

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Abstract. STEM education (Science, Technology, Engineering, and Mathematic) research has been become more attractive area in science education for a decade. This study was aim to analyze research articles in a SCOPUS database and two journals which were not indexed in SCOPUS including Journal of STEM Teacher Education, and International Journal of STEM Education. The research articles during 2007 to 2017 were reviewed and analyzed according to the authors' nationality, journals, STEM research topics. The research findings indicated that there were 56 published papers related to providing STEM learning activities in school setting, top three countries which published STEM papers over the decades were United States (46), Australia (2), Canada (2). Besides, the journal with the greatest number of published papers was Journal of STEM Teacher Education, with a total of 16 papers, and the second is International Journal of STEM education. The three popular topics which published in STEM papers were innovation for STEM learning, professional development and gender gap and Career in STEM, respectively.

1. Introduction

STEM is an acronym which stands for Science, Technology, Engineering, and Mathematics. At the beginning, STEM education has often been called a Meta discipline, the creation of a discipline based on the integration of other disciplinary knowledge into a new whole [4]. Now, many educators and policy makers have concerned for emphasis on science, technology, engineering and mathematics (STEM) disciplines integration in our schools. The challenges the world faces today call for a global society that is multidisciplinary and may "require the integration of multiple STEM concepts to solve them" [8]. Therefore, it is important to train and prepare a diverse STEM-literate workforce with the capability to understand and comprehend the technological world [5].

Over the past decade, numerous researchers have been conducted STEM education in many contexts and subject areas. For instance, in a high school level, [7] studied an engineering curriculum in school, identify teaching strategies used to increase math and science literacy, and discover challenges and constraints that occur during its development and delivery, as well as what strategies are used to overcome these obstacles. Besides, in a university level, [2] conducted the research to provide a model, an example, and suggestions for establishing and fostering meaningful partnerships to construct authentic and relevant STEAM learning experiences for pre-service teachers. Obviously, the given example of the studies about STEM education were varies used. Therefore, to understand the trends of STEM education research in science education, literature on SCOPUS database and two



journals; Journal of STEM teacher education, and International Journal of STEM education from 2007 to 2017 were analyzed in this study. The research questions of this study were:

1. How did the authors' nationality and journals of STEM education article publish across these decades (2007-2017)?
2. How about the topics of the published articles in journals vary across these ten years (2007-2017)?

2. Research Methodology

We use the content analysis method which helps us find and identify some of the features that appear in the research paper. This method provides a simple, easy and understandable and is the most recent one used among the research trends in science education.

2.1 Selection Research Papers Related to STEM Education

The criteria by which studies are to be included in, or excluded from, the review were determined. The studies which appear to meet these criteria were listed by means of electronic database searching, and then the abstracts of the studies were screened to see if they meet the inclusion criteria

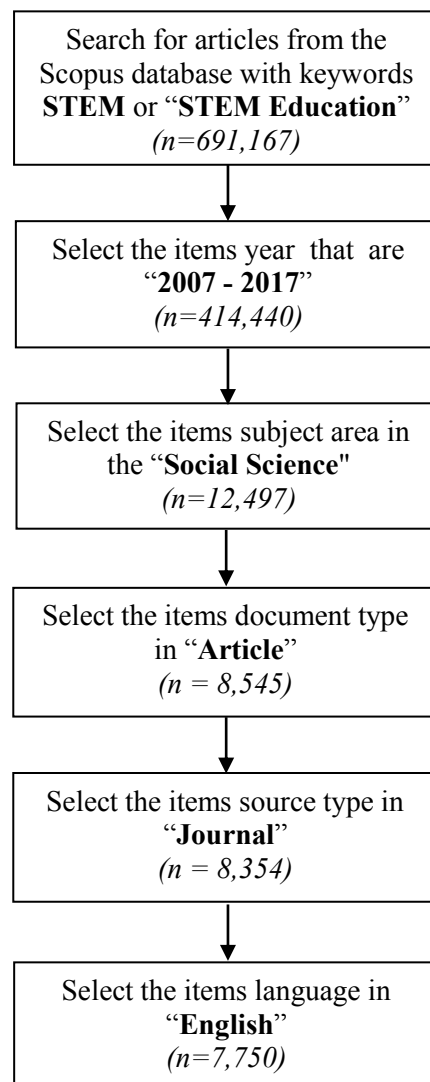


Figure 1. Scopus database searching steps on October 19st, 2017.

2.1.1 Criteria for selection research papers Related to STEM Education:

The research articles of each journal related to STEM Education between 2007 and 2017 were searched in the Scopus database on October 19st, 2017, where the criterion was to include the keyword 'STEM' or 'STEM Education' to detect all words related to STEM sources, STEM Education contexts and STEM learning. The result from searched in Scopus database found that, there were 691,167 papers were related to STEM or STEM Education, among them 414,440 papers were published in 2007 - 2017 and 12,497 papers were related to social science. In addition, we selected document type in 'Article', source type in 'Journal' and language in 'English'. Finally we found a total of 7,750 were selected in the final list for analysis, as shown in Figure 1. However, the result from searching by used the keywords 'STEM' or 'STEM Education' were too large and wide range that was difficult to analyze. So, the next step we focus on keyword that we interested in. That was providing STEM learning activities in school setting.

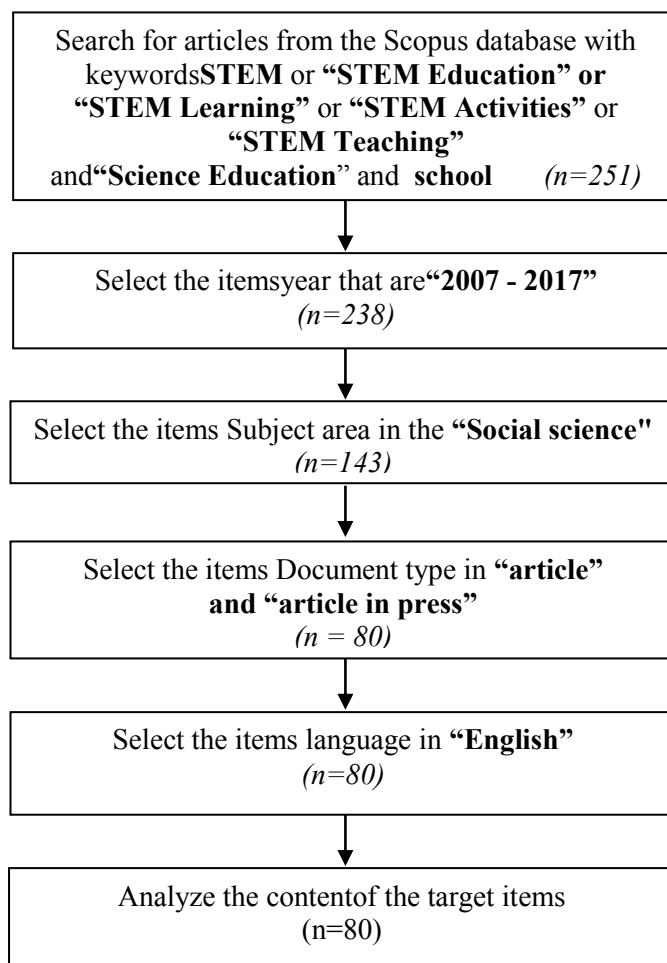


Figure 2. Scopus database searching steps on October 20st, 2017.

2.1.2 Criteria for Document Selection for Data Analysis:

In addition, the study based on the review of publishing article in Journal of STEM Teacher Education (JSTE) from 2011 to 2017, and International Journal of STEM Education (IJSE) from 2016 to 2017. The rationale for the choice of these two journals is that they are the major journals that focused in STEM education research. The number of total access was 53 articles.

A second-level in-depth screening by reading the abstracts resulted in the exclusion of some of the articles since the keyword STEM or “STEM Education” or “STEM Learning” or “STEM Activities” or “STEM Teaching” and “Science Education” and school was relevant to another context in STEM Education. This step eliminated irrelevant 80 articles. The resulting number of research articles is provided in Table 2.

2.2 Identifying and generating systematic categories

2.2.1 The categorization of coding system:

Considering STEM education research topic, the categories were created as a coding system to use for a structured observation. Research articles could be identified and categorized by a coding system that describe the characteristic of the article, allow the researcher to literate and categorize clearly. The Table 1 showed the categories to identify STEM education articles.

Table 1 Summarization of the categories in a coding system.

No.	Categorize	Description
1.	Professional Development	Pre-service teachers in math and science experiencing with integrated STEM task, Technological pedagogical content knowledge (TPACK) for science teacher, Promote Science Education and Provide Hands-On Experiences
2.	Gender gap and Career in STEM	Gender disparities in STEM, Immigrant–native educational attainment gap in STEM, Students’ motivation and promote students’ STEM career choice
3.	Integrated Engineering into STEM	Engineering-based STEM integration , apply scientific knowledge and skill to help solve engineering challenges in science class
4.	Innovation for STEM learning	Developed program, promote STEM competency through the game, Innovative Technologies
5.	STEM learning/activity	Metasynthesis focused on STEM teaching and learning practices in middle and high school classrooms
6.	Integration of STEAM/STEAM learning	Development measurement for researchers and educators to use to assess student collaboration in STEAM activities.
7.	STEM School Framework/Model	Critical components of STEM schools and derived a theoretical framework
8.	Other	Paper suggestion/review/perspectives

Table 2 The distribution of STEM education research articles across Journals.

Journals	Number of STEM education articles
International Journal of STEM Education	12
Journal of STEM Teacher Education	16
Research in Science Education	2
Journal of Research in Science Teaching	3
Cultural Studies of Science Education	3
Journal of Science Education and Technology	4
Journal of Pre-College Engineering Education Research	2
International Journal of Science and Mathematics Education	2
ACM Transactions on Computing Education	1
Computers & Education	1
Educational Researcher	1
International Journal of Educational Research	1
International Journal of Technology and Design Education	1
Journal of Chemical Education	1
Pacific Economic Review	1
Social Psychology of Education	1
Social Science	1
Sustainability	1
Technology, Knowledge, and Learning	1
The Curriculum Journal	1

3. Research Finding and Discussion

The 56 articles reviewed in this research included all aspects of STEM Education published in SCOPUS database as well as in Journal of STEM Teacher Education (JSTE) and International Journal of STEM Education (IJSE) from 2007– 2017. The results and discussion are given in relation to the research questions.

1. How did the authors' nationality and journals of STEM education article publish across these decades (2007-2017)?

Figure 3 showed the publication situation of providing STEM learning papers from 2007 to 2017. The earliest paper was written by Yu, Iskander, Kapila, and Kriftcher (2007), and promoted engineering careers using sensor in high school science labs. Fewer than five papers were published each year from 2007 to 2011. It was not until 2012 that it started to receive more attention from researchers. In Figure 2, it could be seen that 30 papers were published in the STEM education domain in 2017. Such a finding is reasonable since, due to the policy have focused on development knowledge and skills in area of STEM. In particular, in recent years, the rapid growth of the STEM career policies around the globe has encouraged in schools which increases science literacy, and enables the next generation of innovators.

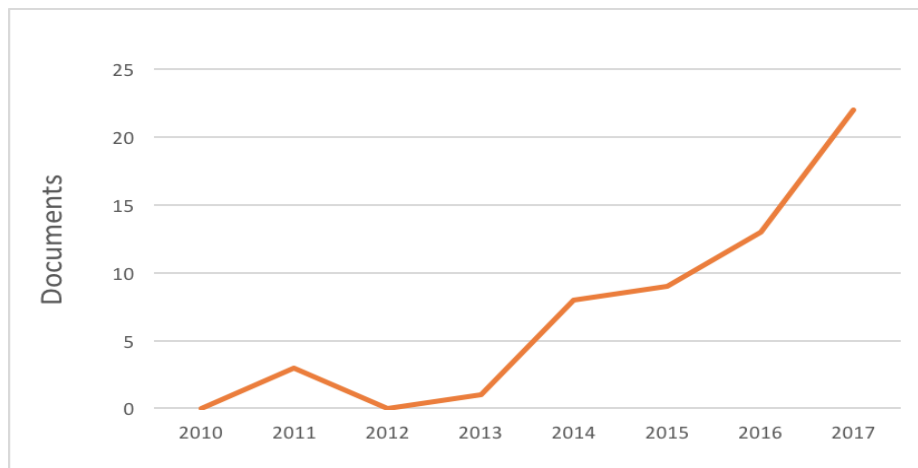


Figure 3. Published papers providing STEM learning from 2007 to 2017.

Only the nationalities of the first authors of the published papers in STEM education were counted in this study. From the results, it can be found that there were many researchers from different countries attempting to conduct STEM education. Fig. 4 shows the distribution of the top 10 countries which published STEM papers over the decades. The top three countries were the United States (46), Australia (2), and Canada (2).

The Figure 5 presented eight journals which published about STEM education paper during year 2007 to 2017. These journals included International Journal of STEM education, Journal of STEM Teacher Education, Research in Science Education, Journal of Research in Science Teaching, Cultural Studies in Science Education, Journal of Science Education and Technology, International Journal of Science and Mathematics Education, and Journal of Pre-college Engineering Education Research. The journal with the greatest number of published papers is Journal of STEM Teacher Education, with a total of 16 papers, and the second is International Journal of STEM education.

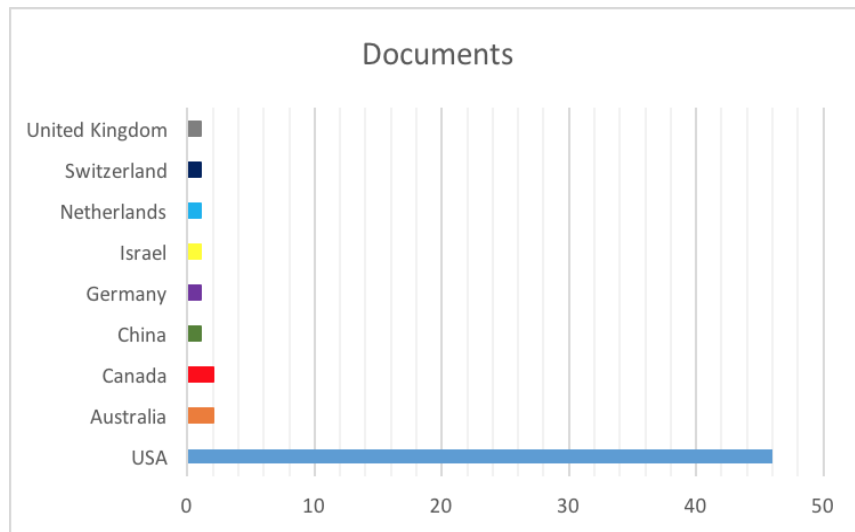


Figure 4. Top ten countries publishing papers on providing STEM learning during 2007 to 2017.

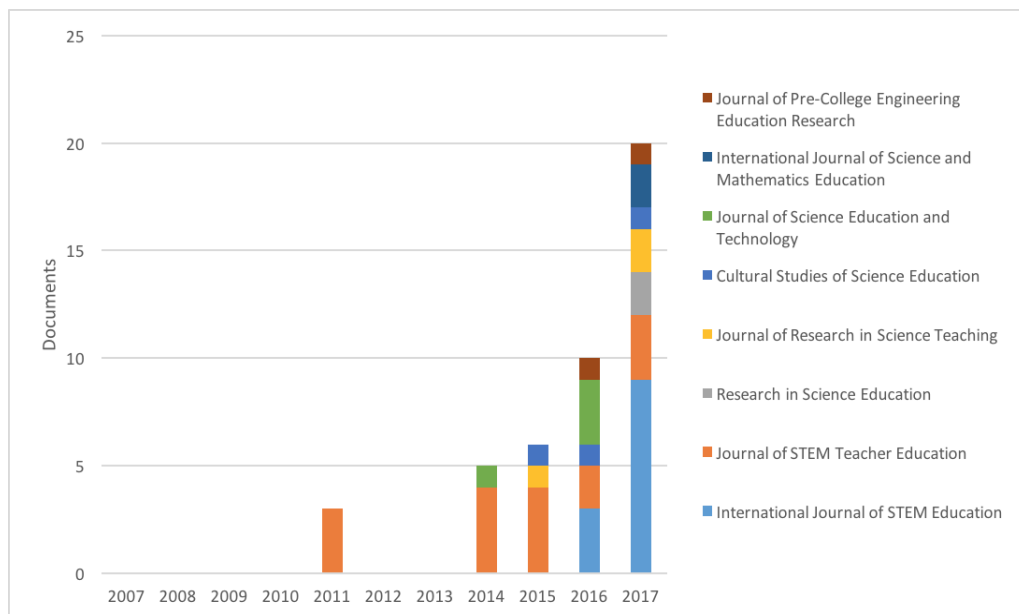


Figure 5. Journals publishing papers on STEM learning from 2007 to 2017.

2. How about the topics of the published articles in journals vary across these ten years (2007-2017)?

The selected 58 STEM education articles were searched from SCOPUS database which keywords related to STEM education and were selected from the obviously STEM education journals including the Journal of STEM Education Teacher and International Journal of STEM Education. A coding system could categorize the aims of research into 8 categories. These included Professional Development (C1), Gender gap and Career in STEM (C2), Integrated Engineering into STEM (C3), Innovation for STEM learning (C4), STEM learning/activity (C5), Integration of STEAM/STEAM learning (C6), STEM School Framework/Model (C7), and Other: paper suggestion /review/perspectives (C8). The frequency of papers in each category could be provided as shown in the Table 3. It found that the most popular STEM education research category (from 2007 to 2017) was

Innovation for STEM learning (C4) (20 papers). The top three ranking on STEM education research categories included Innovation for STEM learning (C4), Professional Development (C1), and Gender gap and Career in STEM (C2); respectively.

C1: Professional Development

Professional development is the second popular topic which concept of pre-service teachers in math and science experiencing with integrated STEM task, technological pedagogical content knowledge (TPACK) for science teacher, promoting science education and provide hands-on experiences.

C2: Gender gap and Career in STEM

Gender gap and career in STEM was categorized to research that focused on the concepts of gender disparities in STEM, immigrant–native educational attainment gap in STEM, students' motivation, promote students' STEM career choice and the integration of STEM practices into the curriculum.

C3: Integrated Engineering into STEM

Integrated Engineering into STEM was described to research that focused on engineering-based STEM integration, apply scientific knowledge and skill to help solve engineering challenges in science class.

C4: Innovation for STEM learning

The innovation for STEM learning is the most clarification on the STEM education research as shown in the Table 3. The innovation learning for STEM learning was labeled to represent to the research that focused on the concept of developed program, promote STEM competency through the game, innovative technologies and technology and design activity.

C5: STEM learning/activity

STEM learning and STEM activities was focused on STEM teaching and learning practices in middle and high school classrooms.

C6: Integration of STEAM/STEAM learning

Integration of STEAM and STEAM learning was concentrated on learning development measurement for researchers and educators to use to assess student collaboration in STEAM activities

C7: STEM School Framework/Model

STEM School Framework and Model was represent to the research that focused on critical components of STEM schools and derived a theoretical framework.

C8: Review STEM perspectives and suggestions

Review STEM perspectives and suggestion on STEM and STEM integration.

Table 3 Frequency of STEM education papers in each category.

Journals	Frequency of STEM education papers							
	C1	C2	C3	C4	C5	C6	C7	C8
International Journal of STEM Education	2	1	-	-	-	1	1	3
Journal of STEM Teacher Education	4	2	2	2	2	1	-	3
Research in Science Education	-	1	-	1	-	-	-	-
Journal of Research in Science Teaching	1	1	-	1	-	-	-	-
Cultural Studies of Science Education	-	1	-	2	-	-	-	-
Journal of Science Education and Technology	-	-	1	3	-	-	-	-
Journal of Pre-College Engineering Education Research	-	-	1	1	-	-	-	-
International Journal of Science and Mathematics Education	-	-	1		-	-	-	-
ACM Transactions on Computing Education	-	-	-	1	-	-	-	-

Journals	Frequency of STEM education papers							
	C1	C2	C3	C4	C5	C6	C7	C8
Computers & Education	-	-	-	1	-	-	-	-
Educational Researcher	-	1	-	-	-	-	-	-
International Journal of Educational Research	-	1	-	-	-	-	-	-
International Journal of Technology and Design Education	-	-	-	1	-	-	-	-
Journal of Chemical Education	1	-	-	-	-	-	-	-
Pacific Economic Review	-	-	-	1	-	-	-	-
Social Psychology of Education	-	-	-	1	-	-	-	-
Social Science	-	1	-	-	-	-	-	-
Sustainability	1	-	-	-	-	-	-	-
Technology, Knowledge, and Learning	-	-	-	1	-	-	-	-
The Curriculum Journal	-	1	-	-	-	-	-	-
Total	10	10	5	20	2	2	1	6

The most popular topics from 2007 to 2017 was ‘innovation for STEM learning’ (20 papers), which the concept of developed program, promote STEM competency through the game, innovative technologies and technology and design activity. The methodology of these topics was mixed method, quantitative and qualitative research. Among the participants including: pre-service teachers, students and students of STEM Education course at graduate level. The second popular topics was ‘Professional Development’ (10 papers), which the concept of pre-service teachers in math and science experiencing with integrated STEM task, technological pedagogical content knowledge (TPACK) for science teacher, promoting science education and provide hands-on experiences. In this concept, the researcher use quantitative, qualitative and mixed method, the qualitative data including: focus group interview transcripts, responses from open-ended survey questions and all researcher notes (including classroom observations and notes from teacher workshops). The participants including: pre-service teachers, science teachers, scientists and educational technology. For the third popular topic was ‘Gender gap and Career in STEM’(10 papers), which the concepts of gender disparities in STEM, immigrant–native educational attainment gap in STEM, students’ motivation, promote students’ STEM career choice and the integration of STEM practices into the curriculum. In ‘Gender gap and Career in STEM’ topic, the researcher use case study, qualitative, quantitative and mixed method and the participants were students: postsecondary students, school-aged girls.

As discussed by Christine V. McDonald in 2016, the integration of technology and engineering into school education has been proposed as an effective means to enhance student learning and raise student achievement in STEM disciplines [1]. Technology and engineering activities have been shown to develop STEM literacy and increase motivation, in addition to providing real world contexts for learning scientific and mathematical concepts [6]. The majority of research on professional development in STEM disciplines has been conducted in science and mathematics, with findings indicating that engaging in professional development has been shown to be beneficial to teachers [3].

4. Conclusion

A systematic review was used in this research to analyze STEM education in science education published in SCOPUS database and two journals included Journal of STEM teacher education, and International Journal of STEM education from 2007 to 2017. It was found that the number of published paper rapidly increasing over the decades. Moreover, we found that top three countries which published STEM papers over the decades were United States (46), Australia (2), and Canada (2). Besides, the journal with the greatest number of published papers was Journal of STEM Teacher Education, with a total of 16 papers, and the second is International Journal of STEM education. The three popular topic which published in STEM papers were innovation for STEM learning, professional development and gender gap and Career in STEM, respectively. Although we reviewed only some of English communicated journal, this report may suggest some trends of research in STEM education.

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