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Meta-Analysis of the Influence of the STEM-Integrated Learning Model on Science Learning on 21st Century Skills

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Abstract: One of the skills that students must have 21st century skills. In order for students to understand and master the skills of learning materials, especially science learning, it is necessary to apply the STEM integrated learning model. Meta-analytic research is needed on the effect of the STEM integrated learning model on science learning on 21st century skills based on different previous research findings. The purpose of this research is to see how much influence the STEM integrated learning model has on science learning on 21st century skills in terms of educational level, learning models, and types of 21st century skills. The research method used is a meta-analysis of 22 articles in national and international journals. Coding is a data collection technique, and for effect size analysis it is used for data analysis techniques. The research results obtained, namely with variations in educational levels, learning models, and 21st century skills, state that the application of STEM integrated learning models in science learning has a high influence on 21st century skills. The conclusion from this meta-analysis research is that there is a high influence from the application of the model STEM integrated learning in science learning towards 21st century skills.

Keywords: Learning model; Science learning; STEM; 21st century skills

Introduction

Twenty first century skills are one of the skills that students must have. National Education System Law Number 20 of 2003 states that the purpose of national education is to assist students in realizing their full potential as religious and pious individuals who are knowledgeable, independent, capable, responsible and creative. The nation's educational goals reflect the demands and challenges of the 21st century. Citizens of a country are expected to have a variety of skills, including critical thinking and problem-solving abilities, which are highly desirable, as well as creativity, communication, and teamwork to find solutions to 21st century problems. The 21st century is period focused on science and technology (Kusuma et al., 2022).

STEM learning is one of the high-level learning that is creating. STEM learning can increase student learning motivation because students are directly involved in the learning process and create generations who like learning science and mathematics. Through STEM learning, students are required to solve problems, be innovators, build independence, think logically, be literate in technology, and be able to connect STEM education with the real world (Artobatama et al., 2020). The learning process with the STEM approach can shape students to practice principles, concepts, technology, techniques, and applied mathematics by properly integrating these disciplines into learning activities connected to everyday life. Using the STEM approach to education is the right learning to apply according to 21st century developments (Siswanto, 2018).

The application of STEM in the learning model is needed to streamline the process and help students understand and capture academic content, especially learning science, because learning science currently does

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not only rely on rote memorization but also requires students to always be involved and active in class, in addition to the scope broad material and direct relevance to everyday life. According to Dasuki et al. (2020) integrating STEM into learning models is a breakthrough in education because it includes the elements needed to improve students' mastery of the scientific method. According to Widana et al. (2021) The STEM learning approach aims to, firs foster a cooperative problem-solving mentality. Second, improve critical and creative thinking skills. Third, promote rational, innovative, and productive thinking. Fourth, introducing and preparing perspectives on the world of work. Five, using technology to create and communicate innovative solutions. Six, using media to develop problem solving skills.

Based on research conducted by Mutowi' ah et al. (2020) STEM integrated inquiry learning has a moderate impact on students' creative skills in the kinetic theory of gases. Meanwhile, Santoso & Arif's research (2021) states that learning through the Inquiry model with the STEM Education approach has a considerable impact on students at MTs Darussalam and can improve critical thinking skills in the interaction of living things. In addition, according to research by Ariyatun et al. (2020) based on the results of the N-gain and t-test show that the application of the PBL model combined with the STEM approach can improve students' critical thinking skills. Thus, students' critical thinking skills can be improved with the STEM integrated problem-based learning model.

Based on the results of different previous studies, it is necessary to conduct a meta-analysis research regarding the effect of STEM integrated learning models on science learning on 21st century skills reviewed based on educational levels, learning models, and types of 21st century skills.

Method

The method used in this research is meta-analysis. Meta-analysis is the process of conducting research by compiling, examining, and interpreting data from various previous studies (Pangesti et al., 2021). The data collected is secondary data, derived from articles published in SINTA accredited national and international journals which describe previous research. As research subjects, 22 national and international journal articles published between 2018-2022 were used. Articles that met the following criteria were selected for analysis. First, the article examines how the STEM integrated learning model influences science learning on students' 21st century skills. Second, articles with ISSN and DOI that have been published in accredited national and international publications. Third, the work was published no more than five years ago.

The procedure used in this study was modified from the procedure described by David B. Wilson and George A. Kelley to carry out a meta-analysis (Komalasari et al., 2021). The steps taken are first determining the problem or subject being investigated. Second, determining research topics with the free variables of STEM integrated learning models, and the dependent variable 21st century skills with a time span of 2018-2022. Third collecting articles related to research topics. Fourth, focusing research. Five, categorizing each study. Six, determining the effect size of each article. Seven, analyzing research findings and making conclusions based on the meta-analysis research that has been completed. The research flow can be seen in Figure 1.

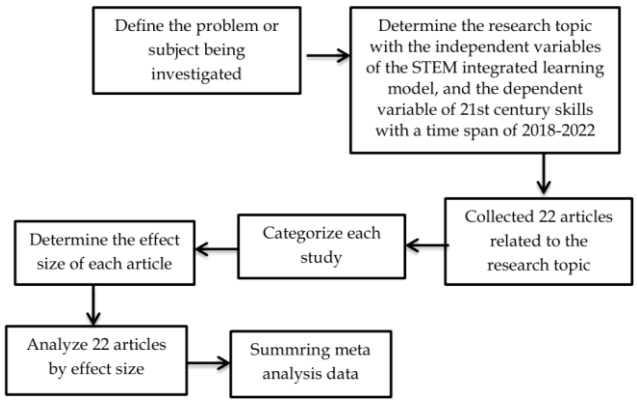

Figure 1. Research flow

Coding is a data collection technique, and effect size analysis is used for data analysis techniques. The following statistical factors are used in the calculation of effect sizes:

Table 1. How to Determine the Effect Size (Becker & Park, 2011)

Statistics Data	Formula	Formulas
Average in one group	$ES = \frac{\bar{x}_{post} - \bar{x}_{pre}}{SD_{pre}}$	Fr-1
Average in each group	$ES = \frac{\bar{x}_{eksperimen} - \bar{x}_{kontrol}}{s_{kontrol}}$	Fr-2
Average in each group	$ES = \frac{(\bar{x}_{post} - \bar{x}_{pre})_E - (\bar{x}_{post} - \bar{x}_{pre})_C}{\frac{SD_{preC} + SD_{preE} + SD_{postC}}{3}}$	Fr-3

Statistics Data	Formula	Formulas
T count	$ES = t\sqrt{\frac{1}{n_E}+\frac{1}{n_C}}$	Fr-4
Chi-Square	$ES = \frac{2r}{\sqrt{1-r^2}};\ r = \sqrt{\frac{x^2}{n}}$	Fr-5
P value	CMA (Comprehensive meta-Analysis Software)	Fr-6

Effect sizes are then characterized using the following criteria after being calculated using the appropriate formula:

Table 2. Effect Size Criteria (Anwar, 2021)

ES	Category
0 – 0.20	Weak Effect
0.21 – 0.50	Modest Effect
0.51 – 1.00	Moderate Effect
> 1.00	Strong Effect

Results and Discussion

By reviewing and evaluating a number of previous studies, this research was conducted to find out how the STEM-integrated learning model affects students' acquisition of 21st century skills when learning science. The data included in the analysis comes from a number of related articles published over the last five years and supports the calculation of the effect size of each article. Data was collected by researchers from a variety of sources, including Google Scholar, ERIC and others. The 22 articles used in this study met the following criteria: research on STEM integrated learning models, use in science learning, and influence on 21st century skills.

The 22 articles with codes AR1 to AR22 that were analyzed and effect sizes calculated were grouped according to three criteria: educational level, learning model, and 21st century skills. Table 1 presents the findings from the overall analysis of the article on the influence of STEM-integrated learning models on science learning on 21st century skills.

Table 3. General Effect Size Result Data

Code Article	Source Article	Article Status	Effect Size	Category	Formulas
AR1	(Mawarni & Sani , 2020)	National	0.48	Modest Effect	Fr-4
AR2	(Mutowi'ah et al., 2020)	National	0.84	Moderate Effect	Fr-2
AR3	(Gandi et al., 2021)	International	0.36	Modest Effect	Fr-2
AR4	(Mukaromah & Wusqo, 2020)	International	2.76	Moderate Effect	Fr-5
AR5	(Hasancebi et al., 2021)	internationall	0.50	Modest Effect	Fr-4
AR6	(Khoiriyah et al., 2018)	National	2.56	Strong Effect	Fr-4
AR7	(Mustfa et al., 2021)	National	1.60	Strong Effect	Fr-2
AR8	(Santoso & Arif, 2021)	National	3.72	Strong Effect	Fr-2
AR9	(Davidi et al., 2021)	National	2.16	Strong Effect	Fr-2
AR10	(Ariyatun & Octavianelis, 2020)	National	2.07	Strong Effect	Fr-4
AR11	(Dywan & Airlanda, 2020)	National	0.64	Moderate Effect	Fr-3
AR12	(Oktavia & Ridlo, 2020)	International	1.65	Strong Effect	Fr-4
AR13	(Widyasmah et al., 2020)	International	2.49	Strong Effect	Fr-1
AR14	(Widana & Septiari, 2021)	National	0.64	Moderate Effect	Fr-2
AR15	(Rahardian, 2022)	National	2.62	Strong Effect	Fr-1
AR16	(Renandika et al., 2020)	National	0.95	Moderate Effect	Fr-2
AR17	(Hadi, 2021)	National	0.69	Moderate Effect	Fr-4
AR18	(Riyanti, 2020)	National	2.71	Strong Effect	Fr-4
AR19	(Yulaikah et al., 2022)	National	1.17	Strong Effect	Fr-3
AR20	(Asigigan & Samur, 2021)	International	0.42	Modest Effect	Fr-5
AR21	(Rizkiyah et al., 2020)	National	0.74	Moderate Effect	Fr-1
AR22	(Nurwidodo et al., 2022)	National	1.23	Strong Effect	Fr-5

Based on the data in table 3, it can be seen the effect size of each article about the effect of the STEM integrated learning model in science learning on 21st century skills. The average effect size result is 1.71 which is included in the high category. Thus, the application of the STEM integrated learning model to science learning has a high influence on 21st century skills. Relevant research by Gandi et al. (2021) revealed that students' critical thinking skills were influenced by the PJBL learning model which incorporates STEM in the learning process. According to a different study by Davidi et al. (2021) revealed that teaching elementary school students in Wae Ri'i District using the STEM-PBL approach has a large and positive impact on how well they can think

critically. Another study by Rizkiyah et al. (2020) found that the STEM-integrated project-based learning model had an impact on students' collaboration skills. According to research by Mawarni et al. (2020) the STEM-based PJBL learning model has a positive impact on students' creative thinking abilities.

One of the subjects in formal education that can improve human resource standards is science learning. Quality science education will have an impact on the achievement of a country's development. Science education depends on the learning used in each country. Through science education, students can be involved in the impact of science in everyday life and the role of students in society. By applying science concepts in science education, Indonesian students are expected to be able to solve real-life problems in the 21st century (Pratiwi et al., 2019). IPA is not only a collection of laws, unlike a catalog that is detached from concrete reality, but is a creation of the human mind with free discovery ideas and concepts. Natural science theories try to describe reality and determine its relationship with facts that exist on earth (Wahyu et al., 2020). Thus, it is very important for students to develop 21st century skills when engaging in science-related learning activities.

STEM stands for science, technology, engineering and mathematics, which are studied in an interdisciplinary manner. This approach from all four perspectives is a perfect blend of real-world challenges as well as problem-based learning. Because these four components are needed independently and together to solve problems, this technique can produce an integrated teaching and learning system (Mawarni & Sani, 2020). Students who choose STEM-based learning must become more analytical and able to use experience to solve problems and learn new things.

The Influence of STEM Integrated Learning Models on Science Learning Against 21st Century Skills Based on Educational Level

Table 4 shows the research findings on the effect of the STEM integrated learning model on science learning on 21st century skills by educational level, with 10 articles at the elementary level, 6 articles at the junior high school level, and 6 articles at the senior high school level.

Table 4. Effect Size Analysis Based on Education Level

Educational level	Article Code	Effect Size	Average Effect Size	Category
Elementary School	AR3	0.36	1.35	Strong Effect
	AR4	2.76		
	AR9	2.16		
	AR11	0.64		
	AR12	1.65		
	AR16	0.95		
	AR17	0.69		
	AR18	2.71		
	AR19	1.17		
	AR20	0.42		
Junior High School	AR5	0.50	1.44	Strong Effect
	AR7	1.60		
	AR8	3.72		
	AR14	0.64		
	AR15	0.95		
	AR22	1.23		
Senior High School	AR1	0.48	1.53	Strong Effect
	AR2	0.84		
	AR6	2.56		
	AR10	2.07		
	AR13	2.49		
	AR21	0.74		

Based on the data in table 4, the average effect size in the high category at the Elementary School, Junior High School, and Senior Hight School levels is 1.35, 1.44, and 1.53, respectively. Thus, the average effect size for the three levels of education is in the high category. Thus, the application of the STEM integrated learning model to science learning has a significant impact on improving 21st century skills at all levels of education. This is in line with Santoso & Arif's research (2021) which revealed that the application of the STEM approach in the inquiry learning model has a major impact and can help students at MTs Darussalam develop their critical thinking skills. According to another study by Yulaikah et al. (2022) states the impact of applying the STEM approach with the PJBL learning model on the creativity and knowledge of elementary

school children about understanding the concept of science is significant in the large category. Then according to the research of Khoiriyah et al. (2018) stated that using the STEM-integrated PBL model in learning has an effect on developing high school students' critical thinking skills.

The STEM approach is not only applied in elementary and secondary schools but can also be implemented in lectures and even in doctoral programs. The STEM approach connects the four pillars of learning components, namely natural sciences, technology, engineering, and mathematics. In line with that, the STEM approach can be applied at all levels of formal education and non-formal units There have been a lot of STEM in recent years implemented in countries such as Taiwan. Learning with a STEM approach that focuses students in learning learning activities, is gradually added to the improvement of the nine-year curriculum. Approaches with STEM support can seek to extract students' abilities, for example 21st century competencies such as critical thinking, creativity, collaboration, and communication when these competencies are very important for strengthening human resources (Khoiriyah et al., 2018). Improvements to the nine-year curriculum are gradually included, learning.

The Influence of the STEM Integrated Learning Model on Science Learning Against 21st Century Skills Based on the Learning Model

The results of research on the effect of the STEM integrated learning model on science learning on 21st century skills are presented in Table 5. The project-based learning model (PJBL) has 12 articles, namely problem-based learning (PBL) has 6 articles, and the inquiry learning model has 4 articles.

Table 5. Effect Size Analysis Based on the Learning Model

Learning Model	Article Code	Effect Size	Average Effect Size	Category
	AR1	0.48		
	AR3	0.36		
	AR4	2.76		
	AR11	0.64		
	AR12	1.65		
Project Based Learning (PJBL)	AR13	2.49	1.43	Strong Effect
	AR14	0.64		
	AR15	2.62		
	AR16	0.95		
	AR18	2.71		
	AR19	1.17		
	AR21	0.74		
	AR6	2.56		
	AR7	1.60		
Problem Based Learning (PBL)	AR9	2.16	1.59	Strong Effect
	AR10	2.07		
	AR17	0.69		
	AR20	0.42		
	AR2	0.84		
Inquiry	AR5	0.50	1.57	Strong Effect
	AR8	3.72		
	AR22	1.23		

Based on the data in table 5, where the PJBL, PBL, and inquiry models each have an average effect size in the high category of 1.43, 1.59, and 1.57. Consequently, the average effect size of the three learning models falls into the high range. Based on the type of learning model it can be said that the STEM integrated learning model in science learning significantly improves 21st century skills. This is in line with the research of Ariyatun et al. (2020) which states that based on the results of the N-gain and t-test it shows that the use of the STEM integrated PBL learning model can improve students' critical thinking skills. The PJBL model combined with STEM according to research by Widyasmah et al. (2020) can improve creative thinking skills. Another relevant research by Hasacebi et al. (2021) states that the application of the inquiry model in learning combined with the STEM approach can improve students' creative thinking skills.

A model known as PBL or problem-based learning, helps students prepare for the challenges of the 21st century. PBL integrates the 4C learning concepts namely creativity, communication, collaboration, and critical thinking in the learning process (Ariyatun & Octavianelis, 2020). Problem solving skills can be obtained through learning steps that direct students to think and find solutions to a problem. Problem solving

is a very important component of the curriculum and needs attention in learning (Sari et al., 2021). Problem solving skills refer to a set of cognitive-behavioral activities by which a person tries to find or develop effective solutions to real life problems (Simanjuntak et al., 2021).

The use of the PjBL or Project Based Learning model combined with the STEM approach is expected to improve students' critical thinking skills. This can occur due to the pressure of activities in learning that are more oriented towards student participation, which can also encourage students to reflect critically. Thus, using the PjBL STEM (Science, Technology, Engineering, and Mathematics) model can help students improve their critical thinking skills (Setyawati et al., 2022).

The 21st century is known as the digital era, where all sectors, including education, must be digitized, and where technology plays a fundamental role in education. The 21st century learning paradigm leads to the development of student competencies, such as critical thinking, communication, collaboration, creative thinking, and innovation (Sumardi et al., 2020). A teaching strategy called inquiry-based learning helps foster student creativity. The learning model known as inquiry prioritizes problem solving and is student-centered. It is very important to provide students with challenges to encourage the growth of their creative thinking. The purpose of problem solving is to activate previous knowledge and then combine it with understanding the new knowledge students acquire (Mustowi'ah et al., 2020).

The Influence of STEM Integrated Learning Model on Science Learning Against 21st Century Skills Based on Types of 21st Century Skills

The results of the research on the influence of the STEM integrated learning model on science learning on 21st century skills based on the types of 21st century skills can be seen in table 6, where there are 10 articles on critical thinking skills, 8 articles on creativity skills, 2 articles on collaboration skills, and on skills communication there are 2 articles.

Table 6. Effect Size Analysis Based on Types of 21st Century Skills

21st Century Skills	Article Code	Effect Size	Average Effect Size	Category
	AR3	0.36		
	AR6	2.56		
	AR7	1.60		
	AR8	3.72		
Think critically	AR9	2,16	1.68	Strong Effect
	AR10	2.07		
	AR11	0.64		
	AR15	2.62		
	AR17	0.69		
	AR20	0.42		
	AR1	0.48		
	AR2	0.84		
	AR5	0.50		
Creativity	AR13	2.49	1.22	Strong Effect
	AR14	0.64		
	AR16	0.95		
	AR18	2.71		
	AR19	1.17		
Collaboration	AR21	0.74	0.98	Moderate Effect
	AR22	1.23		
Communication	AR4	2.76	2.20	Strong Effect
	AR12	1.65		

Based on the data in table 6 it is stated that the average effect size for critical thinking skills is 1.68 with the high category, the average effect size for creativity skills is 1.22 with the high category, the average effect size for collaboration skills is 0 .98 in the high category, and the mean effect size for communication skills is 2.20 in the high category. The average effect size of the four types of 21st century skills is in the high category. Therefore, based on 21st century skills it can be concluded that the STEM integrated learning model in science learning has a high influence on improving 21st century abilities. Relevant research by Mukaromah et al. (2020) states that combining the STEM approach with the PJBL model has a significant effect. good for students' creativity and communication skills. Another study by Mustofa et al. (2021) states that students can improve their critical thinking skills by applying the PBL model combined with the STEM approach in the learning process.

21st century skills encourage each person to have unique abilities which are often called 21st century skills. These include specific abilities that help people overcome today's difficulties. The Partnership for 21st Century Skills (P21), established in the US, examines the four skills that make up individual competencies known as "The 4Cs " namely collaboration, communication, critical thinking, and creativity. Fostering and training students' creativity has become a separate agenda in the school curriculum because it determines success (Haryanti, 2018).

Conclusion

Several conclusions can be drawn from the data that has been examined in this meta-analysis study. First, the average effect size of the three levels of education, namely Elementary School, Junior High School, and Senior Hight School, is in the high category. So that the STEM integrated learning model in science learning has a high influence in improving 21st century skills at all levels of education. Second, the average effect size of the three learning models, namely PJBL, PBL, and inquiry, is in the high category. So that the STEM integrated learning model in science learning has a high influence in improving 21st century skills based on the type of learning model. Third, the average effect size of 21st century skills is in the high category. So that the STEM integrated learning model in science learning has a high influence in improving 21st century skills based on 21st century skills.

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Conflicts of Interest
The authors declare no conflict of interest.

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