Critical study of stem-based learning in order to develop century skills 21

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Abstract. The term STEM was introduced by the United States National Science Foundation (1990) as an abbreviation of "Science, Technology, Engineering, & Mathematics". In the Indonesian context, STEM refers to four fields of science, namely science, technology, engineering, and mathematics. STEM learning is an approach to learning where Science, Technology, Engineering, and Mathematics are learning processes that focus on solving problems in everyday life. Does STEM learning can print students who have 21st century skills in order to solve various problems in everyday life. In order to answer these questions, it is necessary to do research with the title: A critical study of STEM-based learning in order to build 21st century skills. In connection with that, the purpose of this study is to find out how much STEM learning is able to improve student learning outcomes so that they have 21st century skills in order to solve various problems in daily life. This research was conducted through the study of literature as an activity of gathering information that is relevant to the topic that was used as the object of research. Data collection techniques are carried out by conducting a study of a number of reference books and relevant research results. Data analysis techniques are done through descriptive-qualitative techniques with sentences that are easily understood in an effort to get answers to the problems under study, so that an overview of the contribution of STEM learning to student learning outcomes is obtained in order to solve various problems in daily life. The study found that: (1) STEM-based learning is one of the right lessons to prepare skilled human resources to live in the 21st century; (2) STEM-based learning can be integrated with cooperative learning models, Project Based Learning (PBL), Problem Based Learning (PBL) and other learning models; (3) STEM-based learning can be applied to all levels of education (elementary, secondary and high); and (4) STEM-based learning is useful in the context of developing student careers.

1. Preliminary

Today we have entered the life of the 21st century which is marked by the increasing use of technology, communication and information so that it changes the style and patterns of daily living in the community. These changes have implications for increasingly competitive labor qualifications and competencies [1].

In the 21st century competition to produce jobs and get jobs is very tight, so that a country needs to have qualified human resources in various fields of life in order to compete with other countries' human resources [2]. Indonesia, with a population of more than 250 million people, needs to print quality human resources through the national education system. National education is a very important program in the life of a country, as well as an indicator of the country's progress [3]. A country is said
to be progressing, if national education from that country is classified as advanced. One feature of national education that is classified as advanced is by applying STEM (Science, Technology, Engineering, and Mathematics) learning along with the demands of 21st century skills.

In Indonesia STEM learning is not too popular when compared to developed countries like the United States, but this learning model has been incorporated into the school curriculum [4]. In STEM learning students have the opportunity to learn science, mathematics, and techniques to deal with problems in the real world (National Research Council = NRC, 2011).

In STEM learning, students are required to solve real-world problems and engage in ill-defined tasks into well-defined outcomes through collaboration in groups [5]. STEM education is a top priority in solving global issues and the problems facing the world today that are related to: (1) global warming; (2) air and water pollution; (3) clean drinking water, and food security [6].

In its application, STEM learning emphasizes several aspects (NRC, 2011), namely: (1) asking questions (science) and defining problems (engineering); (2) developing and using models; (3) planning and carrying out investigations; (4) analyze and interpret data (mathematics); (5) using mathematics; information technology and computers, and computational thinking; (6) building explanations (science) and designing solutions (engineering); (7) involved in arguments based on evidence; (8) obtain, evaluate and communicate information. With the focus on these eight aspects, can STEM learning produce students who have 21st century skills in order to solve various problems in daily life. In order to answer these questions it is necessary to do research with the title: A critical study of STEM-based learning in order to build 21st century skills. In connection with that, the purpose of this study is to find out how much STEM learning is able to improve student learning outcomes so that they have 21st century skills in order to solve various problems in daily life.

2. Theoritical Review

The term STEM was introduced by the NSF (National Science Foundation) of the United States in 1990 as an abbreviation of "Science, Technology, Engineering, & Mathematics". In the Indonesian context, STEM refers to four fields of science, namely science, technology, engineering, and mathematics. STEM learning is an approach in education where Science, Technology, Engineering, and Mathematics are integrated with the educational process that focuses on solving problems in everyday life and can also be applied in professional life [7]. STEM learning is also referred to as a learning approach between two or more STEM components or between a STEM component and other disciplines [8]. The aim of STEM learning is to produce students who will later be involved in the community, they are able to develop the competencies they have to apply to various situations and problems they face in their daily lives so that they will be able to compete with life's challenges in the 21st century [9].

STEM-based learning is one solution to answer the challenges of 21st century life, because the STEM curriculum involves "4C" as a 21st century skill, which includes creativity (creativity), critical thinking (critical thinking), collaboration (collaboration), and communication (communication) [10]. Integration of STEM education in learning can be carried out at all levels of education, starting from elementary school to university, because the aspects of implementing STEM such as intelligence, creativity and design ability are not dependent on age [7]. STEM stands for science, technology, engineering, and mathematics, which includes instruction in several fields of study [10] as shown in Table 1 below.

| Bidang       | Mata Pelajaran          |
|--------------|-------------------------|
| Science      | Biologi, Kimia, Fisika, Sains |
| Technology   | Komputer, Sistem, Informasi |
In addition to developing knowledge in the fields of science, technology, engineering and mathematics, STEM learning also seeks to foster scientific inquiry skills and problem solving skills [11]. Practicing problem solving skills supported by scientific procedures and behavior, STEM learning seeks to build a community that is aware of the importance of caring for the daily problems that surround them.

STEM learning shows students how the concepts, principles, techniques of science, technology, engineering and mathematics (STEM) are used in an integrated manner to develop products, processes, and systems that benefit human life [7]. STEM learning also refers to an individual's ability to apply an understanding of how tight competition works in the real world that requires four interrelated domains, namely science, technology, engineering and mathematics.

In order for STEM-based learning to work well, according [12] must have 4 aspects, namely: (1) aspects of support, related to support in the application of STEM learning, both in collaboration with schools and industry, and collaboration with others teacher in one school; (2) teaching aspects related to mastery of learning, both concerning the preparation and implementation of classroom learning; (3) efficacy aspects, related to the trust of educators to implement STEM learning, starting from the teaching of the material and commitment to implementing learning; (4) aspects of materials, related to infrastructure supporting learning. The main objective of STEM learning is to show that knowledge is holistic between STEM subjects, which means that STEM learning can be said to be successful, if all four aspects of STEM are found in each learning process [12].

At present, STEM learning has begun in several countries, including the United States (US), which is initiating education by developing STEM learning, because the achievement of US children's scores in math and science is decreasing every year. In Taiwan the learning curriculum began to be integrated with STEM learning, while Malaysia had collaborated with the United States by involving students in the STEM field, with the aim of preparing students in the 21st century economy. Likewise Indonesia has begun to collaborate with USAID (United States Agency for International Development), in order to develop STEM-based learning, and it is encouraging that research on STEM learning has been carried out by students and lecturers in several universities in Indonesia and it turns out the result is good.

3. Research Methods

This research was conducted through the study of literature as an activity of gathering information that is relevant to the topic or problem that is being used as the object of research [12]. Data collection techniques are carried out by conducting a study of a number of reference books and relevant research results. The relevant references include the concepts and definitions of critical thinking, the policies of the Government of the Republic of Indonesia, and books on vocational and vocational education. While the study of the results of relevant research, is a study of studies related to STEM learning. Data analysis techniques are done through descriptive-qualitative techniques with sentences that are easily understood as an effort to get answers to the problems under study [13] so that an overview of the contribution of STEM learning to student learning outcomes is obtained in order to solve various problems in daily life.
4. Result and Discussion

According to Amal [4] to be able to play a role in the development of technology and information is by preparing quality human resources, where one way is to implement the STEM learning model. STEM learning is not limited to the knowledge of science, technology, engineering and mathematics, but can be used in other scientific fields as a basis for learning and developing potential for students.

In order to support [14] (Muhadjir Effendy) has collaborated with Executive Vice President Casio Computer Co., Ltd Hiroshi Nakamura. With this cooperation, one of the programs that has been carried out is the opportunity for 20 Indonesian students to carry out fieldwork practices with STEM-based learning at the Casio plant in the Amphoe Chokcai district, Nakhon Ratchasima, Thailand [15]. This field work practice program with the STEM model is an initial pilot program with the hope of obtaining good results.

If examined further, it turns out that there have been many studies conducted related to STEM-based learning and in the form of integration between learning models with the STEM method and it turns out that it has good results. Research conducted by [11] entitled "STEM Education: Innovation in Science Learning" concluded that STEM learning can be used as a learning innovation to build 21st century skills. The results of the study also concluded that STEM learning can also be done in the form of cooperative learning models, Problem based Instruction (PBI), Project based-learning (PjBL) and other learning models.

A similar study was conducted by [16] entitled "Implementation of the Science Approach, Technology, Engineering, And Mathematics (STEM) to develop multi-representation skills of high school students in Newton's legal material on motion" which concluded that the class using the approach STEM has multipresentation skills that are significantly better than students who learn using the scientific approach. In line with these findings, Khoriyah, Abdurrahman and [17] research entitled "Implementation of the STEM learning approach to improve the critical thinking skills of high school students in sound wave material" concluded that learning using the STEM approach was able to improve students' critical thinking skills with a mean N increase -Gain of 0.63.

Furthermore, [18] conducted a study entitled "Implementation of Integrated STEM Project Based Learning to improve Student Science Literacy Viewed from Gender" concluded that: (1) scientific literacy between female and male classes was insignificantly different; (2) male and female students expressed pleasure in STEM learning; (3) students gain experience when following the stages of STEM learning so that their motivation and interest in learning increases; and (4) with STEM learning, there is an increase in multipresentation skills and critical thinking skills of students.

Other findings about the positive impact of STEM learning were obtained by [19] through a study entitled "The Effect of STEM Project Based Learning Implementation on Vocational Students 'Mathematical Creativity'" which found that: (1) there was an increase in the average achievement of students' creative thinking after STEM project based learning compared to before; and (2) there are significant differences in critical thinking skills for students before and after STEM learning. In line with these findings, [20] through experimental research entitled "The Influence of STEM Integrated Project Based Learning on Science Literacy, Student Creativity and Results" concluded that the PjBL-STEM model had a positive and significant effect on scientific literacy skills, creativity and learning outcomes of students. These findings were obtained from hypothesis testing that there were differences in scientific literacy skills, creativity and learning outcomes of students significantly between the experimental class and the control class, where the experimental class using the PjBL-STEM learning process had better results than the control class.

On the other hand STEM learning can also be used to develop a module or assessment in the learning process. Research conducted by [3] entitled "Application of Performance Assessment in the STEM Approach (Science, Technology, Engineering, Mathematics) to Reveal Science Process Skills" concluded that: (1) performance assessments made using the STEM approach were able to uncover science process skills students; and (2) modules made using the STEM approach, student learning
outcomes get better. Similar to the study, [21] conducted a study entitled "Development of Chemistry Learning Modules Using Approaches (Science, Technology, Engineering and Mathematic (STEM) in Chemical Equilibrium Materials" concluded that the module developed received a positive response from students with a percentage reaching 82, 91% (very good category) In addition, research conducted by [22] entitled "Development of Mathematical Modules with the Approach of Science, Technology, Engineering, and Mathematics (STEM) in Quadrilateral Material" concluded that the module was developed received a good response from students and teachers with an average percentage of 88%, which means that students are very happy with the modules created using STEM learning, thus improving their learning outcomes.

In addition to the upper and middle secondary level, STEM can also be applied to the tertiary level. The research conducted by [22] with the title "Understanding Ability of Concepts and Interests of Students with the STEM Approach (Science, Technology, Engineering and Mathematics)" concluded that students were very interested in learning with the STEM approach, and their ability to understand concepts to increase. This means that at the college level, students accepting STEM are very well received.

From some of the results of these studies, STEM-based learning is supposed to be applied in Indonesia, because abroad STEM education is already very popular. [23] study entitled "The Prospect of A "in STEM Education" shows that in the United States (USA) there is a special budget to recruit and train teachers about STEM for $ 250. STEM curriculum has also been made in America, which focuses on solutions to solving problems in people's lives. The United States views that STEM learning is important to be applied in their education, as well as preparing teachers and students as well as possible, in order to solve problems that exist around them, according to their respective fields of expertise. In line with the study [24] conducted a study entitled "Introducing STEM Education: Implication for Educating Our Teacher for the Age of Innovation", which concluded that STEM learning succeeded in transforming from a standard teaching model to a stressed learning model. on innovation and problem solving.

STEM-based learning can be integrated with other learning models, and it turns out the results can effectively improve student creativity. [25] entitled "The Effect of STEM-PjBL learning on creative thinking skills" found that STEM-based learning integrated with the Project Based Learning model was able to improve students' creative thinking skills. The results of the study support the findings of [26] through a study entitled "A Study of Creativity in CaC2" Steamship-derived STEM Project-based Learning "which shows that the main learning of the five stages of STEM-PjBL-based learning consists of preparation, implementation, presentation, evaluation, and correction can improve student creativity.

The two results of the research above provide an indication that STEM learning is integrated with other learning models, it turns out to support students' ability to think creatively to solve problems faced. These findings are in line with the results of [27] entitled "Integrated STEM Education: A Systematic Review of Intructional Practices in Secondary Education" which concluded that to get maximum results, STEM must be integrated with other learning models, among them are problem-centered learning, inquiry-based learning, design-based learning, and cooperative learning.

The latest research from STEM learning is very positive in the field of career guidance and student learning interest. [28] study of the effect of STEM entitled "The effect of authentic project-based learning on career and career aspirations in STEM" concluded that learning using project based learning influences students' perceptions of STEM skills, perceptions of participation in courses STEM, and STEM career aspirations. In line with the results of the study, [29] through his research entitled "The impact of out of school STEM education programs on students' attitudes toward STEM and STEM careers" found that STEM learning increased students' interest in learning, and helped them connect learning in schools to solve problems in everyday life. The results of this study provide clues that STEM-based learning makes students more confident in developing careers and helps solve problems in the daily life environment.
5. Conclusion

- Based on a study of a number of literatures and relevant research results, and continued with focus group discussion (FGD), the following conclusions were obtained:
- STEM-based learning is one of the right lessons to prepare skilled human resources to live in the 21st century.
- STEM-based learning can be integrated with cooperative learning models, Project Based Learning (PjBL), Problem Based Learning (PBL) and other learning models.
- STEM-based learning can be applied to all levels of education, both at the elementary and secondary levels of education, as well as at the tertiary level, depending on the learning objectives to be achieved.
- STEM-based learning is useful for students' career development and problem-solving skills in everyday life.

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