

Key Definitions of STEM Education: Literature Review

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ABSTRACT

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This literature review aims to identify common theme in STEM education and to find out the scope of STEM education from previous studies that would provide information to researchers as well as the stakeholders on how they should focus on the implementation of STEM education. The author creates the research questions, “What are the common themes in STEM education?” and “What are scopes in STEM education that can cover the common themes based on the literature reviews?”. The literature search in electronic databases was conducted through the Education Resources Information Center, Scopus, Web of Science and Google Scholar using the varieties of Keyword such as “STEM education”, “STEM Implementation”, “STEM definitions”, “Instruction”, “Curriculum”, “Major”, “Career”. The author concludes that the definitions of STEM education depend on the stakeholders in the implementation. Four key definitions and three scopes that cover those key definitions based on literature reviews are found and discussed.

Keywords: STEM education, STEM definitions, STEM disciplines, instruction, major career

INTRODUCTION

STEM education is initially called Science, Mathematics, Engineering, and Technology (SMET) and was an initiative as STEM by the National Science Foundation (NSF), which stands for science, technology, engineering, and mathematics in 1990 (Sanders, 2009). “S” for Science is very concerned with what is the natural world and preparing students to think and act like real scientists, ask questions, hypothesize, and conduct investigations using standard science practices (Burghardt & Hacker, 2004; Kelley & Knowles, 2016). These courses deal with physics, biology, chemistry, astronomy, etc. Meanwhile, “T” technology is the modification of the natural world to meet human wants and needs. It is very concerned with what can and should be (designed, made, and developed) from natural world materials and substances to satisfy human needs and wants. Besides, “E” engineering stands as a profession in which knowledge of the mathematical and natural with judgment to improve ways to utilize the materials and forces of nature economically for the benefit of humankind. Meanwhile, “M” mathematics is defined as the science of patterns and relationship that provides the exact language for technology, science, and

engineering (Dugger, 2010). The understanding of these four disciplines is considered for 21st-century economies’ development. Hence, many countries are trying to improve the quality of education with given subjects such as science, technology, engineering, and mathematics (Yildirim, 2016).

STEM education is an integration of those four disciplines with two possibilities: as an input and output in education. National Research Council (1996) in (Bozkurt, Ucar, Durak, & Idin, 2019) and Sander (2009) described STEM education as a teaching and learning method that integrates the content and skills of science, technology, engineering and math which is functioned as an input. Otherwise, STEM also is connected to economic competitiveness in the global market and to fill recent requests such as guaranteeing adequate and maintaining energy and productivity that is managed as an output (Boe, Henriksen, Lyons, & Schreiner, 2011).

In general, STEM education refers to providing opportunities for students to be able to solve problems, to be innovators, inventors, self-confident, logical thinkers, and technologically literate (Morrison, 2006; Stohlmann,

Moore, & Roehrig, 2011). Breiner, Harkness, Johnson, and Koehler (2012) and Kelly & Knowles (2016) revealed that STEM education has been contemplated since the 1990s and can be successful in K-16 education in preparing competent students at all levels with the skills in the rapidly expanding scientific society especially for the future success of the students. Improving STEM education may also increase the literacy of all people across the population in technological and scientific areas (NAE & NRC, 2009; Pleasants et al., 2019).

Few stakeholders seemed to know how to operationalize STEM education several years later because it has been unclear about how the stakeholders can start with STEM implementation. There is no clarification about the standard definitions of STEM education. This literature review is conducted in order to identify common ideas in STEM education and to find out the scope of STEM education from previous studies. The findings will provide information to researchers as well as the stakeholders on how they should focus on the implementation of STEM education. The author creates the research question:

- What are the common themes in STEM education?
- What are scopes in STEM education that can cover the common themes based on the literature reviews?

METHOD

This study was a secondary source or literature review about the definition of STEM education that was categorized based on the scope of implementation; thus, researchers as well as educators could get a picture of how they identify and implement STEM education on their study field. The literature search in electronic databases was conducted through the Education Resources Information Center (ERIC), Scopus, Web of Science and Google Scholar using the varieties of keyword such as “STEM education”, “STEM Implementation”, “STEM definition”, “Instruction”, “Curriculum”, “Major”, “Career”.

In analyzing the data process, researcher organized data extraction and made an overview with characteristics including (a) Author, (b) and Definition on STEM education on the studies. The data extraction was conducted through reading the details of each selected articles. The STEM key definitions extracted from all articles were rearranged and similar elements were grouped, leading to four different categories that were most frequently in the articles of the literature review. This was aimed to find out the scope of the STEM education and the key definitions of STEM education.

RESULT AND DISCUSSION

In total, 17 selected studies were reviewed and published from 2010-2019. In this literature review, STEM education focused on four key definitions based on the selected studies: (a) STEM as discipline, (b) STEM as instruction, (c) STEM as field, (d) STEM as a career that is pictured in [Table 1](#).

STEM as Discipline

The first key is the STEM discipline. Based on the literature review, 16 of 17 studies defined STEM education as discipline due to the strategy of STEM implementation that should cover two or more subjects among STEM subjects. STEM discipline becomes a fundamental part of STEM education because most of the initiatives in STEM education would be related to the disciplines. Kubat and Guray (2018) believed that these four disciplines to be taught as a holistic and an undistinguished collective, rather than teaching these four disciplines independently. Otherwise, Hobbs, Clark, & Plant (2018) revealed five various models of STEM implementation based on the discipline:

1. The first model is “Four STEM disciplines were taught separately”; for example, in science classes, there is an updated focus on using representations to develop the concept. In mathematics, teachers can utilize complete problem solving to prepare the students.
2. The second model is “teaching all four but more emphasis on one or two”; for example, a teacher integrated sciences and mathematics through a problem-based learning where students design a vehicle.
3. The third model is “integration at least three disciplines”; for example, the engineering processes of teamwork, identify and investigate a problem, design a solution, and testing and evaluation are added into science and mathematics units, but there are limited points across the science and mathematics subjects.
4. The fourth model is “the integration of all four subjects by a teacher”. Science teacher integrates technology, engineering, and mathematics into science, for example, a school promoted new STEM initiatives that focused on designing digital solutions to real-world problems.

The other researchers also believe that STEM discipline will depend on the school curriculum (Breiner et al., 2012; McDonald, 2016).

Table 1. The key definitions of STEM education

Authors	Key Definitions			
	STEM as Discipline	STEM as Instruction	STEM as Field	STEM as Career
Bybee (2010)	√			√
Breiner, Harkness, Johnson, & Koehler (2012)	√	√	√	
Ostler (2012)	√	√		
Micah Stohlmann, Moore, & Roehrig (2012)	√	√		
Ejiwale (2013)	√		√	
Marrero, Gunning, & Germain-Williams (2014)	√		√	√
White (2014)	√		√	√
Fitzallen (2015)	√			
Kelley & Knowles (2016)	√	√		
McDonald (2016)	√	√		
Yildirim (2016)	√			
Kubat & Guray (2018)	√	√		
Thibaut et al. (2018)	√	√		
Wright & Ellis (2018)				√
Beswick & Fraser (2019)	√	√		
Pleasant et al. (2019)	√			
Schreffler, III, Chini, & James (2019)			√	

STEM as Instruction

The second key is STEM instruction. Eight of 17 studies defined STEM as instruction. In this domain, STEM education was considered as an approach that was built upon natural connection among STEM disciplines for (1) furthering students understanding of each discipline by building on students' prior knowledge; (2) broadening students' understanding of STEM disciplines through exposure to socially relevant STEM context and (3) making STEM disciplines and career more accessible and intriguing for students (Wang et al., 2011).

STEM instruction is transformed from conventional teaching, teacher-centered learning to active, student-centered learning. McDonald (2016) summarized the pedagogical instructions, including inquiry; argumentation and reasoning; digital learning; computer programming and robotics; integration of some STEM

content; cooperative learning; student-centered; hands-on, assessment; 21st-century skills, that were useful in developing student engagement and achievement in STEM disciplines. STEM instruction also referred to solving problems that described concepts and processes from science and mathematics while incorporating the teamwork and design methodology of engineering and using appropriate technology (Smith & Karr-Kidwell, 2000).

The previous study confirmed that STEM instruction has considerable effects on the students' attitudes towards students' career interest in their future. STEM instruction also could increase the effectiveness of STEM education, make meaningful learning possible, develop relevant careers content standards and skills useful in everyday life (John et al., 2018; Maarouf, 2019; Pawilen & Yuzon, 2019; Sari, Alici, & Sen, 2018). Pawilen and Yuzon (2019) established six critical things that need to be

considered in designing STEM instruction:

1. The interest of the students on the topics and activities
2. Availability of materials to be used
3. Appropriateness of the topics and activities to the learners
4. Relevance to learners' daily lives
5. Connection of the contents and activities to the K-12 curriculum
6. Integration of science, technology, engineering, and mathematics

In addition, three of the studies defined STEM instruction as a STEM curriculum in a bigger scale of education (Kubat & Guray, 2018; Ostler, 2012; Thibaut et al., 2018). STEM instruction reveals the learning process on the class scale. Meanwhile, the STEM curriculum discusses the learning process on the school scale. In both scale, STEM was believed to provide opportunities for more relevant, less fragmented, and more stimulating experiences for learners' (Furner & Kumar, 2007).

Any coordination of the teaching across disciplines makes some knowledge demand about the other disciplines in order to have practical conservations for coordinated planning. A capacity to collaborate, and to think creatively and innovatively about one's teaching is a minimal requirement (Beswick & Fraser, 2019; Eckman, Williams, & Silver-Thorn, 2016). It can be solved through STEM teachers' training in a different way than scientists, mathematicians, and engineers who contributes to all facets of responsible 21st-century learners and citizen (Ostler, 2012). The implementation of STEM instruction in an educational system that has a very established segregated and discipline-based structure that required the profound restructuring of the curriculum and lessons (Nadelson & Seifert, 2017). Likewise, STEM instruction required numerous materials and resources for students (Pawilen & Yuzon, 2019; Stohlmann et al., 2012). They discovered the critical content standards to learn in a STEM curriculum identified by the student teachers:

1. Science concepts: life sciences, physical sciences, chemical sciences;
2. Technology concepts: technology as tools, technology as ideas, technology as a product of science;
3. Engineering design concepts: models, designs, problem-solving, communicating ideas, planning, implementing;
4. Mathematical concepts: numbers, problem-solving, geometry, measurement, representation of math ideas using objects, symbols, and words.

STEM as Field

NSF defined STEM field broadly, including not only the standard strategies of Natural Sciences, mathematics, engineering, and computer and information, but also such behavioral sciences as psychology, economics, sociology, and political science (Green, 2006). The STEM field is described as the push for graduating more students in the science, technology, engineering, and mathematics fields. Thus, the country could maintain their competitiveness and no fall behind other countries and improve critical reasoning and logical thinking of their citizens (Breiner et al., 2012; Sadler & Zeidler, 2004).

Five of 17 studies defined STEM as a field. Lack of research collaboration across STEM fields was considered one of the identified barriers to STEM education. Research collaboration through cluster concepts across STEM fields for an integrated curriculum will enhance connectivity and information sharing among the stakeholders (Ejiwale, 2013; Haruna & Ibrahim, 2015).

Gandhi-Lee et al. (2017) categorized three broad factors that influenced the retention of undergraduates in STEM fields:

1. Interactions with faculty: The faculty-student interactions can have a significant impact on students' persistence in a STEM-related field;
2. Student/faculty interactions in the classroom: Personal classroom interactions with faculty in the college setting can have a critical role in students' choice of whether to continue in STEM;
3. The environment of undergraduate science courses: Although most faculty interactions happen within a classroom, student interactions with faculty outside of formal teaching are also found to impact student retention in the STEM field positively. Positive interactions out of the classroom, those happen during office hours, during a research forum, and in a laboratory, could encourage students' continued commitment in STEM.

STEM as Career

In total, four of 17 studies revealed STEM as a career. This domain focuses on the students' career in the future, which is related to STEM fields, for example, if a student is majoring molecular biology, they will enter the STEM career as a scientist. They may or may not be exposed to technology, or mathematics or engineering, that specifically pertains to their field, but chances are they would be exposed in some way, shape, or form. Therefore, the integration in terms of STEM may or may not be occurred. However, it must be noted that they were within a STEM field (White, 2014). Some researchers revealed that

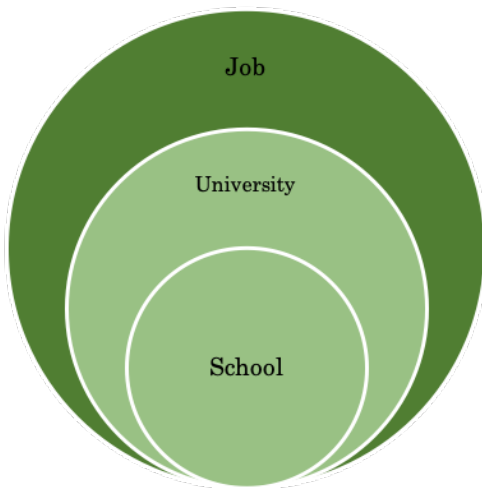


Figure 1. The Scopes in STEM Education

increasing the number of individuals qualified for and pursuing STEM careers can help the country stay competitive with others and improved the global economy through increased innovation and technology (Freeman, 2005; Lacey & Wright, 2009). Therefore, it is vital to develop a population of college graduates with STEM degrees to meet these increasing demands (Rozek et al., 2017).

The Relationship among Key Definitions

The first two-key definitions of STEM education are covered in the school scope (Primary to secondary level), the third key definition is included in university scope (High school level), and the last key definition is revealed as job (Profession) scope that is shown in Figure 1.

STEM discipline and instruction exists idnn school level K-12 education, which are mostly implemented among the selected studies. This scope is considered as the basic implementation of STEM education, which also becomes the most critical part. Researchers believed that STEM education should start from earlier education, such as an elementary school that also provides a robust environment and supports STEM implementation (Ching et al., 2019; English, 2017; Estapa & Tank, 2017).

Meanwhile, STEM as the field is included in the university scope because students could freely choose the STEM or non-STEM field at this level. The STEM field is called as STEM major that is not covered science, technology, engineering, and mathematics major only, but also the other majors such as information technology, natural science, statistics, chemical engineering, etc.

Based on the 17 selected studies, only five studies were conducted to identify the STEM field, which means it is rarely getting concern from the researchers. The last scope is STEM Job, with four studies worked on it. STEM education is defined as a career that also becomes the

main future goal of STEM education. Students in each country are believed they could move from national competitiveness to international competitiveness through STEM career and direct/indirectly improve the global economy.

CONCLUSION

Based on the literature review, researcher reveals that the definition of STEM education is too broad and depends on the stakeholders during the STEM implementation. In this study, the researcher concludes STEM educations into four key definitions: STEM as discipline, STEM as instruction, STEM as the field, and STEM as a career. From these four key definitions, it seems that STEM discipline becomes the most frequent research as well as the fundamental definitions of STEM education. Further, these four key definitions are also covered into three scopes. STEM discipline and instruction are included in the school scope, which mostly talks about how to provide an active learning process through STEM learning. The next is a STEM field that exists in the university scope. The students are supported to choose the STEM field at the university level after learning STEM discipline in the School. Lastly, STEM career is included in a STEM job or profession as the highest scope as well as become the last goals in STEM education. The researcher is hoping this study will provide information to the other researchers as well as the stakeholders around the world on how they should focus on the implementation of STEM education.

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