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STEM Effect In Problem Solving: A Meta Analysis

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Abstract: The STEM approach to learning helps prepare students with the skills needed for the future. Concrete and real-world problems can be solved by training students in STEM education. This research aims to analyze the influence of STEM on problem-solving abilities in education. The research method used is meta-analysis. The research process begins with determining the topic, data criteria, article search, data classification, analysis, and conclusion. The topic used is STEM and problem-solving, and the data criteria used are effect sizes. Articles used in the analysis are published in Scopus-indexed journals, ERIC, DOAJ, and SINTA-accredited journals. The articles analyzed are from the years 2018-2023. The result of the study shows that the use of STEM has a significant impact, with an average effect size of 1,709. STEM education has a very large influence on problem-solving abilitie.

Keywords : Effect size; Meta-analysis; Problem solving; STEM

Introduction

The changes in education reflect efforts to prepare learners. These changes can be seen in aspects such as learner-centeredness, the use technology, emphasis on 21st century skills development, interdisciplinary and contextual approach. The aspects differ from what was provided in the past. The current perspective on education focuses on how learners acquire the skills and abilities to face challenges and opportunities (Surani, 2019). These aspects can be developed through innovative 21st century learning approaches. Innovative 21st century learning is characterized as an interactive, holistic, integrative, scientific, contextual, thematic, effective, collaborative and learner-centered (Muhali, 2019). One of the innovative approaches that facilitate 21st century need is STEM (Fathoni et al., 2020; Nugroho et al., 2019; Permanasari, 2016).

STEM, as an interdisciplinary approach, provides practical reinforcement by integrating science, technology, engineering, and mathematics into solving real-world problems. The design of STEM education allows learners to implement knowledge in the real world. Many real-world problems are related to science subjects. STEM education is considered best practice for science teachers (Nugroho et al., 2021). The syntax of STEM education in Indonesia, integrated with the scientific method, PjBL, and the 2013 curriculum, includes identifying problems, designing to answer problems, making products, conducting product trials and evaluations, revising, concluding, and communicating findings (Arlinwibowo et al., 2021). In developed countries, STEM generates interest in careers and serves as a way to address the quality of human resources and national competitiveness (Rustaman, 2016). STEM bridges the gap between abstract science concepts and contextual problems for meaningful learning (Tan et al., 2023). STEM provides logical thinking for learners (Hudha et al., 2019). STEM-based learning is suitable for developing 21st-century skills (Rusminati & Juniarso, 2023; Suwardi, 2021). One of the 21st-century skills is critical thinking and problem-solving (Septikasari & Frasandy, 2018).

Problem-solving skills and critical thinking work together to solve problems, where the analysis of problems leads to solutions based on logical thinking that can differentiate truth from falsehood, facts from opinions (Aslamiah et al., 2021). STEM education

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encourages learners to solve problems using the knowledge they are learning (Zeng et al., 2018; Hidayat & Irawan, 2017). The connection between STEM and problem-solving is supported by research through research reports in articles and books. Problem-solving is one of the crucial skills for learners in facing life's challenges. The ability to identify, analyze, and find creative solutions to complex problems is a relevant skill in various aspects of life. Problem-solving involves critical thinking, analytical and creative skills, collaboration, making accurate decisions, and adapting to change.

Various studies on STEM have started to develop to develop 21st-century skills both nationally and internationally. However, there is still a lack of research analyzing the effectiveness of STEM in improving problem-solving skills in science learning. This research is important to find out the effect of STEM on science education, especially on students' problem solving abilities. The result, of this study will provide information for educators and researchers who use STEM in learning to improve problem solving skills. Thus, the aim of this article is to analyze whether STEM in science learning can truly enhance learners' problem-solving abilities. This research will analyze articles that discuss STEM, problem-solving abilities in science learning.

Method

The methodology is a meta-analysis study using a quantitative approach**.** Meta-analysis is created by summarizing data from several articles in national and international journals. Search literature using the keyword "STEM, Problem Solving and Science Education" through google scholar and Publish or Perish 8. Database are articles published in scopus, ERIC, EBSCO indexed and Sinta accredited journal.

Inclusion criteria for the articles used are as follows: 1) the independent variable is STEM, and the dependent variable is problem-solving, 2) the samples are from primary school, junior high school, Senior high school, and college student, 3) the data used are effect sizes, 4) the articles employ experimental methods, and 5) the publication years range from 2018 to 2023. A total of 22 articles were found to meet these criteria, supported by 25 effect size data.

The instrument used is a table that includes the necessary information from each article. Data analysis is conducted using effect sizes. If the effect size value is not found in the article, the following information is obtained first: 1) mean scores of pretest and posttest for both experimental and control groups, 2) standard deviation, 3) sample size, and 4) t-value. Then, the effect size is calculated using the following formulas.

Average of two sample groups (for posttest data only):

$$ES = \frac{\bar{X}E - \bar{X}C}{SD\ C} \tag{1}$$

Average of pretest and posttest scores of one sample group:

$$ES = \frac{\bar{X}post - \bar{X}pre}{SD\ pre} \tag{2}$$

Average of two sample groups for both pretest and posttest:

$$ES = \frac{(\bar{X}post - \bar{X}\ pre)E - (\bar{X}\ post - \bar{X}\ pre)C}{\frac{SDpreC + SD\ pre\ E + SD\ post\ C}{3}} \tag{3}$$

Using the t-value when SD data is not available:

$$ES = t\sqrt{\frac{1}{nE} + \frac{1}{nC}} \tag{4}$$

Information:

ES	:	Effect Size	E	:	Experiment group
X	:	Average	C	:	Control group
Pre	:	Pre-Test	SD	:	Standar Deviation
Post	:	Post-Test	n	:	Number of Students
t	:	t value			

The obtained effect size values are then interpreted according to the predetermined categories. The effect size categories are indicated in Table 1.

Table 1. The Effect Size Category (Cohen, 2013)

Effect Size	Category
0.00 < ES < 0.19	Ignored
0.19 < ES < 0.49	Small Effect
0.49 < ES < 0.79	Medium Effect
0.79 < ES < 1.29	Large Effect
ES > 1.29	Very Large Effect

This method is Network meta-analysis, that meaning combining direct and indirect evidence to compare the effectiveness between different interventions (Wang et al., 2021).

Result and Discussion

Based on the criteria, there are 25 data that meet the criteria from 21 articles. Some articles provide more than one data, as they involve more than two groups in the study, resulting in up to three Effect size values for each treatment. Table 2 present the article data based on scopus, ERIC, EBSCO indexed and Sinta Accredited journal.

The data obtained from the information table used as instruments include, first, a list of articles based on national and international journals, as well as the types of articles and proceedings. Second, the effect size values and their percentages for each category. Third, the publication year of the articles. And fifth, the data related to the effect size values at each level of education from elementary school to higher education.

Table 2. List of Article

Code	Author	Year	Journal		Type	
			National	International	Article	Proceeding
P1	Wildani & Budiyono	2022	✓		✓	
P2	Purwaningsih, Sari, Sari, Suryadi	2020	✓		✓	
P3	Parno, Yuliati, Hermanto, Ali	2020	✓		✓	
P4	Parno, Yuliati, Munfaridah, Ali, Rosyidah, Indrasari	2020	✓			✓
P5	Fiteriani, Diani, Hamidah, Anwar	2020	✓			✓
P6	Parno, Estianinur, Latifah	2021	✓			✓
P7	Parno, Yuliati, Ni'mah	2019	✓			✓
P8	Parno, Anggraini, Hidayat, Fauziyah, Pramono, Supriana, Ali	2021	✓			✓
P9	Yuliati, Putri, Taufiq, Purwaningsih, Affriyenni, Halim	2019	✓			✓
P10	Sarı, Çelik, Pektaş, & Yalçın	2022		✓	✓	
P11	Zengin, Kayak, Kececi, and Zengin	2022	✓		✓	
P12	Hebebci and Usta	2022		✓	✓	
P13	Chen, Yoshimatsu, Goda, Okubo, Taniguchi, Oi, Konomi, Shimada, Ogata, Yamada	2019		✓	✓	
P14	Puchongprawet and Chantraukrit	2022		✓	✓	
P15	Kartini, Widodo, Winarno, Astuti	2021	✓		✓	
P16	Muzana, Jumadi, Wilujeng, Yanto, Mustanim	2021		✓	✓	
P17	Istiana, Herawati, Herniningtyas, Ichsan, Ali	2023	✓		✓	
P18	Parno, Yuliati, Ndadari and Ali	2020	✓			✓
P19	Stehle and Peters-Burton	2019		✓	✓	
P20	Sarican, Bakanlığı, and Akgunduz	2016		✓	✓	
P21	Bicer, Nite, Capraro, Barroso, Capraro, Lee	2017		✓	✓	
P22	Sarwi, Baihaqi, Ellianawati	2021	✓			✓
Sum			14	8	14	8
Percent (%)			64	36	64	36

Based on Table 2, 61% and 39% of national and international journals are used. The type of article used is 65% article and 35% proceedings. Based on the overall articles, measuring problem-solving outcomes is influenced by STEM within the scope of science. The analyzed articles were published between 2018 and 2023. research on STEM and problem-solving skills has shown an increase from 2018 to 2020. However, in 2021, there was a decrease compared to previous years. This could potentially be attributed to the COVID-19 pandemic, which resulted in suboptimal learning conditions.

Table 4 and Table 5 show that the average effect of STEM approaches in learning on problem-solving abilities is 1.709 indicating a very large effect size. The data from each article indicate that the largest effect size is 60%, followed by medium effects at 28%, and large, small, and ignored effects at 4% each. Based on this data, it can be stated that STEM education effectively enhances students' problem-solving abilities. This is consistent with the research conducted by Fiteriani et al. (2021), which found that STEM has a significant influence on students' problem-solving abilities. The research conducted by Zeng et al. (2018), as well as STEM education through methods and students' learning experiences, has a positive impact.

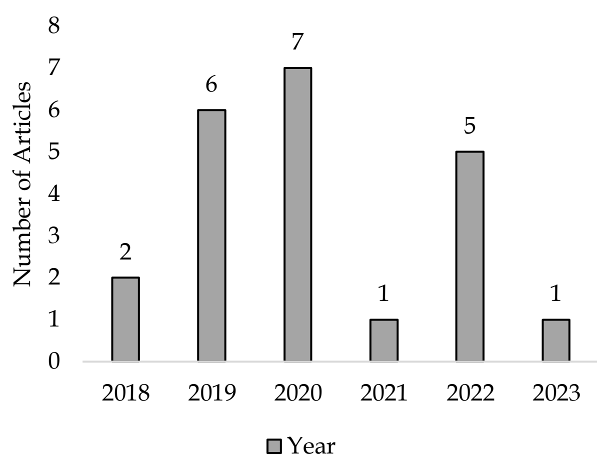

Figure 1. Publication year

Table 3. Effect Size

Code	ES	Category	Level
P1	2.77	Very Large	CS
P2	0.057	Ignored	SHS
P3-A	0.721	Medium	SHS
P3-B	1.962	Very Large	SHS
P4	1.65	Very Large	SHS
P5	0.72	Medium	SHS
P6	5.2	Very Large	SHS
P7-A	0.59	Medium	SHS
P7-B	1.75	Very Large	SHS
P7-C	1.41	Very Large	SHS
P8	2.642	Very Large	SHS
P9	3.293	Very Large	SHS
P10	2.635	Very Large	CS
P11	0.77	Medium	PS
P12	0.904	Large	JHS
P13	2.01	Very Large	SHS
P14	1.84	Very Large	JHS
P15	2.75	Very Large	JHS
P16	1.37	Very Large	JHS
P17	4.2	Very Large	SHS
P18	1.315	Very Large	JHS
P19	0.77	Medium	SHS
P20	0.535	Medium	PS
P21	0.66	Medium	SHS
P22	0.207	Small	PS
X	1.709	Very Large	

Table 4. Percentage of Effect Size

Category	N	Percent (%)
Ignored	1	4
Small	1	4
Medium	7	28
Large	1	4
Very large	15	60
∑	25	100

STEM is applied as both a model and an educational approach. The applications of STEM in the analyzed articles are shown in Table 5.

Table 5. Application of STEM

Model	n	Percent (%)	X ES
Project based learning	7	28	1.15
Problem based learning	6	24	1.5
STEM education	4	16	1.5
STEM Learning	3	12	2.29
Inquiry	1	4	3.29
Other (Practical, Applications, Inclusive, Experiental)	4	16	2.34
∑	25	100	1.709

The application of STEM in education is used both as a learning model and an approach within a model. Out of the 25 analyzed data, STEM is most commonly used as an approach in project-based learning, accounting for 32%. Harun (2020) states in his research that STEM-PjBL is a model that can enhance higher-order thinking skills (HOTS). Problem-Based Learning (PBL) and Project-Based Learning (PjBL) have an impact on attitudes and careers in STEM in the future (Laforce et al., 2017). In the study by Euefueno (2019), STEM through PBL and PjBL fosters the development of self-efficacy, real-world experiences, and requires students to think critically. The use of these models influences problem-solving abilities. Inquiry learning according to Yuliati et al. (2020) the positive impact given by inquiry learning with the STEM program increases conceptual knowledge through each learning stage, students are able to apply concepts to solve problems.

Table 6. Effect Size of Level

Sample	N	X-ES	Category
Primary school	3	0.504	Medium
Junior High School	5	1.6358	Very large
Senior High School	16	1.83	Very large
College Student	2	2.7	Very large

Based on Table 5, it is evident that the effect size values, from small to large, increase progressively from elementary school to junior high school, followed by senior high school, and finally college students. This indicates that as the level of education increases, the problem-solving abilities also improve. This can be attributed to the prior knowledge possessed by each sample, where older samples tend to have more prior knowledge. Additionally, with age comes an increased capacity for higher-level thinking, especially in problem-solving. Grandis et al. (2023) stated that innovative learning through STEM-PBL allows students to experience benefits, efficiency, ease, and mastery.

Conclusion

The use of STEM in science education has a high impact, with an effect size of 1.93, indicating a very large effect on problem-solving abilities. Based on the data, this research recommends conducting STEM-based studies to measure problem-solving abilities at the junior high school level. This is because there are still limited references regarding the influence of STEM on problem-solving at the junior high school level.

Author Contributions

Conceptualization STEM and Problem Solving in meta-analysis from first authors. The design methodology suggested by the fifth author. Supervision in writing article to improve, correct and develop better research results by the second, third and fourth authors.

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Conflicts of Interest
The authors declare no conflict of interest.

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