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# The Urgency of STEM Education in Indonesia

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## Abstract

Industry 4.0 and 21st-century skills are quickly increasing and becoming more knowledgeable. In this century, the primary purpose of our educational system should be to prepare students to live in the world. STEM Education has garnered increasing attention in recent years, and it is important to comprehend STEM Education. Indonesia is one of the largest countries in Southeast Asia with a vast number of human resources that need to be developed. The purpose of this study was to investigate the urgency of STEM education in Indonesia within the scope of 21st-century skill categories using the content analysis method, to investigate best practices of STEM education for teachers by investigating engineering design skills training, and to review the literature from 1990 to 2016 that has focused on the development of STEM education around the world. The data demonstrated that STEM Education has grown over the world and has a significant influence on students' idea comprehension, literacy, and creativity. Many studies show that the best strategy for science teachers is to incorporate STEM education. STEM is relevant to everyday life and improve student performance. These findings are important to be implemented in Indonesia for STEM Education implementation in Indonesia.

Keywords: STEM Education, 21st-Century Skills, Indonesia

## INTRODUCTION

Industry 4.0 and 21st-century skills are quickly increasing and becoming more knowledgeable. In this century, the primary purpose of our educational system should be to prepare students to live in the world. Science, technology, engineering, and mathematics (STEM) have advanced rapidly in the twenty-first century. This movement has an impact on the quality of life and produces changes in many facets of human life. Even when things change, they have both positive and negative consequences. Meanwhile, technology has advanced swiftly, which has had a good influence. STEM Education has garnered increasing attention in recent years, and it is important to comprehend STEM Education. Numerous journal papers describe STEM Education in various ways, ranging from disciplinary to transdisciplinary approaches (Burke et al., 2014; Honey et al., 2014; Moore and Smith, 2014).

STEM education is an interdisciplinary approach to learning in which students use science, technology, engineering, and mathematics in situations that draw links between school, community, job, and the global business enabling in the new economy (Teupros, Kohler, & Hallinen, 2009). According to Bybee (2013), STEM Education is a strategy that is closely tied to real-world activities and involves four disciplines as science, technology, engineering, and mathematics, all of which should be taught together. According to Bybee (2013), the goal of STEM education is for all students to study and apply the knowledge of those disciplines, as well as practice STEM disciplines, to real-life situations. Instead of offering knowledge comprehension of a subject, those curricula should teach students how to get information. Regarding those points of view, how does the curriculum prepare students for real-life situations and enable them to use the information and skills required to be an educated citizen?

Indonesia is one of the largest countries in Southeast Asia with a vast number of human resources that need to be developed. According to data from the BPS - Central Bureau of Statistics Indonesia, 88 million unskilled laborers continue to dominate Indonesia's workforce. There are 22.1 million skilled workers, but only 6.5 million master their fields. Based on the data shown above, Indonesia should be better prepared and make more efforts to expand and improve students' grasp of STEM. Essentially, prior to kids' comprehension of STEM, we must consider the teacher who will incorporate STEM in their classroom. A teacher will be the first liner for Indonesia as a STEM Education facilitator. According to the Central

Bureau of Statistics Indonesia, there is a disparity between the availability of skilled labors and qualified labors.

STEM is fundamentally vital to our generation's ability to live in modern society. STEM empowers our generation in a variety of ways. Science and mathematics can give answers to fundamental concerns about nature and how to interpret the world in STEM. Meanwhile, STEM fields have the potential to improve our quality of life. Developing knowledge in STEM may also help the government foster innovation and provide the groundwork for future success.

The following concepts from the sources clarify the breadth of STEM education, which was formerly limited to elementary and secondary school.

a. The teacher's role in STEM education (called initial teacher education)
b. The most effective approaches to assisting STEM teachers in their current situation center on continued professional development.
c. The implementation of teaching and learning methods that would improve STEM education.
d. Improving learning using digital technology.
e. Methods for boosting and increasing students' interest and involvement in STEM subjects.

According to McKinsey (2016), the world's top-performing school system is one in which "the quality of an education system can never exceed the quality of its teachers." Obviously, pre-service and in-service teachers should be familiar with the implementation and fundamental concepts of STEM. Pre-service and in-service teachers, hopefully, will have a better grasp of how to use STEM and integrate several 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 highlighted not only for children but also for their parents.

This article strives to guarantee that STEM education in Indonesia meets international standards. Meanwhile, if we merely try to provide for children, the level of performance and participation in STEM disciplines will be insufficient. If we are not to transition to STEM education, we must implement step-change techniques that are appropriate for our country and outcomes across the educational system. As a result, the quality of pre-service and in-service teachers will improve significantly and sustainably. STEM Education, on the other hand, is for all students who learn to apply basic STEM concepts and practices to real-life circumstances (Bybee, 2013). The value of STEM education is clear, in part, since employment in STEM-related industries is expected to increase to more than 9 million between 2012 and 2020. (Vilorio, 2014). Furthermore, the Economics and Statistics Administration, as well as the Center on Education and the Workforce, forecast that STEM occupations will expand by 17%, compared to less than 10% growth for non-STEM occupations (Butcher, 2013).

## METHOD

Using the content analysis approach, the current study investigated the importance of STEM education in Indonesia within the context of 21st-century skill categories. Content analysis is a study approach that allows researchers to analyze human behaviors indirectly by examining their products, which include textbooks, articles, newspapers, commercials, music, political statements, novels, and pictures—virtually all forms of communication. Furthermore, content analysis helps evaluate evolving trends in education by examining professional and popular publications (Fraenkel, Wallen & Hyun, 2012). Similarly, in this study, the best practices of STEM education for teachers in terms of engineering design skills training were studied. This research examines the literature from 1990 to 2016 that focuses on the advancement of STEM education throughout the world.

## RESULTS AND DISCUSSION

### The Urgency of STEM Education to Indonesia

Many studies suggest that teacher quality is the most important factor influencing student achievement. Evidence demonstrates that the quality of teacher education has an influence on teachers' educational outcomes in terms of teacher knowledge and abilities (Blömeke et al. 2012), which are in turn connected to instructional quality and student accomplishment (Kersting et al. 2012). Professional development activities range from very brief sessions to full programs in practically all nations (Goldsmith et al. 2014). These include school-based programs as well as coaching, seminars, and other sorts of out-and-in-service training aimed at assisting teachers in developing their abilities. Based on prior research, it can be determined that implementing STEM teacher education is one attempt aimed at improving STEM education. The following are three strands of technical knowledge that may be utilized to increase instructors' awareness and capacity to grasp the instructional process.

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

Subject matter knowledge is concerned with knowledge of content, pedagogical knowledge is concerned with knowledge of pedagogy, and pedagogical content knowledge is concerned with the interaction between pedagogy and content itself. Preparatory and training programs are meant to help pre-service teachers enhance their skills. In Indonesia, it is mandatory to finish a teacher training program in order to build content knowledge and pedagogical expertise, which are then implanted as pedagogical content knowledge.

The learning experiences are designed to pique our students' interest and raise questions about how pre-service or in-service instructors build the activity to make it more interesting for students and improve their ability to address industry 4.0 and 21$^{st}$-century skill demands. A study of development activities was conducted. The teacher should consider science process skills and how scientists think and act while designing the task. Through these tasks, students gain experience noticing changes, touching materials, measuring items, documenting data, anticipating impact, inferring reasons, and communicating ideas.

However, teachers should concentrate on designing STEM-based learning activities that focus on certain major topics in scientific courses. The activity should give possibilities for in-depth research of a specific topic. This implies that individuals not only practice their particular science process skills but also move these skills when they apply critical thinking and problem-solving. Students are encouraged to create their own questions and difficulties based on their curiosity and enthusiasm for the topic during the exercise. There will be a quick description of how to build a STEM program in elementary, middle, and high schools. Essentially, the application is adaptable.

Teachers are sometimes referred to as "lifelong learners," which indicates that they must constantly enhance and update their subject knowledge (the "what" in STEM teaching) as well as their pedagogical expertise (the "how" in STEM teaching). According to McKinsey (2016), Continuing Professional Development can motivate and assist teachers throughout their careers, as well as capitalize on current and potential links between formal and informal learning. Meanwhile, the promise of formal STEM education for boosting student learning and STEM teacher education is acknowledged but underutilized.

Inquiry-Based Learning (IBL), Project-Based Learning (PjBL), and Problem-Based Learning (PBL) methods encouraged students to interact with mathematics and scientific concepts in the context of real-world applications. These techniques are shared by all STEM courses while there are some variances in individual subject areas. Inquiry-Based Learning and Problem-Based Learning place an emphasis on inquiry and observation, as well as identifying and solving problems. It emerges as a component of 21st-century skills such as critical thinking, creativity, problem-solving, and so on. Meanwhile, project-based learning focuses on students' creativity in creating and designing the project. Students are able to summarize the meaning and obtain knowledge as well as evidence. The investigations in contemporary practice were supposed to be open-ended, but in actuality, many students just follow textbook instruction to finish the learning process.

In recent years, there has been a fast increase in the interest in STEM subjects in schools in Indonesia. Those subjects attempt to break through the barriers that have been identified as industry 4.0 between school output and stakeholders. To make a positive contribution to society, schools must guarantee that their students have the skills and aspirations to participate in an increasingly scientific and technological world. Teachers (both pre-service and in-service) should be aware of what constitutes 21st-century skills in education. To clarify, the maps of the skill have been identified. It is critical for all students to improve as they advance through the educational system at each step, according to McKinsey (2016) in Table 1.

According to the National Academy of Engineering and the National Research Council, four STEM disciplines are outlined in order to better comprehend STEM. Science is defined as the study of the natural world, encompassing the laws of nature connected with disciplines such as physics, chemistry, and biology, as well as the treatment or application of actions, principles, concepts, and norms linked with these fields. Science is both a corpus of accumulated information and a process that creates new knowledge. The engineering design process is informed by scientific knowledge. While not strictly speaking a field, technology encompasses the complete system of people and organizations, information, procedures, and equipment involved in the creation and operation of technical artifacts, as well as the objects themselves. Science and engineering are responsible for much of contemporary technology, and technical tools are employed in both professions. Engineering is a collection of knowledge regarding the design and construction of human-made objects, as well as a problem-solving technique. As we last technical tools, engineering makes use of principles from science and mathematics.

The study of patterns and connections between quantities, numbers, and space is known as mathematics. Unlike in science, where empirical data is used to support or refute statements, claims in mathematics are supported by logical arguments based on fundamental assumptions.

According to Ejiwale (2012), an excellent STEM lecture has six features. The first is that STEM teachings concentrate on real-world difficulties and problems. Students in STEM classes confront real-world social, economic, and environmental issues and seek answers. The second distinguishing feature is that STEM classes are directed by the engineering design process (EDP). The EDP offers a customizable method that guides students through the steps of recognizing a problem or a design challenge, as well as conceiving and implementing a solution. The first step in this process is for students to establish issues, perform background research, locate and generate several ideas for solutions, build and produce a prototype, and then test and evaluate the product they created. Finally, the product will be modified depending on the assessment part. During the EDP, the class is divided into multiple teams, and each team of students conducts their own research based on their ideas. They should adopt different techniques, accept and learn from their failures, and try again. In the end, their focus is on developing solutions to further the study.

STEM teachings, the third characteristic, involve students in hands-on inquiry and open-ended investigation. Students' work is hands-on and collaborative in this trait, and judgments concerning solutions are made based on student responses. Students have access to communicate in order to discuss their thoughts and, if necessary, rework their prototypes. They are in charge of their own ideas and studies. STEM teachings engage students in constructive cooperation, which is the fourth attribute. The sixth feature is that STEM programs require students to master difficult math and scientific subjects. STEM education should include material from math and science classes. Students may then realize that science and math are not separate topics; rather, the teachings immerse them and require them to collaborate to solve issues. Technology is also employed in suitable ways, and people create their own goods based on issues and ideas. The final point is that STEM education allows for numerous correct answers and reframes failure as a crucial part of the learning process.

Table 1. Analysis categories on STEM in each stage.

| 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 | Engaging in learning | | Critical and creative thinking |
| Learning to learn, metacognition | | | Developing learning, thinking, and life skills | | |
| Communication | Ways of working | Communicating | Communicating 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 | Being well | Staying well | |
| Personal and social responsibility | | Identifying and belonging | Having a strong sense of identifying and belonging | Managing myself | Being personally effective |

The STEM environment provides richer and broader opportunities for innovative problem-solving solutions. Students in STEM education are required to learn from what went wrong throughout the exercises and to attempt again to find a better solution to the difficulties. Meanwhile, the student is engaged in the activities of creating and discovering solutions; failure or incorrect solution/design is regarded as a good step on the path of discovering and designing answers.

This technique is known as 'integrated STEM education' when science, technology, engineering, and mathematics (STEM) are combined. While there are various definitions, integrated STEM education is commonly used to describe an instructional approach in which students participate in engineering design and/or research and experience meaningful learning through the integration and application of mathematics, technology, and/or science (Moore & Smith, 2014). While the need for integrated STEM education has been emphasized in our modern culture, several definitions of integrated STEM exist (Kelley & Knowles, 2016). Sanders (2009) defines integrated STEM education as "approaches that investigate teaching and learning across any two or more STEM topic areas." He proposes that each STEM course provides learning outcomes for at least one other STEM course, such as a math or science learning outcome in a technology or engineering program (Sanders, 2009). However, this definition does not clearly represent the focus that other academics have placed on technical design and real-world scenarios. They define integrated STEM education as an instructional technique in which students participate in engineering design or research and get meaningful learning experiences by integrating and applying mathematics, technology, or science (Moore & Smith, 2014).

**STEM Education Best Practice for Science Teacher**

Pre-service teachers must develop positive attitudes toward the nature of science and the teaching of mathematics and science because elementary teachers are frequently the first representatives of the science community with whom young children come into contact, and teachers' attitudes will undoubtedly influence the attitudes of their students (Otero and Gray 2008).

In the current study, the increased curriculum acquired by pre-service teachers in a science course for primary teachers may have contributed to their usually more favorable opinions toward scientific teaching compared to STEM and non-STEM majors enrolled in other courses. Another method that technology may be used to promote STEM learning in ways that correlate with real-world practices is through project-based learning (PjBL). PjBL has long been acknowledged as a successful constructivist teaching method that actively involves students in inquiry-based processes centered on real questions and activities (Blumenfeld, Fishman, Krajcik, Marx, & Soloway, 2000; Blumenfeld, Soloway, Marx, Krajcik, Guzdial, & Palincsar, 1991; Savery, 2006).

According to Verma, Dickerson, and McKinney (2011), PjBL also “bridges the gap” between academics and practitioners of a profession. For example, Maritime Tech is a program of study for middle and high school students that focuses on shipbuilding and includes education and hands-on learning experiences in marine engineering, physical science, and computer technology (Verma et al., 2011). Marine kits with simulations enable students to engage in both open-ended and structured activities that address various shipyard operations and construction scenarios; the curriculum also includes enrichment activities such as field trips to shipbuilding companies, marine science museums, and aquariums.

Student-centered teaching, also known as student-centered learning or learner-centered teaching or learning, gives students more freedom to express themselves creatively and participate in deeper thought (e.g., Costa, 2013; Motschnig & Holzinger, 2002; Weimer, 2013; Wright, 2011). Students’ interests drive the materials and activities in student-centered education; students are self-directed, have more responsibility and accountability for their own learning, and engage in active learning (Gningue, et al., 2013). In student-centered teaching, the instructor serves as a facilitator, the learning environment is rich in resources and activities, and students participate and learn together (Hsu, 2008; Jansen, 2011; Park & Ertmer, 2008; Russell et al., 2004).

Teachers entering the field are ill-prepared to handle the requirements and problems of high-need metropolitan regions, and a large percentage of them quit the profession (Berry, Montgomery, & Snyder, 2008).

Several academics have highlighted effective approaches in teacher professional development, such as active learning, chances to reflect on teaching techniques, an emphasis on topic knowledge, closeness to classroom practices, and adequate time to learn and execute what has been taught. Studies in a variety of subjects have found that students who participate in an integrated curriculum perform as well as, if not better than, their classmates who get standard education with distinct specialties (Czerniak, Weber, Sandmann,

& Ahern, 1999; Hinde, 2005). Furthermore, it has been discovered that using an integrated curriculum improves students' non-cognitive learning outcomes, such as interest and motivation (Erlandson & McVittie, 2001). Empirical evidence suggests that integrated STEM education improves students' success (Austin, Hirstein, & Wallen, 1997). Furthermore, it has been stated that integrated STEM education improves students' higher-order thinking abilities and technology literacy, making them better problem solvers, innovators, and inventors (Moore, 2012).

Several studies have indicated that before moving on to the modules comprising the engineering design cycle, students were given a preparation session that ranged from a single lesson to weekly sessions. The session offers an introduction to the engineering design cycle via conversation, as well as how to handle or use LEGO materials (Wendell & Rogers, 2013), which will subsequently be employed as building materials along with the modules. Furthermore, the teacher emphasizes the fundamental element of engineering design in this session, which is that it is all about brainstorming, planning, and iterating as the engineering process is being carried out (Wendell & Rogers, 2013; Yanyan et al., 2016). Another research (Yanyan et al., 2016) employed engineering design training for as long as two hours per week for five weeks, as well as a warm-up lesson in the form of a design assignment before the learning of scientific units with engineering design began.

Since 2014, Universitas Pendidikan Indonesia a public university in Indonesia has been working on STEM education. In accordance with the study on STEM education, Universitas Pendidikan Indonesia obtained certain STEM-based workbooks designed by Sejati (2017) to improve students' STEM abilities on the lever system. According to Suwarna (2015), who researched strategies used in the United States and Japan to generate STEM-based activities. The results indicated that two strategies implemented in formal and non-formal settings that incorporated engineering practice in program activities had a favorable impact. Suwarna (2015) explained the procedure of how to make a collaboration between the school and the university; this implementation embedded school practitioners and STEM experts in the university.

Aside from that, this university did a number of STEM-related studies in 2016. During this year, researchers discovered an advance in scientific teaching. STEM education, according to Apriani (2016), is an alternate method for improving students' 21$^{st}$-century abilities.

Project-based learning, problem-based learning, and other methods can be used to carry out the learning activity. STEM-PjBL in science learning was researched by Jauhariyyah (2016), and the results revealed that it could promote scientific literacy, motivation, and creativity.

STEM education has a significant impact on students' understanding of the current state of Indonesian land, which is prone to earthquakes, as well as the issue of human resources and reaction preparation (Fitriani, 2017). She created STEM materials for a project involving the construction of an earthquake-resistant building model. Another project research involves building a boat model to improve kids' STEM knowledge (Tati, 2017). Tati (2017) also showed the link between engineering design and other STEM components. According to her research, students' understanding of the project task affected engineering design activities.

Prima (2018) showed high-quality research by using Arduino-phet to enlarge the meaningful STEM education. The result showed the high improvement was seen in every meeting, which can influence students' technology literacy, and the result is higher than another. The warm-ups to STEM education that can be implemented in class activity are as follows.

1. Identifying Problems

Engineering design-based science, like inquiry techniques, begins with the issues to be solved. During this stage, students must unpack the design task or design challenges in order to tackle the problem using applicable scientific knowledge. To assist them in discovering the design issue, the instructor might create a situation by offering poorly organized problems, which are thought to be an excellent scaffold for learning science (Yanyan et al., 2016). One scaffolding strategy that might be employed is to provide the problem in the form of statistics about specific difficulties (Barrett et al., 2014) or to include videos, audios, or photographs (Schnittka et al., 2016). Furthermore, teachers can assist students 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 (Wendell & Rogers, 2013), as well as what the current condition is and what the things to solve are (Yanyan et al., 2016). Students should then be given the flexibility to respond freely to the leading questions, which can be done by written answers, artworks (Wendell & Rogers, 2013), or an entire class discussion (Marulcu & Barnett, 2016).

The design challenges should be made relevant for the students since it may impact their engagement with the learning if it is firmly tied on a personal level (Kolodner in Schnittka et al., 2016). For example, in one research (Barrett et al., 2014), the STEM Camp instructor posed a series of interactive questions on thunderstorms and tornadoes based on the kids' hometown, interests, and personal weather experiences. Another example is the use of the Common Loon as a backdrop for an elementary level design problem because kids who get this course reside in a state where the Common Loon is the state bird (Guzey et al., 2016).

Defining challenges in the first place is critical because it will assist students in making connections between science and engineering (Guzey et al., 2016), hence increasing motivation to learn science (Marulcu & Barnett, 2016). Furthermore, design challenges expose students to natural settings and engineering procedures (Marulcu & Barnett, 2016). According to most research, this critical stage generally only requires one instruction.

2. Developing Possible Solutions

After identifying the main design issue, students must obtain the essential knowledge and abilities to generate potential solutions. To do this, they must collaborate with at least one student as a dyad or as a team of more than two students. This stage seeks to provide the essential background information and abilities to tackle the design issue. It can be done through hands-on activities or guided investigations (Guzey et al., 2016). (Wendell & Rogers, 2013).

Drawing on the design card is another great technique to explore potential solutions (Yanyan et al., 2016). Drawing is considered an important activity in engineering design since it allows students to analyze the progression of ideas through time as well as portray relevant science concepts (King & English, 2016). Furthermore, King and English (2016) claim that student sketching will help students perceive technology, mathematics, and science as a whole.

3. Deciding the Best Solution

Engineering journals (Hernandez et al., 2014; Marulcu & Barnett, 2016; Wendell & Rogers, 2013), design cards (Yanyan et al., 2016), storyboards (Schnittka et al., 2016), and other record-keeping will make it easier for students to compare and analyze which of the possible solutions best meet the need and satisfy the constraints. This stage may need more than one lecture hour since students must apply their discoveries or obtained knowledge from the previous step's research (Marulcu & Barnett, 2016).

To simulate a real-world situation, teachers should also give a design challenge with economic, aesthetic, and societal restrictions for students to consider while deciding on the best solution. For example, while creating common loon platforms, students must pick which materials to utilize based on buoyancy, wave stability, predator protection, access to water, and cost (Guzey et al., 2016). Another example is when the kids were required to create a tornado-proof house, the teacher only provided limited resources, but the structure still needed to appear like a house with walls, a roof, a door, and windows (Barrett et al., 2014).

4. Building the Prototype

In this stage, students must build a working artifact based on the best solution design they choose that meets the requirements of the overarching design challenge (Wendell & Rogers, 2013; Yanyan et al., 2016). Modeling, developing alternatives, and employing imagination are all examples of building or constructing (Marulcu & Barnett, 2016). The building process is a key component of engineering design processes. It is because the outcomes of the building serve as an important mediator for students' learning (King & English, 2016; Wendell & Rogers, 2013). Construction allows students to engage in model-based reasoning, conduct in-depth investigations of scientific issues, and examine mathematical relationships (Penner et al. in Wendell & Rogers, 2013). In accordance with this, Roth (Wendell & Rogers, 2013) sees building as a representation of students' cognitive processes that may be explored in class. Furthermore, Kolodner et al. claim (Wendell & Rogers, 2013) that building functional products allows students to participate in scientific thinking. In this phase, a teacher or instructor might assist students by asking questions about the construction they are working on (Barrett et al., 2014).

5. Testing the Prototype

Students were given many opportunities to test the product to see if their build worked well or not. It is similar to the experimentation and assessment used by professional engineers (Marulcu & Barnett, 2016). During the testing process, the instructor might follow up by asking which structures are still weak and why (Barrett et al., 2014). Students would be able to study deeper underlying science ideas through scientific discourse as a result of this. The inclusion of question prompts in students' engineering journals may also be beneficial (Wendell & Rogers, 2013) in guiding students in determining if the product functions as planned.

6. Redesigning and Communicating

Students will discover specific limitations of their product in solving issues as a result of the testing process, which includes assessment, iteration, and optimization (Marulcu & Barnett, 2016). Nonetheless, the research conducted by King & English (2016) found unexpected findings that the redesign process did not allow for the elaboration or expansion of scientific and mathematical principles used in the initial design. In this situation, kids are exclusively concerned with enhancing their physical appearance. The failure that happened during testing resulted in numerous side-talks about the structures in a STEM camp context (Barrett et al., 2014).

In other studies, once students completed their final design and justified the improvements they made, they were given the option to discuss their design ideas through a poster (Guzey et al., 2016) or symposium of research poster (Hernandez et al., 2014). When students are able to convey their work to others, it may be claimed that they have cognitively grasped what they have studied (Hernandez et al., 2014).

Various techniques of incorporating engineering design into scientific instruction have varying effects on certain learning areas. The findings indicated that engineering design-based science is somehow related to an increase in science content gain (Barrett et al., 2014; Marulcu & Barnett, 2016; Moreno et al., 2016; Wendell & Rogers, 2013). Even though the mean gain score in this example was fairly low (Wendell & Rogers, 2013), this was most likely due to an evaluation that was not in line with the learning. Furthermore, Yanyan et al. (2016) discovered that students' problem-solving abilities did not alter much after they were engaged in engineering design-based science.

The use of construction materials, such as LEGO, has also been found to be appropriate for specific science content, such as simple machines (Marulcu & Barnett, 2016; Wendell & Rogers, 2013; Yanyan et al., 2016), life sciences (Guzey et al., 2016; Wendell & Rogers, 2013), and material properties, but not for other concepts, such as those related to sound (Wendell & Rogers, 2013). Although engineering design-based science produces positive attitudes toward science and engineering (Guzey et al., 2016; Wendell & Rogers, 2013), it has been discovered that when working in teams extensively, students at the elementary level may be frustrated if there is no scaffolding for peer cohesion (Wendell & Rogers, 2013). According to Farwati (2012) stated STEM approach based on EDP facilitated essential skills in design and collaboration.

## CONCLUSION

STEM Education has grown throughout the world in response to the 21st century and Industry 4.0, and it has had a significant influence on improving students' idea comprehension, literacy, and creativity. Many studies have been conducted to give evidence of the best practices for science teachers to adopt STEM education. STEM is relevant to daily life and raises student understanding of the environment. This method can improve students' skills, allowing them to be competent and ready for STEM jobs. Regarding Industry 4.0 and 21st-century skills, this approach is already entrenched in classroom activities through the use of hands-on activities and a student-centered focus. These findings are important to be implemented in Indonesia for STEM Education implementation in Indonesia.

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