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STEM on Science Learning in Indonesia: An Opportunity and A Challenge

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Abstract

STEM has become a strategic issue in learning on an international scale, as well as in Indonesia. Related to the term "STEM" in Indonesia, it is often referred to as an approach to learning. This research is a literature study that examines four things, namely, the introduction of STEM, which is an integration of four disciplines (Science, Technology, Engineering, and Mathematics) in learning; Approaches that can be used in STEM implementation are The SILO Approach, The Embedded Approach, and The Integrated Approach; STEM opportunities in science learning in Indonesia can improve concept understanding, problem-solving skills, scientific literacy skills, creative thinking skills, and critical thinking skills; and the challenge when implementing STEM in learning is the demand for teachers to be able to understand the relationship between disciplines in STEM and demands in the technological aspects that all schools in Indonesia cannot meet.

Keywords: *Science, Technology, Engineering, Mathematics, STEM, Science Learning*

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Introduction

STEM education involves students in exploring problems in real-world contexts, using science, technology, engineering, and math skills (Gee & Wong, 2012). Thus, STEM education is not a simple integration of these components but rather an authentic and attractive approach to equip students with skills to manage dynamic knowledge and complex and authentic scenarios. Thus, STEM education is not just an integration of the four components. STEM is more appropriate if it becomes an authentic and attractive approach that can equip students with skills to manage dynamic knowledge. Through STEM education, students develop knowledge and skills related to the components in STEM. Students who are able to develop these skills will be able to pursue future careers and be able to adapt to a world that is rapidly developing by technological advances (Zollman, 2012). Jurisdictions worldwide have dedicated significant funds and efforts to implement STEM education strategies which calls on educational educators and researchers to deliver better STEM education programs (Gough, 2015; UNESCO, 2015).

Internationally, the STEM education movement has set a broad mission that aims to impact students of all ages and from different social and cultural backgrounds. STEM education needs to be started in early childhood because with good initial competence, and it will predict future achievements (Johnston, 2011; Watts et al., 2014). However, in implementing STEM in learning, there are problems. Female students felt less positive about STEM and were much less likely to pursue STEM studies or careers (Marginson et al., 2013). Another problem that may arise is that students with low economic levels or certain cultural backgrounds will have low opportunities for STEM education (Thomson et al., 2017). These issues are important for attention. All students should have the same opportunity in education.

In Indonesia, STEM is often referred to as a learning 'approach' (Lestari et al., 2018; Siswanto, 2018; Utami et al., 2018). However, the implementation of STEM in Indonesia is still not too serious and deep. There are still many deficiencies in STEM implementation because STEM, which is applied in learning tends to be simple.

This study aims to explore information about (1) Science, Technology, Engineering, and Mathematics (STEM), (2) approaches that can be used in STEM implementation, (3 STEM opportunities in science learning, and (4) challenges when implementing STEM in learning.

Methods

This research is a qualitative research using library research techniques. This study aims to describe and analyze existing phenomena, which are taking place now or in the past through analyzing valid literature sources (Sugiyono, 2012). In this study, the topics analyzed with literature study is the application of STEM-based learning in Indonesia. This research examines four things, namely, the introduction of STEM, which is an integration of four disciplines (Science, Technology, Engineering, and Mathematics) in learning; Approaches that can be used in STEM implementation are The SILO Approach, The Embedded Approach, and The Integrated Approach; STEM opportunities in science learning in Indonesia can improve concept understanding, problem-solving skills, scientific literacy skills, creative thinking skills, and critical thinking skills; and the challenge when implementing STEM in learning is the demand for teachers to be able to understand the relationship between disciplines in STEM and demands in the technological aspects that all schools in Indonesia cannot meet.

The research was conducted by reviewing STEM-related articles. This article discusses STEM definitions, various STEM approaches to learning implementation, STEM opportunities in science learning in Indonesia, and the challenges of STEM implementation for teachers. The data was reviewed in depth and explained again and linked to one another. This aims to reveal the impact and factors that influence the application of the STEM approach.

Results and Discussion

What is Science, Technology, Engineering, and Mathematics (STEM)?

STEM is basically an acronym for Science, Technology, Engineering, and Mathematics where the four components cannot stand alone (Pimthong & Williams, 2018). STEM is an integration between the four components which are related to various situations and experiences of everyday life. STEM has relevance because each component in a scientific discipline (S-T-E-M) does not stand alone and basically, complex multidimensional problems are never separated from the four disciplines (Moomaw, 2013; Talley, 2016; Webb, 2013). STEM education appears with a mission to achieve educational goals that prepare students to be able to compete in the future life and answer the challenges of the demands of a reliable workforce. All students require integration and application of STEM concepts and processes (Bybee, 2010; English, 2016; Stohlmann et al., 2011).

STEM Approach to Learning Implementation

There are 3 approaches in implementing STEM education in learning, namely Integrated Approach, Embedded Approach, and SILO Approach (Roberts & Cantu, 2012; Widya et al., 2019). The following is an explanation of each approach that can be adapted when implementing STEM in learning.

The SILO Approach

The SILO approach has the principle that in learning, each discipline in STEM is isolated from one another (Dugger, 2010). Suppose it is illustrated how the relationship between the four STEM components is shown in Figure 1. The components of science and mathematics are independent, while technology and engineering are combined because they are still in the same knowledge domain. Learning in each STEM discipline which is carried out in a separatist manner, allows students to gain a deeper understanding of the content of a subject topic. This separatist-focused learning can trigger an appreciation of the “beauty” of the subject itself (Roberts & Cantu, 2012). Learning with the SILO approach is characterized by the large role of the teacher in directing learning. Students are given few opportunities to learn while practicing "learning by doing", they are more taught what to know (Janice Morrison, 2006).

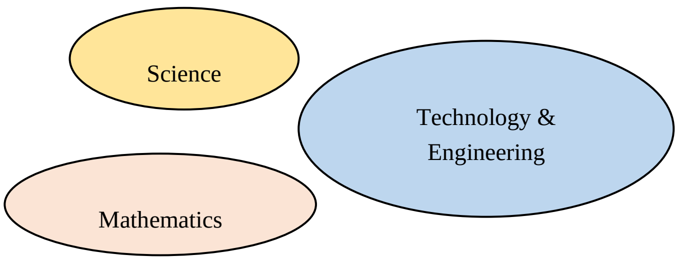


Figure 1. The SILO Approach in STEM Education

The Embedded Approach

In implementing the Embedded approach, students can gain knowledge through solving problems that exist in the real world, where the problems solved must vary, such as those related to social, cultural, and so on (Chen, 2001). In the Embedded STEM technology content and techniques are more emphasized (as taught in the SILO approach). What is different about this embedded approach is implementing learning, which is more emphasized in reviewing several contexts (Rossouw et al., 2011). However, the material planted is not designed to be evaluated or assessed. In the Embedded STEM, science and mathematics integration in learning through planting in the technology and engineering domains. For more details, how the four STEM components for this embedded approach are shown in Figure 2.

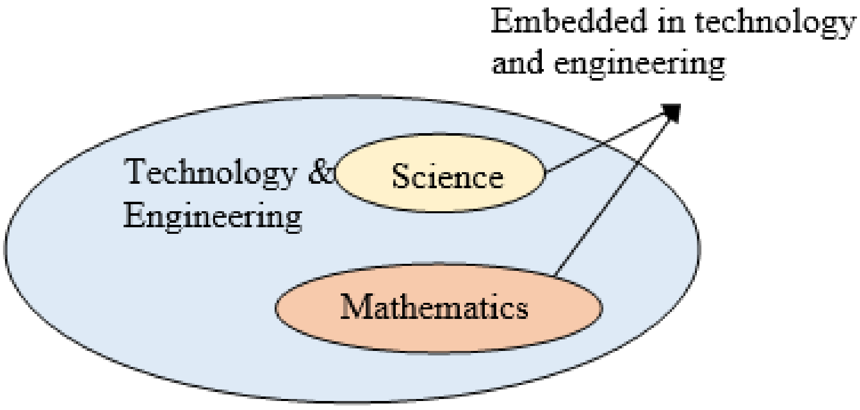
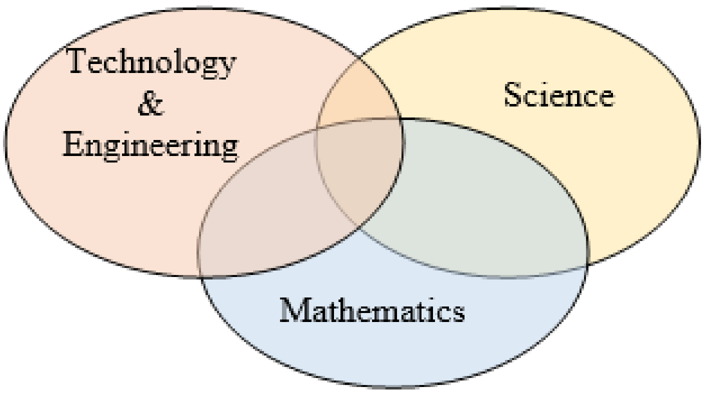


Figure 2. Embedded Approach in STEM Education

The Integrated Approach

An integrated approach to STEM education is carried out by removing the four components' barriers and making them a subject (Breiner et al., 2012; Morrison & Bartlett, 2009). The depiction of the integrated approach is as shown in Figure 3. The meaning of this integration is different from embedding it in the embedded approach. Ideally, the integrated use of the four components in STEM allows students to gain mastery of the competencies needed to solve problems Ideally, the acquisition of student competencies in solving problems can be done by integrating the four components in STEM (Harden, 2000). Teachers who can teach STEM well will be very useful for students in facing a "multi-disciplinary" world so that they will be better trained in solving the problems they will face (Wang et al., 2011). Also, teaching through this integrated approach can increase interest in STEM content, especially if it is taught to students from an early age (Barlex, 2011).



Gambar 3. Pendekatan Terintegrasi dalam STEM

STEM Opportunities on Science Learning in Indonesia

STEM has a great opportunity to increase the capacity and capability of students. In Indonesia, STEM is more often integrated with the learning model. Some researchers also develop learning media by integrating STEM education in it. This opportunity must be taken into consideration for educational practitioners to optimize the achievement of learning objectives. Several STEM opportunities in optimizing the achievement of science learning objectives that have been researched are presented in Table 1.

Table 1. Findings of the Use of STEM on Science Learning

Skills/Abilities	Findings
Conceptual Understanding & Mastery of Concepts	• Students' understanding of the concept of motion systems in humans has increased significantly with the implementation of STEM-based e-books (Komarudin et al., 2017). • Students' understanding of physics concepts taught with STEM is better than conventional learning (Sagala et al., 2019). • Understanding of physics concepts increases by providing STEM-based teaching materials (Pangesti et al., 2017; Yuanita & Kurnia, 2019). • Understanding of the concept of ecosystem material has increased in the high category with the implementation of the STEM integrated Project Based Learning (PjBL) learning model (Astuti et al., 2019). • Students' mastery of concepts on the topic of business and energy has increased significantly by implementing authentic inquiry-based learning for STEM education (Pranita et al., 2019). • Students' mastery of concepts on dynamic fluid material has increased with the implementation of problem-based STEM learning (Rivai et al., 2018). • Students' mastery of concepts in Biology has increased in the medium category with the implementation of the STEM-based Project Based Learning (PjBL) Model (Afifah et al., 2019). • Students' mastery of concepts on the sub-topic of environmental pollution has increased significantly by applying the STEM-based Problem Based Learning learning model (Melati et al., 2019).
Problems Solving	• Students' problem-solving abilities on the topic of wave and sound have improved by implementing problem-solving-based STEM modules with the theme of the DOME house (Alfika et al., 2019). • Students' problem-solving abilities on dynamic electricity topics increased significantly with the STEM approach (Dewi et al., 2018).
Scientific Literacy	• Students' scientific literacy skills have increased in the medium category with the implementation of STEM-based virtual labs (Ismail et al., 2016).
Creative Thinking	• Students' creative thinking ability on solubility material and solubility product increase with good criteria by applying the Problem Based Learning learning model with the STEM approach (Ariani et al., 2019). • Students' creative thinking skills on the topic of

Skills/Abilities	Findings
	environmental pollution have increased with the application of the STEM-PjBL model (Sukmawijaya et al., 2019).
Critical Thinking	• Students' critical thinking skills in Biology subjects increased in the high category with the implementation of the STEM-based Project Based Learning (PjBL) Model (Afifah et al., 2019). • Students' critical thinking skills in physics lessons increased in the medium category by applying worksheets with the STEM approach (Lestari et al., 2018).

Based on the analysis of the literature study we conducted, we still have not found many studies on science learning that apply STEM. Especially the application of STEM in improving scientific literacy skills which are still difficult to find. This opens up opportunities for other researchers to develop research in that area.

STEM Challenges in Learning Science

STEM education is built on the basis of curriculum integration theory which is present in two perspectives (views). First, this perspective states that STEM education allows teachers to integrate several related subjects. Integration is carried out without neglecting the characteristics of each integrated subject, for example unique characteristics, depth, and depth. On the other hand, there is a gap between teacher knowledge and skills required for STEM education and how STEM subjects are taught (Cuadra & Moreno, 2005). Teachers must have the ability to transition from monodisciplinary to transdisciplinary understanding. It is important to reduce the gap between current learning and the skills teachers must have in implementing STEM education (Furner & Kumar, 2007). Based on these demands, teachers are not only responsible for understanding one subject, but must be able to explain other relevant subjects in STEM education (Sanders, 2009), which entails investing in teacher professional development and reorganizing teacher education programs. at university (Klein, 2005). Then for the second, this perspective is related to the STEM education curriculum that can guide teachers in implementing STEM. Teacher effectiveness in learning is limited if the curriculum is designed to have boundaries that are too rigid (Pinar et al., 2000). On the other hand, a flexible curriculum allows teachers to teach STEM subjects in their natural context, but this will certainly be different from the curriculum of different disciplines (Jardine, 2006). So that if forced to be integrated, it might be difficult for students to accept.

Aspects of STEM emphasis in learning include: asking science questions and defining problems, planning and carrying out investigations, using mathematics; information technology, and computers; and computational thinking, and obtaining, evaluating and communicating information (Afriana et al., 2016). In order for students to be able to implement STEM and be able to learn well, teachers need to design a strategic approach for the needs of STEM integration in learning (Kelley & Knowles, 2016). Kelley & Knowles (2016) suggest that the integration of the four components in STEM is not done all at once because it can make it difficult for students (Afriana et al., 2016; Kelley & Knowles, 2016). At least in the learning process the teacher is able to integrate the two components in STEM. Teachers must be able to have a strong understanding of the relationship between disciplines in STEM. This is a challenge in itself for teachers.

Another challenge of STEM is related to technology, because STEM is closely related to Engineering and Technology, and not all schools can apply it. Technology and engineering programs in schools are generally quite low (Bybee, 2015). The most significant challenges center on introducing STEM-related problems, such as developing competencies to address students' problems as citizens (Bybee, 2015)

Conclusion

STEM is an acronym for Science, Technology, Engineering, and Mathematics. The four components cannot stand alone when implementing in learning. The four components are integrated with everyday life experiences. In implementing learning, three approaches can be used, namely The SILO Approach, The Embedded Approach, and The Integrated Approach. In Indonesia, STEM has the opportunity to improve students' skills in terms of concept understanding, problem-solving abilities, scientific literacy skills, creative thinking skills, and critical thinking skills. What is a challenge in implementing STEM is the demand for teachers to be able to understand the relationship between disciplines in STEM and demands in technological aspects that cannot be met by all schools in Indonesia. Even though STEM has long been developing in the world of education, in Indonesia it is still not a focus. Teachers in Indonesia have not yet implemented STEM widely. The development of students' abilities in scientific literacy with STEM has not been done much by researchers. This is a great opportunity for further research.

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