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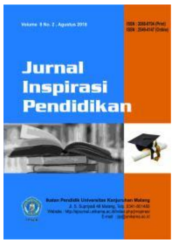

STEM Learning for Science Education Program: Reference to Indonesia

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ABSTRAK

Pendidikan STEM kini telah menjadi perhatian para peneliti pendidikan untuk dianggap sebagai pembelajaran yang sangat penting. Di Asia Tenggara, Indonesia merupakan salah satu negara terbesar yang memiliki banyak sumber daya manusia yang perlu ditingkatkan keterampilan dan kemampuannya. Penelitian ini bertujuan untuk mengkaji apakah urgensi pembelajaran STEM di Indonesia dengan melihat keterampilan abad 21. Penelitian ini menggunakan metode analisis isi, termasuk mengkaji implementasi terbaik pendidikan STEM yang ditujukan untuk guru dengan menyelidiki pelatihan keterampilan desain teknis untuk guru dan siswa dan juga meninjau literatur dari penelitian sebelumnya dari tahun 1990 hingga 2016 yang berfokus pada pengembangan pendidikan pembelajaran STEM di seluruh dunia. Dalam penelitian ini ditemukan bahwa pendidikan STEM menunjukkan perkembangan yang sangat signifikan di seluruh dunia dan berdampak besar dalam upaya meningkatkan pemahaman konsep, literasi, dan kreativitas siswa. Dari berbagai sumber penelitian telah memberikan bukti bahwa implementasi dalam implementasi STEM Education kepada guru. STEM merupakan aplikasi kehidupan sehari-hari yang dekat dan meningkatkan kesadaran siswa terhadap lingkungan.

Keywords:
STEM Education
21st century skills
Science Education

ABSTRACT

STEM education has now become a concern for researcher of education to be considered as a highly demanding learning. In Southeast Asia, Indonesia is one of the largest countries that has a lot of human resources that need to be improved in skills and abilities. This study aims to examine whether the urgency of STEM learning in Indonesia by looking at 21st century skills. This study uses content analysis methods, including examining the best implementation of STEM education aimed at teachers by investigating technical design skills training for teachers and students and also reviewed the literature from previous research from 1990 to 2016 which focused on developing STEM learning education throughout the world. In this study it was found that STEM education showed very significant developments throughout the world and had a major impact in efforts to improve students' understanding of concepts, literacy and creativity. From various research sources have provided evidence that implementation in implementing STEM Education to teachers. STEM is an application of daily life that is close and increases students' awareness of the environment.

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Introduction

In the current environment, Industry 4.0 and 21st-century capabilities are on the rise, and information is moving at a breakneck pace. The twenty-first century tells us that the primary purpose of our educational system should be to prepare students to live in the twenty-first century. Science, technology, engineering, and mathematics have advanced at a breakneck pace in the twenty-first century (STEM). This movement has an impact on human life quality and creates changes in many parts of life. Even when things change, they have both positive and negative consequences. Meanwhile, technology has rapidly developed, which has had a favorable impact. STEM Education has gotten a lot of attention in recent years, and it's important to understand it. STEM Education has been defined in a variety of ways, ranging from disciplinary to trans disciplinary methods, according to multiple journal papers summarize to (Sivarajah et al., 2019)

STEM (science, technology, engineering, and mathematics) education is an interdisciplinary approach to learning in which academic principles learned in school are integrated with real-world learning. Students' activities in applying science, technology, engineering, and mathematics demonstrate the activity. In the new economy, the framework provided in this study is to make links between schools, communities, jobs, and global corporations conceivable (Tsupros, 2019). STEM Education, according to (Nugroho, Permanasari, & Firman, 2019), is a strategy that is closely tied to real-world activities combining four disciplines: science, technology, engineering, and mathematics, which should be taught together. Based on Bybee (2013), the goal of STEM education is for all students to study and apply the core content of those disciplines, as well as the practice of STEM disciplines, to real-life situations. Instead of supplying kids with knowledge understanding of a concept, those curriculums should teach them how to acquire information. In light of those viewpoints, how does the curriculum prepare students for real-life situations and enable them to use the knowledge and skills required to be educated citizens?

There are many human resources that need to be developed in Indonesia, one of Southeast Asia's largest countries. Unskilled employees continue to dominate Indonesia's labor market, according to the Indonesian Central Bureau of Statistics. Out of the 22.1 million skilled workers, only 6.5 million are masters in their field of expertise. A deeper knowledge of STEM should be fostered among students in Indonesia as a result of the information given in the preceding paragraphs Before evaluating a teacher's ability to implement STEM in the classroom, it's important to assess the students' understanding of STEM. Teacher will be the first Indonesian liner.

As a generation, our capacity to operate in today's world is heavily reliant on STEM. STEM education has several benefits for our generation. As a part of STEM, science and mathematics may give solutions to fundamental questions about nature and how to perceive the universe, However, STEM fields can improve our quality of life. In addition to helping the government encourage innovation, developing a STEM competency may assist lay the foundation for future success. The following terminology are taken from the references to explain the scope of STEM education, which was previously limited to primary and secondary school:

a. The scope of a STEM teacher (also known as initial teacher education)
b. The greatest approaches for assisting STEM teachers in their current state focus on continued professional development.
c. The implementation of teaching and learning strategies that will improve STEM education
d. The use of digital technologies to boost learning.

e. Methods for developing and improving students' interest and involvement in STEM subjects.

"The quality of an education system can never exceed the caliber of its teachers," says McKinsey (2016) on the world's finest performing school system. Pre-service and in-service teachers, for example, should be familiar with the implementation and fundamental concepts of STEM. Pre-service and in-service teachers, hopefully, will gain a better grasp of how to use STEM and connect many topic areas to give learning opportunities. Pre-service and in-service teachers, on the other hand, recognized and pursued a STEM career path that should be promoted not just to children but also to their parents.

Meanwhile, there was no articles pursued a the movement of STEM Education as a career development especially in Indonesia. Most of study explain the model of STEM Education. Unfortunately, as a research and teachers/ lecturers need more data of historical of STEM Education to implement in learning activity. The correlation between history of the movement of STEM Education could be inspired every teachers and lecturer in science education to developed learning activities more relevance into pupils.

It is the goal of this article to make sure that Indonesian STEM education is up to par with international expectations. The level of competence and involvement in STEM fields will be insufficient if we only aim to provide for children. To avoid STEM education, the entire educational system must adopt approaches that are suited for our country's needs and outcomes. This will lead to a considerable and sustainable improvement in the quality of preservice and inservice teachers. On the other hand, STEM education is for students who learn to apply the basic knowledge and techniques of STEM fields to real-life issues by Bybee (2013). One reason for this is that by 2020, the number of people employed in jobs connected to STEM fields is anticipated to rise to more than 9 million (Pimthong & Williams, 2020). STEM jobs are expected to grow by 17 percent, compared to less than 10 percent for non-STEM occupations, according to the Economics and Statistics Administration as well as the Center on Education and the Workforce.

Method

The goal of this study is to use content analysis method to investigate the importance of STEM education and its implementation in Indonesia within the context of the 21st century skills category. Content analysis is a study method that enables academics to investigate human behavior in an indirect manner. This research looks at textbooks, articles, newspapers, commercials, music, political comments, novels, photographs, and nearly any other form of communication produced by teachers. Furthermore, content analysis helps the exploration of shifting trends in the area of STEM-based education by examining different findings of professional and popular publications. This study was continuing the research published by (Nugroho, Permanasari, Firman, et al., 2019) Similarly, it is desired that a visualization of the application of STEM education best practices for teachers explored in relation to training in technical design abilities would be included in this study. This study reviews the literature on STEM education development research results from 1990 to 2016 that emphasizes the development of STEM education throughout the world. The aims of this research was to examine the movement of STEM Education and the development of STEM Education around the world specifically in Indonesia.

Results and Discussion

3.1. Indonesia's need for STEM education is critical.

Numerous studies have shown that the quality of the instructor is the most significant element in student success. Researchers found that teacher education's quality has a substantial influence on teacher knowledge and abilities, which has a big impact on student achievement. Most countries have implemented a wide range of activities aimed at improving teacher professional development, ranging from very brief sessions to whole programs. Besides school-based programs and coaching for teachers in STEM education, there are also seminars, workshops, and other forms of outside and in-service training.

Doing STEM teacher education, based on previous research, is one way to improve STEM teaching. It's possible to increase teachers' understanding and ability to grasp teaching by using the following three strands of teacher knowledge:

a. Subject Matter Knowledge.
b. Pedagogical Knowledge.
c. Pedagogical Content Knowledge. (Shulman, 1987)

When it comes to topic understanding, knowing the subject matter is one thing, but knowing pedagogy is another. As a last point, the link between the real material and pedagogy is addressed by knowledge of pedagogical content Training and preparation programs for teacher candidates are expected to assist them in developing their skills. Pedagogical content knowledge is implanted when teachers complete a teacher training program in Indonesia, which develops subject knowledge and pedagogical competency.

Before and during the course of teaching, instructors develop activities to make them more engaging for students and to increase their capacity to answer questions about industry 4.0 and 21st century skills. Research on developing activities was carried out in order to determine their effectiveness. Teacher should think about what it is like to be a scientist and how they think and act before to creating the exercise. Students learn how to observe changes, handle materials, measure things, and document outcomes as a result of these activities. Their ability to anticipate outcomes and infer causes as well as their ability to articulate their views improves as well.

For their part, teachers need to create STEM-based learning activities that focus on specific essential themes in scientific courses. A specific topic should be studied in depth, if feasible, as part of the activity. Students develop their critical thinking and problem-solving skills as they experiment with their own science process abilities. This exercise allows students to come up with their own questions and challenges based on their enthusiasm and love for the topic matter they are learning about. It will be quickly described how to develop a STEM curriculum in elementary, middle, and high schools. There are a variety of ways to customize the program.

Educators who work in STEM fields must continually update both their subject knowledge (the "what" in STEM education) and their pedagogical abilities (the "how" in STEM teaching). CPD has the ability to keep teachers engaged and inspired throughout their careers as educators (CPD). He or she may also utilize it as a way to harness the present or future relationship between formal education and informal education In spite of its promise, STEM education is underutilized.

There is a strong emphasis on inquiry-based learning, project-based learning (PjBL), and problem-based learning (PBL) while reading about practical applications. However, there are exceptions to this rule. In question-based learning (QBL), curiosity and observation are combined with problem-solving. Other 21st century abilities, such as critical thinking, creativity, and problem-solving, are also included. It enables them to apply their own imagination in the process of designing and executing the project. Because of this, they may summarise and gather information The investigations in current practice were supposed to be open-ended, but many students just follow a text book's instructions to finish the learning process.

In recent years, STEM subjects have become increasingly popular in Indonesian schools. Known as "industry 4.0," these topics aim to tear down barriers between educational output and stakeholder groups and stakeholders themselves. Schools must ensure that students develop the abilities and goals necessary to engage in a scientifically and technologically sophisticated world in order to succeed. Whether you're a student or an experienced teacher, it's vital to know what 21st century education talents are. So, the skill maps have been clarified as a result of that. All pupils must develop as they progress through the educational system. As a consequence, the findings may be shown in Table 1.

Table 1. Analysis categories on STEM in each stages.

21st Century Skills	Categories of 21st Century Skills	Stages of Education			
		Early childhood themes	Primary priorities	Junior cycle key skills	Senior cycle key skills
Creativity and Innovation	Ways of Thinking			Being creative	
Critical thinking, problem solving decision making		Exploring and thinking	Engage in learning		Critical and creative thinking
Learning to learn, metacognition			Develop-ing learning, thinking and life skills		
Communication	Ways of working	Communicating	Communicate well	Communicating	Communicating
Collaboration				Working with others	Working with others
Information literacy including ICT	Tools for working			Managing information and thinking	Information processing
ICT literacy					
Citizenship, local and global	Living in the world				
Life and career		Well being	Be well	Staying well	
Personal and social responsibility		Identify and belonging	Have a strong sense of identify and belonging	Managing myself	Being personally effective

The implementation of STEM education will be explored in the following paragraphs based on the National Technical Academy and the National Research Council. The study of nature encompasses physics, chemistry, and biology, as well as the treatment or application of physics, chemistry, and biology actions, principles and norms. Scientists have accumulated vast amounts of knowledge over time. The process by which new skills and information are acquired. Science, technology, engineering, and math (STEM) information is utilized to guide engineering design processes. A number of today's technologies are also the result of scientific and engineering knowledge and application, and technical tools are used in both fields of research and development. An engineering degree is a compilation of information about the creation and development of man-made items with the objective of enhancing society's social life. As a problem-solving cognitive process, it's equally important. Science and mathematics are among the most advanced technological instruments used in engineering. Mathematics is the study of patterns and relationships between numbers, numbers, and space. It is true that mathematical assertions are supported or refuted by logical arguments that are founded on fundamental assumptions, unlike in science, where empirical data is sought for support or refutation.

According to (Backes et al., 2018), a great STEM lecture should include six characteristics. As a result of this, STEM classes tend to focus on real-world challenges and issues. Science, technology, engineering, and mathematics (STEM) students face real-world social, economic, and environmental problems and seek answers. The second aspect of STEM education is the engineering design process (EDP). As a flexible teaching technique, the EDP leads students through the stages of diagnosing and solving problems or design challenges. To begin, students must identify issues, do background research, identify and generate numerous solution ideas, build and construct a prototype, test and evaluate the product they developed, and lastly, redesign the product based on feedback from the assessment part of the process." This project involves dividing the class into numerous teams, each of which performs its own research based on their own ideas. Using a variety of techniques, accepting and learning from their failures, and trying again are all things that can be done. Finally, their concentration is on finding solutions to further the research.

The third aspect of STEM education is that they involve students in hands-on inquiry and open-ended exploration. For example, students' comments are utilized to make judgments about solutions since their work is hands-on and collaborative. As a result, students may speak with one other and, if required, alter their prototypes. Each of them is responsible for his or her own thoughts and research. The fourth feature of STEM education is collaboration. The sixth feature of STEM education is that it exposes children to difficult math and scientific concepts. It's important to include math and scientific concepts into STEM classes. If science and math are interwoven, kids may see that they aren't distinct subjects. Technology is also used in an acceptable manner, and individuals develop their own commodities based on issues and concepts. Lastly, STEM education allows for many correct answers and reframes failure as an integral part of the learning process, rather than an obstacle. When it comes to problem-solving, the STEM environment offers a plethora of chances for innovative solutions. In STEM education, students are encouraged to learn from their mistakes and try again to find a better answer. Meanwhile, the student is engaged in the activities of creating and discovering solutions; failure or incorrect solution/design is viewed as a positive step on the path of discovering and designing answers.

Many categories of science, technology, engineering, and mathematics (STEM) are merged in this method, which is referred to as "integrated STEM education." The term "integrated STEM education" has a number of meanings, but it may be used to define instructional methods to student activities. Due to the integration and application of the four aspects, students engage in engineering design and/or research activities and get meaningful learning (Stull et al., 2018). Our society's need for STEM education in the classroom has been highlighted (Ibáñez & Delgado-Kloos, 2018), according to another newspaper. It is defined as all "approaches that investigate teaching and learning across two or more STEM subject areas," according to Sanders (2009). He believes that every STEM learning should be organized to incorporate learning objectives from other STEM learnings in order to maximize learning. Learning outcomes in technology or engineering classes, for example, enhance students' math and science abilities and concepts (Sanders, 2009). There is no explicit mention of engineering design and real-world scenarios in the phrase. A number of studies have recognized STEM education as one of the most effective teaching methods, including integrated STEM education. Through the integration and application of mathematics, technology, or science in the classroom, students engage in engineering design or research and gain significant knowledge about theory and social life (Giamellaro & Siegel, 2018).

3.2 STEM Education Best Practice for Science Teacher

A positive attitude towards science and mathematics and science education is essential for pre-service primary school teachers since they are typically the first representatives of a student's scientific teacher group. As a result of teachers' ideas, pupils' opinions will also be influenced. In comparison to STEM and non-STEM majors, pre-service teachers with a stronger scientific curriculum in primary school themes have a more favorable attitude towards teaching science. STEM learning can also be facilitated through project-based learning (PjBL), which combines technology. Real-world experience is the basis for learning. Students actively participate in inquiry-based learning activities that are relevant to their everyday lives using the PjBL approach, which has long been recognized as an effective constructivist teaching style (Michaluk et al., 2018)

With the help of (Robi et al., 2017a), PjBL "bridges the gap" between academics and practitioners of a profession. If you're a middle or high school student, for example, "Marine Tech" gives instruction and hands-on learning experience in the disciplines of marine engineering, physics, and computer science (Robi et al., 2017b). Allowing pupils to develop their own creativity and engage in greater learning through teaching in student-centered classrooms. When students are taught in a student-centered way, they become more responsible for their own learning and actively participate in their education. In student-centered learning, the instructor serves as a facilitator, the learning environment can be dominated by a variety of materials and activities, and students can collaborate and share their own understandings with classmates (English, 2016).

In previous research, a number of researchers have discovered effective methods for teacher professional development. This list includes active learning, chances to reflect on teaching methods, closeness to classroom practice, an emphasis on subject knowledge, and the capacity to offer adequate time for students and instructors to apply what they have learned. According to integrated learning from a variety of knowledge groups, students in the integrated curriculum have the same performance as students in other knowledge groups. That they are superior to their peers in traditional disciplines-based education (Czerniak, 1999) is also evident. As a bonus, incorporating research results into the curriculum has been found to increase student motivation and interest in the subject. Empirical research have shown that STEM education that is integrated into the curriculum improves student success.

In some studies, students were given a preparation session before moving on to the engineering design components, which ranged from a single lesson to weekly sessions. Participants will learn how to handle or utilize LEGO materials that will be used later as construction materials along the modules as well as how to introduce the engineering design cycle through discussion. The teacher also emphasizes in this session that engineering design is all about brainstorming, planning, and iterating throughout the engineering process (Park et al., 2018). Others Yanyan, et al (2016) adopted a two-hour-per-week, five-week engineering design training program. They also provided a warm-up lesson in the form of a design job prior to beginning the study of scientific units with engineering design.

A STEM Education program will be implemented at Universitas Pendidikan Indonesia starting in 2014. Universitas Pendidikan Indonesia created a STEM-based workbook by Sejati (2017) improving students' STEM abilities on a lever system in accordance with studies on STEM education. STEM-based activities from the United States of America (USA) and Japan (Japan) had been studied. As a consequence of the study, two ways of integrating engineering practice into program activities, both in formal and informal settings, had positive results.

With the use of Arduino-phet, Prima (2018) shown how STEM education may be made more relevant. As a result of these variables, kids' technological literacy improves at a faster rate than at any previous time, according to the results. Activity to get students interested in STEM education that may be applied in the class:

1. Identify Problems

It's no different when it comes to engineering design-based science. Using appropriate scientific knowledge, students must deconstruct the design task or design challenge. Student's design challenges may be identified by teachers by presenting them with unstructured issues, which have been shown to be an effective learning tool (Yanyan, et al, 2016). Scaffolding techniques include providing problems in the form of specific data or embedded videos, audios, or pictures.

The teacher can also assist the student in analyzing problems in greater depth by asking scientific questions that guide them to see the key points of the problems, so that it is clear for them to identify resources they already have and what they still need to learn along with what is the current condition and what are the things to solve (Yanyan, et al, 2016). They can do this by written answer, artwork or entire class discussion.

In order to engage students in the learning process, the design problems should be contextualized for them. If you look at, for example, they questioned students about their birthplace, their interests, and their own weather experiences in a sequence of interactive questions about thunderstorm and tornadoes. Students who live in a state where the Common Loon is the state bird can also utilize the Common Loon as a backdrop for a design challenge at the elementary school level (Guzzey, et al, 2016).

2. Develop Possible Solutions

A student's knowledge and abilities must be gathered when a design problem has been identified. As a minimum, they must work as a dyad or as a group of more than two pupils. These steps are aimed at providing background information and preparing you to tackle the design problem. Hands-on activities or guided investigations can be used (Guzzey, et al, 2016).

3. Decide Best Solution

By maintaining engineering notebooks, design cards (Yanyan, et al, 2016), and other records, students may compare and analyze which of several alternative solutions best meets the demand and fulfills the constraints of the situation. As a way of simulating real-world situations, teachers should also offer students with design challenges that include economic, aesthetic, and societal limitations that they must take into account when deciding which solution is ideal. For example, while building the common loon platforms, students must consider buoyancy, stability in waves, predator protection, availability to water, and cost when selecting materials (Guzzey, et al, 2016). Other examples include a project in which students were required to create a tornado-proof house with few materials, yet the building still had to look like a house complete with outside walls and windows.

4. Build the Prototype

Here, students must build a working artifact based on the best solution design they have chosen, which meets the requirements of their design challenge. When we talk about building or constructing, we're talking about modeling, coming up with alternatives, and employing our imagination. As far as engineering design methods are concerned, the building process is crucial. Due to the fact that the final product of building serves as a vital mediator for students' learning. Penner et al., in Construction allows students to engage in model-based thinking, do deeper study of science ideas, and investigate mathematical connections. Following Roth's lead, he sees students' creation as a reflection of their own cognitive processes that may be explored in class. Building a working product allows students to participate in scientific thinking (Nugroho et al., 2017). To assist students understand the underlying science idea, the teacher or instructor might pose questions relevant to the building the students are creating.

5. Test the Prototype

Students were given many opportunity to test their product to see if it worked or not. The instructor might inquire which structures are still weak and why. Students might then use scientific discourse to go further into the underlying science ideas. Questions in the engineering journal might also be useful in guiding the student in determining if the product performs as intended (Sejati, 2017).

6. Redesign and Communicate

A student's product will be evaluated, iterated and optimized after the testing process to discover any flaws (Marulcu, 2016). Here, kids are primarily concerned with enhancing their appearance. During STEM camps, the failures during testing led to several side talks about the projects' structures. If time permits, students may change and retest their designs.

Incorporating engineering design into scientific education has had varying effects in different learning domains. Even if the mean gain score in this particular example was relatively tiny, it is likely due to the evaluation that is not in accordance with the learning. According to Yanyan, et al, (2016), as a result of engaging in engineering design based science, observed that students' problem-solving abilities were unaffected by the lack of assistance in thinking and building a prototype.

When it comes teaching specific science topics like basic machines, biological sciences, and material characteristics,the usage of building materials like as LEGO has been shown to be suitable. Students in primary school may be disappointed while working in teams since there is no scaffolding for peer cooperation, resulting in reduced excitement for working with a partner, even though engineering design-based science produces a favorable attitude toward science and engineering.

Conclusion

This study answered the implementation of STEM education in the 21st century and industry 4.0. STEM Education has been developed by many researchers. The results of this development have developed throughout the world and have a major impact on increasing student's self-awareness, conceptual understanding, and creativity. Many studies describe success in implementing STEM. This provides evidence that best practices for science teachers to apply STEM Education. STEM has a close everyday life. It is also explained that STEM is able to increase students' awareness of the environment. This learning approach can improve student skills that help students have skills and are ready to work in STEM workplaces. Regarding Industry Skills 4.0 and 21st Century, the STEM learning approach has been embedded in classroom activities using direct or indirect activities.

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