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The Effect of the STEM Approach on Improving Students' Science Learning Outcomes: A Meta-Analysis

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Abstract: Skills in the 21st century require students to have a highly cooperative attitude, be able to communicate well, be creative, and think at a high level. To apply these skills, the form of approach that can be applied is to use the STEM approach. This study has the objective of analyzing the effect of the STEM approach on improving students' natural science learning outcomes obtained by analyzing the effect size results. The research articles consist of 20 articles sourced from international and national journals. Effect Size analysis is based on the grouping of educational levels and student learning outcomes. It can be concluded that the STEM approach greatly influences the improvement of science learning outcomes for students at both elementary, junior high, and high school levels who are in the high category. And the STEM-based approach has a high influence on the three elements, especially on the knowledge element.

Keywords: Improvement; Influence; Meta-analysis; Outcomes; Science learning outcomes; STEM approach

Introduction

Currently, Indonesia has experienced several curriculum changes. The independent curriculum is the current curriculum. The independent curriculum comes with direct ideas and ideas from Nadiem Makarim, Indonesian Minister of Education (Kemendikbud Ristek RI), who puts forward that freedom in learning is freedom of thought. The meaning of independence in thinking is that teachers are given the freedom to explore the curriculum before it is given to students. With this the teacher becomes more aware of the learning needs of his students and the concept of learning is no longer focused on educators. The purpose of independent learning is to fulfill the objectives, materials, methods, and assessments in learning for both educators and students. So, this independent curriculum exists as an answer to the intense competition between human resources as a whole in the 21st century.

In facing the 21st century students must have skills that can support their competitiveness which is called 21st-century skills. According to Scott (2015) 21st century skills require students to be able to practice skills in learning activities in dealing with various things, innovating, collaborating, solving problems, communicating effectively, and thinking critically. The National Education Association (2008) argues that 21st-century skills are 4C skills which consist of Creativity, Critical Thinking, Communication, and Collaboration. It is very important to develop these 21st-century skills so that students can face future challenges by having these 4C skills and there will be an increase in student learning outcomes in science lessons at school.

However, in reality, there are still many educators who have not integrated 4C skills into the learning process in their curriculum. The reason is that there are still many teachers who have difficulties in designing 21st-century skill-based learning steps, especially in science subjects.

Science is a subject that is incorporated into the independent curriculum. Redhana (2019) suggests that science is the science that studies the universe to conclude certain methods and observations. Pratama et al. (2017) and Rahayu (2017) argue that people can get to

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know living things through their natural surroundings by studying science. IPA is related to a process of discovery so IPA does not only discuss concepts, principles, facts, and collections of knowledge. In studying science, students can make it a place to learn about the natural surroundings and understand themselves and be able to apply their knowledge in life. Therefore science is very crucial to learn to develop students' abilities in developing their abilities so that they can implement them scientifically in social life. In helping students to implement their knowledge, a multidisciplinary approach is needed, namely an approach that studies and solves problems by applying the principles of two or more fields of science consisting of science, mathematics, technology, and engineering or also called the STEM approach (Kanematsu et al., 2016; Salame et al., 2019).

Septiani (2016), suggests that STEM (*Science, Technology, Engineering, and Mathematics*) is an approach to learning that combines four scientific disciplines, namely technology, natural science (science), engineering results, and mathematics. The STEM approach is an approach to learning that aims to improve students' principles and knowledge and support the ability to think scientifically and socially interact with those around them (McCright, 2012). The STEM approach in the learning process in the classroom is carried out using *active learning methods* which consist of collaboration, communication, problem-solving, and encouraging students to explore nature more and solve problems according to their experiences (Asghar et al., 2012).

Research by Wibawa (2020) suggests that there was a significant dissimilarity in learning outcomes between students who obtained the simultaneous STEM-based guided inquiry model and students who studied with direct learning models. Research by Herak (2021) by applying the STEM approach by using the *Google Classroom application* in learning acids and bases there was an increase in student learning outcomes. Research by Maulidia et al. (2019) that by using the STEM approach using the PBL model on Hooke's law and elasticity in class XI MIPA 3 there is a moderate increase in student learning outcomes at SMA Muhammadiyah 3 Jember.

The project-based STEM integrated science module on pressure material conducted by research by Sugianto et al. (2018) developed by researchers is suitable for use as learning material for junior high school students which can accommodate a significant increase in student learning outcomes. Research by Prismasari et al. (2019) suggests that applying the STEM approach to science learning can improve student learning outcomes in material for separating mixtures using filtration. Research by Laisnima et al. (2020) using STEM-based modules on electrolysis and redox material in chemistry learning in class XII IPA has increased student learning outcomes at YABT Manokwari Christian High School.

Research by Wahyuni, Ni Putu (2021) by implementing STEM-based learning can significantly improve students' abilities and can increase students' interest in learning which has an impact on improving student learning outcomes. Research by Marsya et al. (2022) by implementing STEM-based learning there was a significant increase in student learning outcomes in simple aeronautical material. Research by Abdi et al. (2021) using a PhET virtual lab with a STEM approach can improve students' physics concepts in learning. This is evidenced by the category of the N-gain test in the moderate category and an increase after testing through objective tests.

Based on the research above, the application of the STEM approach can affect students' natural science learning outcomes. So, it is necessary to analyze the *effect size* of the influence of the STEM approach on improving students' natural science learning outcomes at school.

Method

This type of research is meta-analysis research. The data used comes from international and national journals for the last two years. Data collection techniques are carried out by searching for data sources through international and national journals through Google Sholar, Eric, and IEEE. This meta-analysis research uses articles related to improving student learning outcomes with the STEM approach in science learning. The analyzed articles consist of 25 articles. Each article will calculate its effect-size value using the equation in Table 1.

Table 1. How to Determine the Magnitude of the Effect Size

Statistics	Formula
The average of a group	$ES = \frac{\bar{X}_{post} - \bar{X}_{pre}}{SD_{pre}}$
Average of each group	$ES = \frac{\bar{X}_{eksperimen} - \bar{X}_{kontrol}}{SD_{kontrol}}$
Chi-square	$ES = \frac{2r}{\sqrt{1-r^2}}; r = \sqrt{\frac{X^2}{n}}$
T count	$ES = t\sqrt{\frac{1}{n_{eksperimen}} + \frac{1}{n_{kontrol}}}$

After obtaining the effect size value, the results can be categorized according to Cohen (1998), namely for the low category the effect size is ≤ 0.2; for the medium category the effect size is ≥ 0.2 and ≤ 0.8 and for the high category the effect size is ≥ 0.8.

Result and Discussion

This study aims to analyze the effect of the STEM approach on improving students' natural science learning outcomes. The data is obtained by calculating the effect size of the articles that are relevant to the title of this study. The data from this study were collected from various sources, namely Google Scholar, Eric, and other journals.

The selected articles were obtained from national and international journals totaling 20 articles that met certain criteria. The first criterion is research on the STEM approach, the second criterion is its effect on improving students' natural science learning outcomes.

The effect size results obtained from the 20 articles above are grouped into two parts. First, based on the level of education, and second based on the elements of learning outcomes obtained by students. The classification of articles is in table 2.

Table 2. Article Code, Effect Size, and Category Used

Article Code	Effect Size	Category
P1	1.77	High
P2	1.3	High
P3	1.4	High
P4	1.49	High
P5	0.74	Currently
P6	1.03	High
P7	0.78	Currently
P8	1.3	High
P9	1.55	High
P10	1.17	High
P11	0.75	Currently
P12	1.34	High
P13	0.4	Currently
P14	1.06	High
P15	0.62	Currently
P16	0.6	Currently
P17	0.53	Currently
P18	1,9	High
P19	0.65	Currently
P20	0.80	High

Based on the data in table 3, it can be seen that each effect size of the article regarding the effect of the STEM approach on increasing students' natural science learning outcomes. The average result of the effect size on the effect of the STEM approach on improving students' natural science learning outcomes is 1.06 which is in the high category.

Furthermore, the results of the effect size of the research on the effect of the STEM approach on the effect of increasing students' natural science learning outcomes based on their level of education. The effect size results can be seen in Table 3.

Table 3. The Effect of the STEM Approach on Increasing Student Science Learning Outcomes Based on Education Level

Level of education	Article Code	Effect Size	Average Effect Size	Category
Primary School	P1	1.77	1.25	High
	P2	1.3		
	P3	1.4		
	P4	1.49		
	P11	0.75		
	P20	0.80		
	P5	0.74		
	P6	1.03		
	P7	0.78		
	P9	1.55		
Junior High School	P10	1.17	1.06	High
	P12	1.34		
	P13	0.4		
	P18	1.9		
	P19	0.65		
	P8	1.3		
	P14	1.06		
Senior High School	P15	0.62	0.82	High
	P16	0.6		
	P17	0.53		

From the calculation of the effect size, the effect of the STEM approach on improving students' science learning outcomes at the educational level, an effect size value of 1.25 is obtained with the high category at the elementary level, at the junior high school level, an effect size value of 1.06 is obtained with the high category, and at SMA level obtained an effect size value of 0.82 with the high category. Based on the level of education, it was found that the STEM approach greatly influenced the increase in science learning outcomes for students at both elementary, junior high, and high school levels who were in the high category.

Research by Herak (2021) argued that by applying the STEM learning model to science subjects in class VIII of SMP Negeri 11 Kupang there was an increase in student learning outcomes. Research by Lestari, Puji, et al. (2022) suggests that STEM-based learning in class VII at MTSN 3 Bantul can increase student learning activity, which means that there is also an increase in student learning outcomes. Research by Wijayanto et al. (2020) suggests that using the STEM approach in applying the project-based learning model in vector material in class X IPA at SMA 3 Muhammadiyah Jember can improve students' understanding of material concepts and students are also active in preparing projects in solving problems using physics concepts.

Following research by Yanni (2018) that applying the STEM approach can improve student learning activities by training students to develop steps in dealing with problems and increasing students' intelligence in

mastering learning material and there is also an increase in learning outcomes students at Integrated Al-Ulum Islamic Middle School for class VIII students in Medan. Research by Rahmi et al. (2022) stated that the results of learning science in theme 1 in class IV of SD Negeri 001 Muara Badak by applying the STEM-based Pjbl learning model experienced a considerable increase in each cycle.

The result of the second effect size is that the effect of the STEM approach on learning outcomes can be grouped into three elements of learning outcomes. The effect size results can be seen in Table 4.

Table 4. Effect Size Results of STEM-Based Science Teaching Materials on Student Learning Outcomes

Learning outcomes	Article Code	Effect Size	Average Effect Size	Category
Attitude	P10	1.17	1.17	High
	P6	1.03		
	P9	1.55	0.97	High
Skills	P11	0.75		
	P17	0.53		
	P1	1.77		
	P2	1.3		
	P3	1.4		
	P4	1.49		
	P5	0.74		
	P7	0.78		
	P8	1.3		
Knowledge	P12	1.34	1.08	High
	P13	0.4		
	P14	1.06		
	P15	0.62		
	P16	0.6		
	P18	1.9		
	P19	0.65		
	P20	0.80		

From the calculation of the effect size the effect of the STEM approach on improving students' natural science learning outcomes, an effect size value of 1.17 is obtained in the high category in the attitude element learning outcomes, and in the skill element, the effect size is 0.97 in the high category. Meanwhile, the knowledge element obtained an effect size value of 1.08 in the high category. Learning outcomes consist of three elements, which consist of attitude elements, skills elements, and knowledge elements. From the calculations, it is found that the STEM-based approach has a high influence on the three elements, especially on the knowledge element. Sukma (2018) argues that the STEM approach can affect student assessment which consists of affective, psychomotor, and cognitive aspects.

Research by Fitriansyah et al. (2021) suggests that using the STEM approach in learning will improve students' scientific attitudes in compiling scientific work procedures. The STEM approach in the guided inquiry learning model is more effective than not using the STEM approach. Research by Syarifuddin et al. (2022) suggests that after and before learning activities there is an increase in students' ability to think critically by using the STEAM-based PBL learning model. Students can solve a problem, answer several questions, and conclude.

The STEM approach supports students to develop different mindsets and improve their critical thinking skills. The application of this STEM-based approach can also increase the activeness of students in discussions which can increase student achievement. Research by Octaviyani et al. (2020) suggests that the application of STEM-based learning can hone students' creative thinking abilities. Research conducted by Twiningsih et al. (2020) argues that using STEM-based learning can improve students' skills it affects students' learning outcomes. The result of learning is the intelligence possessed by students after participating in the process and experiencing experiences in learning (Kunandar, 2013). Learning outcomes show the success and quality of student learning (Slameto, 2010).

Conclusion

It can be concluded that the effect size results obtained with the STEM approach have a high influence on improving students' natural science learning outcomes at the elementary, middle, and high school levels. Also, from the effect size calculation, it is found that the use of STEM-based teaching materials has a high influence on the three elements, especially on the knowledge element.

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Conflicts of Interest
The author declares that there is no conflict of interest regarding the publication of this paper.

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