

META-ANALYSIS OF THE EFFECT OF INTEGRATION STEM EDUCATION IN A VARIOUS LEARNING MODELS ON STUDENT PHYSICS LEARNING OUTCOMES

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ABSTRACT

The development of science and technology is developing rapidly in the 21st century. The development of knowledge and technology is needed to support human resources to produce quality education. At the 2013 curriculum, integrated learning is important to do to improve students' learning outcomes. One of the skills that students need was problem solving skill. However, the real conditions showed that physics learning outcomes are still low, students have low critical thinking skills, learning is still monodisciplinary, and creative thinking is still low. One solution to solve this problem is to integrate STEM education into learning. This research was conducted by analyzing the data from the article to specify the influence of STEM education integration in learning on student learning outcomes. This research is called a meta-analysis. There were 20 articles analyzed in this research, 6 articles were international and 14 articles were national. The results showed that integration of STEM education in learning has a significant effect on the level of class XI than class X of Senior High School. Then, the integration of STEM education has a significant effect on the sound wave material with an average effect size of 2.45. The integration of STEM education has a significant effect on student learning outcomes in the knowledge aspect with an average effect size of 1.83. The last, integration of STEM education provides a meaningful impact on problem-based learning with an average effect size of 2.17.

Keywords : *Meta-analysis, STEM Education, Learning model, Learning Outcome*



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I. INTRODUCTION

The 21st century is known as the science and technology era. Knowledge and technology are needed in the 21st century to support the quality of human resources. The quality of human resources can be realized through education. Through education, a person can pass on his experiences and habits so that they are useful for practicing abilities and skills. Humans need the education to become intelligent, noble, independent, and useful individuals for society and the nation. The integration of STEM (Science, Technology, Engineering, and Mathematics) into education can produce a quality of human resources that can compete in the 21st century.

The National Science Foundation of the United States of America confronts for the first time about STEM in the 1990s with the acronym "Science, Technology, Engineering, & Mathematics" [1]. STEM has different meanings. Science is the study of the universe, facts, phenomena, and order. Technology is made as innovation, change, modification of the natural environment to give satisfaction to human needs and desires. The technology aims to make modifications so that it meets human needs. Engineering is a profession in which scientific and mathematical knowledge is acquired through study, experimentation, and practice or is applied to operate or design procedures to solve problems to meet the needs of human life. Mathematics is a branch of a discipline that studies patterns or relationships [2].

STEM education is a teaching and learning approach between two or more STEM components [3]. The purpose of STEM education is to develop students' literacy and technology. Therefore, when students enter the communities, their competencies can be developed and applied to daily life problems related to the application of STEM [4]. STEM education may develop students' reasoning skills, think critically, logically, and

systematically. As a result, students will be able to meet global challenges and improve the country's economy. STEM education is an amalgamation of science, technology, engineering, and mathematics lessons. Regarding the environment, STEM education embodies learning by students' real life.

STEM can be integrated into various learning models. The model is a plan that is applied to create a curriculum, design learning materials, and direct teaching and learning activities in the class[5]. The learning model is a systematic pattern procedure that is guided to achieve the learning objectives, including strategies, techniques, methods, materials, media, and learning assessment tools. STEM can be integrated into problem-based learning (PBL), project-based learning (PjBL), and inquiry learning models.

The PBL learning model is a learning model that includes students trying to solving a problem. Problem-solving is carried out through various steps of the scientific method so that students are expected to be able to learn knowledge related to problems. Moreover, students may develop their problem solving skills[6]. PBL learning model begins with problems that can be found by students and teachers, then students deepen knowledge about something that is known and what needs to be known to be able to solve problems. The problem used in this model was the real life of students and the concept is according to the student's needs.

The project-based learning (PjBL) model is one of the student-centered learning, and provide students with meaningful experiences [7]. The PjBL model is student-centered which positions the teacher as a motivator and facilitator, where students are allowed to do work individually or collaboratively to constructing their learning in class. The use of PjBL can help students in solving the problems provided and prioritize product income. In producing products, students can use science and technology which makes students indirectly understand the usefulness of science and technology in the goodness of the environment.

The inquiry model is a model that can also be applied in conjunction with STEM education. The inquiry model is a learning model that requires students to find solutions for themselves through real data based on the results of their observations. Students are required to access information mentally to understand the meaning and participate in active learning. This model seeks to instill the basics of scientific thinking in students, positioning students into a role that requires great effort in bringing up something important to them personally.

The learning model has several objectives for learning activities. In general, the learning model aims to make it easier for teachers to choose process components in learning techniques, strategies, and learning methods to achieve learning objectives. The learning model also serves as a guide in the design and implementation of learning.

STEM can be implemented in Physics subjects. Physics is one of the sciences that studies natural phenomena, not only as knowledge but also as its implementation in human life. This is in line with the STEM theory, namely through the STEM approach students do not only memorize but understand and understand the concept of science and connect it in everyday life[8]. Physics learning is one of the natural sciences which is based on the results of facts that exist in nature. The purpose of learning physics is to find order between human observations and the natural environment[9].

Physics learning is expected to be carried out following the demands of the 2013 Curriculum. However, there are problems in the research. This problem has been resolved by previous research with STEM education. Several problems have been resolved. First, students' ability to think creatively in class is still low or less creative. Lack of creative thinking ability has an impact on students' physics learning outcomes. The physics learning outcomes of IT Miftahul Jannah high school students are relatively below the Minimum Completeness Criteria with an average exam of 28.54 of 73.00 [10]. This proves that students have a level of creative thinking not as expected. Second, namely learning at school is still monodisciplinary. This has an impact on low conceptual mastery and less active learning processes. Third, is the students' low critical thinking skills. This causes students when responding to questions along with reasons, asking questions when they do not understand the material is classified as lacking, students have difficulty analyzing problems, concluding problems, and evaluating per problem [11]. This indicates that students have not been able to use their critical thinking skills in class.

However, research conducted by previous researchers still has limitations. There are several limitations of previous research. First, previous research has the limitation of only determining the effect of one variable on the dependent variable and has not been able to determine how much influence it has. Second, previous research was limited to one material only. Third, previous research was only conducted at one grade level. Fourth, research has not been limited to one learning model.

Starting from the description, the researcher is interested in conducting a meta-analysis of the effect of STEM education on student learning outcomes. This study analyzes several studies that discuss the effect of STEM education on student learning outcomes. The application of STEM to learning in schools is something that is discussed in this study. This STEM education integration combines two or more disciplines of knowledge in learning that are following the real-world context. Students will more easily understand lessons at school. This study analyzes several studies that discuss the effect of STEM education on student learning outcomes. Learning

outcomes are the achievement of competencies by students after participating in the learning process which includes competency attitudes, knowledge, and skills [12].

Meta-analysis is a term for showing a quantitative and systematic approach to looking at existing studies. Meta-analysis is a variety of analyses or statistical analyses from a large collection of analysis results from a single study that aims to integrate a conclusion [13]. Meta-analysis is also a study using existing studies that have been used by other researchers systematically and quantitatively to obtain accurate conclusions.

Meta-analysis research has several objectives. There are six objectives in meta-analysis research. First, to resolve the inaccuracy of the report results. Second, to answer questions or find solutions to unexplored problems. Third, to find consistency or inconsistency with similar studies. Fourth, to get an estimated effect size. Fifth, to carry out inference from the sample data to the population, either by hypothesis or by estimation. Sixth, to control variables that have the potential to confuse so that the relationships and differences in the research that have been carried out are not disturbed [14].

Meta-analysis research is a great solution to do. This research was conducted for several reasons. First, this research can see the consistency of the research results that have been carried out. Second, this research can present research results in a broader scope. Third, this study can determine the effect size (effect size) of a study. Fourth, meta-analysis is a research method that is increasingly popular to be used to summarize research results, so that meta-analysis can conclude broader studies.

This research is based on previous relevant research. The first relevant research undertaken was concerned with integrating problem-based STEMs to improve high school students' mastery of concepts [15]. The second relevant research conducted relates to the effect of STEM-PjBL learning on creative thinking skills [16]. The third relevant research carried out is related to the application of the Project-Based Learning model-based STEM to improve the creative thinking skills of high school students in schools [16].

This research was conducted with several objectives. The first is to review the magnitude of the influence that STEM education has in learning Physics which is reviewed based on grade levels (X, XI, XII). The second is to review the magnitude of the influence given by STEM education in learning physics based on the material being taught (dynamic electricity, static electricity, work and energy, Newton's laws of motion, sound waves). The third is to review the influence given by STEM education in physics learning which is reviewed based on student learning outcomes in the knowledge aspect. Fourth, to determine how much influence STEM education has in learning Physics which is reviewed based on the model used (PBL, PjBL, Inquiry).

II. METHOD

This type of research is meta-analysis research to review research based on a quantitative approach. Meta-analysis uses numbers and uses statistics for practical purposes, which aims to compile and extract information from various kinds of data. The data in this research is secondary data because it is obtained from the results of previous studies.

This research involved 20 articles in international and national journals. The criteria for articles used are on the theme of integration of STEM education, published in the last 10 years, from 2010-2020. The selected article reviewed the effect of STEM education integration in improving the learning outcomes of high school students in learning physics in schools.

The research instrument was carried out with the aid of a coding category sheet. The coding of meta-analysis is an important requirement to be troublesome when analyzing and collecting data. The aim is that the variables used for coding can provide the information needed.

The data collection technique is a documentation technique for the components of several journals to be studied. In the meta-analysis, data tabulation procedures are required in research. The tabulation procedure can be seen as follows: 1) identifying the research variables and entering them into the appropriate variable column, 2) identifying the average value and standard deviation of the control and experimental classes, 3) if the standard deviation is unknown, then the next step is to analyze the t value in each article and 4) perform data analysis to determine the value of the effect size. To calculate the effect size value, the equation is used:

a. Pretest and posttest mean and Standard deviation

$$ES = \frac{\bar{x}_{post} - \bar{x}_{pre}}{SD_{pre}} \dots\dots\dots(1)$$

Informations:

ES = Effect size

Xpost = Posttest mean

Xpre = Pretest mean

SD = Standard deviation

b. Mean and Standard deviation of two group posstest only

$$ES = \frac{\bar{x}_E - \bar{x}_C}{SD_C} \dots\dots\dots(2)$$

Informations:

- ES = Effect size
- X_E = Mean of experimental class
- X_C = Mean pf control class
- SD = Standard deviation

c. Mean and Standard deviation of two group pre-post test

$$ES = \frac{(\bar{x}_{post} - \bar{x}_{pre})_E - (\bar{x}_{post} - \bar{x}_{pre})_C}{\frac{SD_{preC} + SD_{preE} + SD_{postC}}{3}} \dots\dots\dots(3)$$

Informations:

- ES = Effect size
- X_{post E} = Mean of posttest experimental class
- X_{pre E} = Mean of pretest experimental class
- X_{post C} = Mean of posttest control class
- X_{pre C} = Mean of pretest control class
- SD_E = Standard deviation of experimental class
- SD_C = Standard deviation control class

d. If the standard deviation is not known, it can be done with t-test

$$ES = t \sqrt{\frac{1}{n_E} + \frac{1}{n_C}} \dots\dots\dots(4)$$

Informations:

- ES = Effect size
- t = Result of t-test
- n_E = Sum of experimental group
- n_C = Sum of control group

III. RESULTS AND DISCUSSION

A. Result

The articles selected were 20 articles published in the last 10 years and were coded MA1 to MA20. The following shows the group results of STEM education integration and the effect size on student learning outcomes based on class level, learning material, learning outcomes on the aspects of knowledge, and the learning model used.

1. The Effect of STEM Education Integration on Learning Outcomes in terms of Class Level

The first result in this meta-analysis research is related to the effect of STEM education integration on learning outcomes in terms of class level. The average effect size value based on the class level is obtained from the calculation of the effect size of each article. The mean value of the effect size in terms of grade-level used from 10 articles in national journals and 4 articles in international journals is shown in Table 1.

Table 1. Effect Size Result Data Based on Class Level

No	Class	Journal Code	Effect Size	Mean of Effect Size	Category
1	X	MA3 ^[17]	2,33	1,76	High
		MA5 ^[18]	1,88		
		MA6 ^[19]	0,97		
		MA10 ^[20]	2,52		
		MA12 ^[21]	0,70		
		MA14	1,71		
		MA17 ^[22]	2,26		

No	Class	Journal Code	Effect Size	Mean of Effect Size	Category
2	XI	MA1	1,57	2,04	High
		MA2 ^[23]	3,70		
		MA4	0,77		
		MA8	0,72		
		MA9 ^[24]	0,85		
		MA11 ^[25]	3,70		
		MA13 ^[26]	2,25		
		MA15	2,57		
		MA18 ^[27]	2,66		
MA19 ^[28]	1,70				

From the data in Table 1, it can be explained that the results of the meta-analysis of the effect of integrated STEM education on learning outcomes based on class levels found that the integration of STEM education had a high effect on class X and class XI on student learning outcomes in physics learning, the effect size 1,76 and 2,04. These results showed that the integration of STEM education is more effective when it is used in physics learning at the XI class compared to the X class.

2. *The Effect of STEM Education Integration on Learning Outcomes based on Subject Materials*

The second result of this meta-analysis research is related to the effect of STEM education integration on learning outcomes in terms of material aspects. The average effect size is obtained from calculating the effect size of each article. The average effect size value based on the learning material used from 5 articles in national journals of international journals is seen in Table 2.

Table 2. Effect Size Results Data Based on Learning Materials

No	Material	Sum of Research	Effect Size	Mean of Effect Size	Category
1	Dynamic fluid	1	MA1= 1,57 MA2= 3,70	1,57	High
2	Static fluid	4	MA8= 0,72 MA11=3,70 MA19= 1,70	1,79	High
3	Work and energy	2	MA5= 1,82 MA6= 3,08	2,45	High
4	Motion Newton Law	1	MA12= 0,70	0,71	Medium
5	Sound wave	1	MA15= 2,57	2,57	High

Table 2 describes that the results of the meta-analysis of the effect of integration of STEM education based on the material found that in dynamic electricity, static electricity, and effort and energy as well as sound waves the effect of STEM education integration has a high effect on learning outcomes, for Newton's law material about motion the effect of integrated STEM education provides moderate to high school student learning outcomes. So it can be concluded that the effect size of STEM education integration on learning outcomes in terms of the material used has different effects.

3. *The Effect of STEM Education Integration on Learning Outcomes based on Learning Model*

The third result of this meta-analysis research is the effect of STEM education integration on learning outcomes in terms of learning models. The average effect size is obtained from the calculation of the effect size for each article. The mean value of effect sizes based on the type of learning model from 10 articles in national journals and international journals is shown in Table 3.

Table 3. Effect Size Results Data Based on Learning Model

No	Learning Model	Sum of Research	Effect Size	Mean of Effect Size	Category
1	PBL	MA1	1,57	2,17	High
		MA9	0,85		
		MA11	3,70		
		MA15	2,57		
2	PjBL	MA7	1,36	1,58	High

No	Learning Model	Sum of Research	Effect Size	Mean of Effect Size	Category
3	Inkuiri	MA8	0,72	1,34	High
		MA10	2,52		
		MA13	2,25		
		MA20	1,08		
		MA6	0,97		
		MA14	1,71		

Table 3 explains that the analysis of the effect of STEM education integration on learning outcomes based on the type of learning model used found that the integration of STEM education with the PBL model had a high effect on student learning outcomes. Furthermore, the integration of the PjBL model of STEM education has a high effect on the learning outcomes of high school students and the integration of the Inquiry model STEM has a high effect on the learning outcomes of high school students. So it can be concluded that the integration of STEM education is very effective in improving the learning outcomes of high school students.

4. The Effect of STEM Education Integration based on Learning Outcomes

The fourth result of this study is the effect of STEM education integration on student learning outcomes. The average effect size is obtained from calculating the effect size of each article. The mean value of the effect size is based on the learning outcomes of 11 articles in national and international journals. The learning outcomes analyzed were seen from the aspect of knowledge.

Based on the number of 11 journals analyzed, the effect of STEM education integration on student learning outcomes has a different effect on aspects of knowledge. The following is shown in Figure 1.

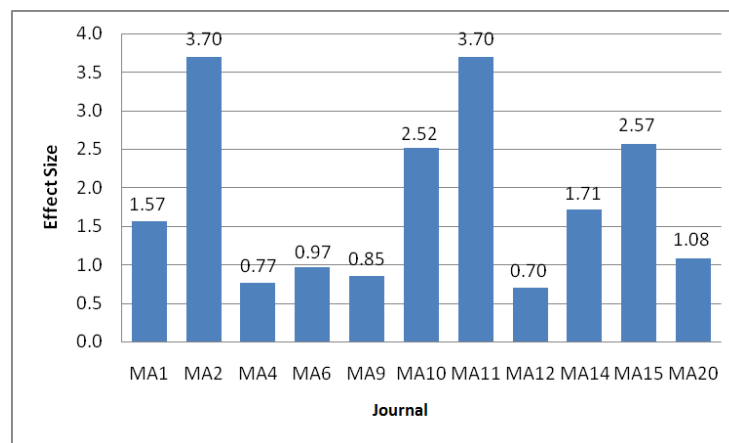


Fig. 1. Effect Size of Each Journal on Knowledge Aspects

Figure 1 shows that the size of the effect of STEM education integration on student learning outcomes is based on aspects of knowledge in each journal. In that journal, the lowest effect size was found in the twelfth journal (MA12), while the highest effect size was found in the second and eleventh journal (MA2 and MA11). Each journal has a positive effect. This shows that the integration of STEM education is effective in improving student learning outcomes in the knowledge aspect.

B. Discussion

The results of this research were carried out in four categories, the effect of integration of STEM education on learning outcomes based on class levels (X, XI, and XII), the effect of STEM education integration on learning outcomes based on the material used (dynamic fluids, static fluids, work and energy, sound waves), the effect of STEM education integration on student learning outcomes, the effect of integration of STEM education based on the learning model used (PBL, PjBL, and Inquiry). The results of this study indicate that the integration of STEM education can improve the learning outcomes of high school students.

The first result showed that the integration of STEM education in the classroom level aspect had a high effect at the XI grade level compared to the X grade level. The integration of STEM has a positive effect on class X and class XI. This means that the integration of STEM education is effectively used in schools.

STEM is effective to be applied in all aspects of education level. STEM integration in the educational aspect has the intention of preparing students to be able to compete and to be ready to work according to their

expertise. To develop creative thinking skills, students must be given opportunities to develop creativity through a lot of work in school learning.

The second result achieved is that the integration of STEM education in terms of the material aspect has a very high effect on the 4 materials used. The use of materials that give a very high effect includes dynamic fluid, static fluid and work, and energy, sound waves. Newton's law of motion has a moderate effect.

Static fluids and dynamic fluids are physics subject matter whose concepts are widely applied in everyday life. hereby students are required to master the concept well. Students who master the concept can explain phenomena in everyday life, identify a problem, choose the right problem-solving strategy and design a project [29]. Mastery of dynamic fluid concepts is needed by students to understand basic concepts, present their thoughts about the concept and apply these problems to solve conceptual and contextual problems. Mastery of concepts is often associated with problem solving in students [30].

Effort and energy are broad topics and are widely used in everyday life. Along with the development of the era, humans exploit business and energy in various fields, namely in the fields of transportation, agriculture, and others [31]. The material of Newton's laws of motion is also a matter of physics that has many applications in everyday life. Newton's law research on motion needs to be carried out so that students understand evaluation and have the ability to correlate. Furthermore, in addition to Newton's laws of motion, there is also sound wave material which is no less important. Sound waves are a material that has many applications in everyday life, for example in Sonar technology. Sonar functions to detect submarines and groups of fish-derived from the characteristics of sound waves, namely reflection.

The third result that was achieved was that the effect of STEM education integration had a very high effect on the knowledge aspect. STEM integration has a significant effect on student learning outcomes in terms of conceptual mastery aspects. Learning by integrating STEM requires students to analyze engineering in technology by using a variety of representations, which causes students to understand concepts well and be able to get used to various representations which have implications for increasing multi-representation skills. So it can be concluded that the integration of STEM education is very effective at the high school level because it can improve student learning outcomes.

The fourth result achieved is the effect of the integration of STEM education from the aspect of the learning model. The PBL model gives a very high effect. Likewise with the PjBL model and the effect inquiry has given was very high. This shows that the STEM PBL, PjBL, and Inquiry learning models are very effective in improving student learning outcomes. STEM has several characteristics including technology-based, performance-based, inquiry-based, problem-based, and Problem-Based Learning (PjBL). Learning can collaborate well between learning resources and learning models in a lesson, so the quality of the learning process will increase [11].

Several aspects of knowledge can be developed by applying the appropriate learning model. The application of problem-based STEM learning can provide a positive, conceptual understanding of students in a dynamic fluid material. Students' mastery of concepts needs to be developed so that students can master the concepts and apply them to solve problems[15]. The PjBL model is a learning model where students have the opportunity to explore their creativity[17]. Meanwhile, the application of the inquiry learning model can improve students' mastery of concepts and be actively involved in learning at school.

IV. CONCLUSION

Based on the data stated in this research, four results of this study can be stated. First, the integration of STEM education has a significant effect on the level of class XI of Senior High School than grade X. The second, integration of STEM education has a significant effect on sound wave material with an average effect size of 2.45. The third integration of STEM education has a significant effect on student learning outcomes in the knowledge aspect with an average effect size of 1.83. The fourth integration of STEM education has a significant effect on the learning model, namely the PBL model with an average effect size of 2.17.

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