IMPLEMENTATION OF SCIENCE, TECHNOLOGY, ENGINEERING, AND MATHEMATICS BASED LEARNING IN VARIOUS LEVELS EDUCATION

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ABSTRACT

Science, Technology, Engineering, and Mathematics or (STEM) are essential issues in education today. The low knowledge on it will be unable to cover a basic understanding of mathematics and science concepts, then lead to a shortage of quality workforce. It affects the gaps in the global industrial sector. The increasing number of jobs in various areas of the economy, science, and engineering has led to the need for an educational background in the STEM field. Therefore, it is important for a country to improve creativity and competitiveness through STEM-based education. So, it is necessary to understand how to apply it at various levels of education, from primary school to the university level of education. The method in writing this article is a systematic review to review 16 articles on STEM implementation in several education level topic. The results showed that the application of STEM at the basic education level by designing a framework for developing teacher professionalism to integrate STEM. The implementation at the secondary education level will be more straightforward if it combines with a problem-based approach such as Project Based Learning. The application of STEM in higher education requires an effective learning strategy, for instance, with a STEM Studio program and the Young Innovator Program. The implementation in higher education adjusted to the majors taken by students, as a form of material deepening. STEM-based implementation from primary education level to the university level education by integrating Science, Technology, Engineering, and Mathematics to improve interest, motivation, and self-awareness about science through an integrated program.

Keyword: - *STEM-based learning, elementary school, secondary school*

1. INTRODUCTION

The education system nowadays requires the learners to build knowledge on their own, while teachers as a facilitator. Teachers can give easiness in the learning process by providing the learners a chance to find and implement their ideas, and teach them consciously using their strategy for learning. (Slavin, 1994). But, students unable to thoroughly understand the scientific concepts without involved in inquiry activities where those ideas can develop correctly (NRC, 2012). Through scientific inquiry activities embedded in the problem-solving design, the learners can develop a solution. (Sanders, 2009). The activities design that directly implemented in the real world to solve the problems in daily life through a problem-solving-based design with the inter-discipline approach is STEM-based education (William, 2011).

Recently some thoughts integrate four disciplines in STEM (*Science, Technology, Engineering, and Mathematics*). As a component of STEM, science is the study of natural phenomena that involve observation and measurement. There are some main domains of science that can be applied to the level of primary and secondary education, which are physics, biology, chemistry. Technology is human innovations that are used to modify nature to meet human needs and desires. *Engineering* is the knowledge and skills to obtain, apply scientific knowledge that is practical and beneficial to humans. Whereas mathematics is the science of patterns and relationships, providing language for technology, science, and engineering. STEM is a combination of interdisciplinary science, technology, engineering, and mathematics that creates new knowledge (Juniaty & Winarni, 2016). STEM is an important issue in education today. Inadequate learning approach in mathematics and science has led to a shortage of quality workforce resulting in gaps in the global industry (Cooney & Bottom, 2003). The increasing number of jobs in various sectors of the economy, science, and engineering leads to educational background needs in the STEM field (Carnevale et al., 2011). Therefore, it is crucial for a country to improve their creativity and competitiveness through STEM-based education.

If education wants to implement STEM-based education, it needs to understand how to apply it in various levels of education, from primary education level until university level. Therefore, the writers will discuss the application of STEM-based education at multiple levels of education through the study of various articles that discuss STEM-based education.

2. METHODOLOGY

The method in writing this article is a systematic review to review several articles on one topic. This article examined 16 main articles that discuss the application of STEM learning in various education levels. The education levels discussed are primary education, secondary education, and higher education. The main article supported by other articles related to the main article.

3. RESULT AND DISCUSSION

The STEM approach is integrative learning between science, technology, engineering, and mathematics to develop students creativity through problem-solving in daily life (Juniaty & Winarni, 2016). With this article, the writer will explain the goal, benefit, and application of STEM-based education at various levels of education, namely primary education (elementary school), middle education (junior and senior high school), higher education. Also, an *assessment* will be conducted to improve STEM-based education.

3.1 STEM of Preliminary Education Level

The application of STEM education at the primary education level needs to develop logical, reasonable, and realistic conceptual conceptualizations with the implementation of problem-based mathematics in the STEM approach. The researcher integrates STEM in Elementary Schools using activities that give rise to responsive, professional development models for teachers. Flexibility professional development strategies are structured by (1) placing participant experience in the STEM curriculum integration; (2) obtain a new vision of STEM integration through open mathematical problems with the context of the clients life, real-life context; and (3) focus on making explicit mathematics content (Courtney & Galanti, 2017). The purpose of the article written by Courtney about integrating STEM in elementary schools is to design a professional development framework for integrating STEM in a mathematics classroom, supporting mathematics learning that based on actual content, innovative accompanied by specific learning goals and implementation plans, responsive professionals for educators. Courtney also stated the benefits of implementing STEM from the results of qualitative analysis of participant discussions and reflections show that: (1) Professional development design supports the participation of the participants that develop in STEM integration. Opportunities to engage with MEA as students, differentiate MEA from problem-based learning and MEA design features that can modify existing curricular tasks allow participants to think more broadly about mathematical content in STEM integration. (2) Participants communicate their readiness to use MEA as a medium for STEM integration that maintains the critical principles in the reality of class-level standard teaching and standardized test preparation. (3) This model allows students to interpret real-world situations in problem-based mathematical formats.

STEM implementation in elementary school McFadden & Roehrig (2017) is centered on teacher involvement in the integrated curriculum development design in science, technology, engineering, and mathematics. In the "participatory" curriculum provides a framework for teachers to explore further the learning design process. This research presents two teacher design teams (TPT) during professional development experience centered in developing an integrated curriculum in science, technology, engineering, and mathematics (STEM). The main activity of research, curriculum design, is framed as a problem to understand better how teachers are involved with the complexity of developing an integrated curriculum.

The findings from the study of McFadden & Roehrig (2017) shows the importance of "encouraging" active class teachers from design (planning) to the mapping arena by focusing on curriculum development activities and strategies. TDT develops a "sound" or "value" source for the curriculum being developed. It will be good and positive for educators and curriculum developed if TDT is willing to express interpretations, perceptions, and beliefs about conceptual ideas embedded in the curriculum being developed. Finally, teachers must be aware of their roles and responsibilities, besides the superficial description and understand participation in the design of the integrated STEM curriculum bringing the possibility of their ideas, perceptions, and beliefs to be integrated with the curriculum.

The results of the research revealed by Estapa & Tank (2017) on how to support the implementation of STEM at the basic education level are conducted by encouraging teachers to learn not only the contents of STEM disciplines but also for pedagogy needed in learning practices.

3.2 STEM of Secondary Education Level

The purpose of STEM-based education for students in junior high school and senior high school is to enable students to fulfill their abilities and skills in learning and innovation. The ability to communicate and collaborate, skill in using media, technology, information, and communication (ICT) (John et al., 2016). It is hoped that the application of STEM to students in middle and high schools can have an attitude to identify questions and problems in their life situations, explain natural phenomena, design and draw conclusions based on the evidence (Gray, 2014). The benefits for implementing STEM for high school students is that students can have the ability to choose study options and further majors (Aeschlimann et al., 2016), preparing to live their life and career, including being able to adapt, be flexible, take the initiative, develop themselves, have social and cultural abilities, productive, trustworthy, have leadership, and responsibility. To meet these expectations, schools should apply STEM education early. Thus, it can provide learning motivation and increase student learning enthusiasm (Aeschlimann et al., 2016), prepare students to be able to produce a competitive workforce and can compete globally.

The research showed that professional development must be active, sustainable, coherent, collaborative, reflective, and focus on content knowledge to produce real change through direct practice. The application of education with the STEM approach in elementary school needs a conceptual framework to implement it so that it can be integrated (Kelley & Knowles, 2016).

The application of the STEM approach for junior high school and senior high school students were by using STEM *Project-Based Learning* (PBL). STEM PBL has been developed from learning methods based on engineering principles to improve or solve problems (Han et al., 2016). Student solving skills, communication skills, and in-depth understanding of a problem. STEM PBL combines interdisciplinary teaching and learning approaches using contextual project-based assignments. One of the strengths of STEM PBL involves students solving problems in individual and group projects, while they explore strategies to solve problems and apply content knowledge to problems in everyday life.

STEM PBL is not only an abbreviation that represents new instructional methods that include four disciplines of science, technology, engineering, and mathematics, but holistic, a reformed curriculum. That is, preparations related to students, teachers, textbooks, and evaluation methods are needed to STEM PBL to be effective. The evaluation method that can be used is EBIPs (*Evidence-Based Instructional Practices*), which is an evaluation of evidence-based learning from work or practice (Landrum et al., 2017). Preparing for the STEM PBL class, the teacher has to provide a project assignment for students. A task that must have solutions from many or groups are not just one individual. Activities at STEM PBL make learning more contextual, motivate students to be enthusiastic in completing projects, help students become more independent and collaborative. In a project, students will work in a group; therefore, a measurement tool is needed to assess problem-solving done by students in the form of CPS (*Collaborative Problem Solving*). Student collaboration assessment is required to identify the dimensions of skills to provide appropriate problem-solving opportunities in it (Herro et al., 2017).

The researchers have reported the positive impact of implementing STEM PBL in schools. STEM PBL is sufficient to improve students and academic performance. The engagement in STEM PBL has increased student knowledge. The positive impact of involvement in STEM PBL on student test scores is examined on a fundamental and intermediate basis. While involved in a project, students have more opportunities to experience activities based on diverse fields and apply their knowledge before problems related to daily life (Han et al., 2016). The process of linking prior knowledge with these problems presented through projects needs a higher level of thinking ability, and finally, contributes to developing students metacognitive skills. The steps on STEM PBL allows the students to think more actual problems and help them try many strategies. Students have collaborative and contextual values with peers and show a higher ability to learn when engaging in activities. As long as their involvement in projects, students often participate in discussions and share their knowledge with their peers. Besides, students can achieve self-progress by reducing anxiety in project learning to complete it in groups.

The application of STEM is not easy; preliminary findings showed that many teachers are interested in an integrated STEM approach, but in fact, they aren't ready to implement it. Teachers and administrators also recommend that adequate preparation in an integrated STEM requires rethinking and redesigning complete pre-service courses and in-service workshops. The findings provide a starting point for better understanding teacher needs in integrated STEM and stepping stones for further study (Shernoff et al., 2017). So those professional teachers are needed and ready to integrate STEM in the learning.

3.3 STEM of Higher Education Level

Concerning the implementation of STEM Education, Bybee (2013) states that in STEM learning, students at the basic education level need to be more encouraged to connect science and engineering. Whereas at the higher education level, it needs to be challenged to do authentic engineering tasks as a compliment for science learning through project activities that integrate science, engineering, technology, and mathematics.

The implementation of STEM-based science learning demands to learn mode shift from teacher-centered learning to learner-centered learning, from individual learning to collaborative learning and emphasizing the application of knowledge, creativity, and problem-solving. STEM-based science learning needs to be implemented in problem-based learning units, in which student is challenged critically, creatively, and innovatively to solve real problems, which involve collaborative group activities. STEM-based science learning in class is designed to provide opportunities for students to apply their academic knowledge into the real world.

The experience of STEM education-based science is expected to be able to simultaneously develop students understanding of science content, innovation ability and problem-solving, soft skills (including communication, collaboration, and leadership). Besides, the further impact of STEM-based science learning is to increase the interest and motivation of students to continue their study and career in science and technology fields, as needed by the country now and in the future.

The application of STEM-based learning in higher education is to increase the motivation, interest, and involvement of students in learning. In implementing STEM-based learning, an effective learning strategy is needed and attracts student learning interest so that students are motivated to learn science (Hora & Oleson, 2017). One way to increase motivation, interest, and involvement of students is by using the STEM Studio program. In the STEM Studio Program participants involved in two programs, that were Save The Penguins and Save The Seabird. According to (Chittum et al., 2017), the research results show that motivational beliefs about science and the intention to achieve a bachelor degree in STEM Studio program participants are more resilient than those who are not participants in the program.

Besides the STEM Studio, there was also the application of STEM in the pharmaceutical field, which is the *Young Innovator Program* (YIP). The Eshelman Institute for Innovation, part of the UNC Eshelman School of Pharmacy, issued the YIP program with the main belief that there is an unappreciated and role that unexplored for professional schools to provide a deep STEM experience to high school students. Through this program, they hope to promote STEM's interest, awareness and self-efficacy by involving students in profoundly based experiences in research laboratories, identifying strategies that can be used to immerse secondary students in STEM-based research in the fields of pharmacy and pharmaceutical practice, and show that Pharmacy schools can provide meaningful experience for the recruitment of secondary STEM students during short experience-based programming.

The YIP program provides in-depth research experience in academic laboratories in pharmacy schools. The finding shows that professional schools can play an important role in promoting STEM awareness, providing STEM experiences in the real world, and connecting secondary students with STEM before they enroll in college, provided innovation and entrepreneurship (Friedman et al., 2017).

Preparing students to enter the world of work is also very much needed. One example of a charity organization that cares for young people from low-income societies through involvement in the STEM field in collaboration with social housing partners is called the *Visions of Science Network for Learning* (VoSNL), where volunteers will teach a skill to young people so that they are ready to take on the world of work (Duodu et al., 2017).

4. CONCLUSIONS

STEM implementation at the primary education level by designing a framework of teacher professional development to integrate STEM, while application at the secondary education level will be accessible by combining with PBL. *STEM-based learning* at the higher education level has a purpose of improving interest, motivation, and self-awareness about science through an integrated program. STEM-based implementation from primary education level to the university level education by integrating Science, Technology, Engineering, and Mathematics to improve interest, motivation, and self-awareness about science through an integrated program.

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