The Effectiveness of STEM-Based Learning in Teaching 21 st Century Skills in Generation Z Student in Science Learning: A Meta-Analysis

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Abstract: This study aims to determine the effectiveness of STEM-based learning to train Z generation students' 21st century skills in science learning. This research is a kind of meta-analysis research. The research sample came from an analysis of 16 reputable national and international journals. Data search was obtained through the Google Scholar database, Springer, Hindawi and Eric. Data screening was carried out strictly and thoroughly. The sampling technique is a purposive sampling technique. The data used as the research sample has a relationship with the independent variable and the dependent variable, namely the effectiveness of STEM-based learning on the 21st century skills of Generation Z students in learning science. Data analysis is a qualitative and quantitative data analysis technique by calculating the value of the effect size (ES), the average value and the N-Gain assisted by the JSAP application with the sig value criteria. 0.05. The results showed that the application of STEM-based learning was effective in training the 21st century skills of Genera Z students in science learning with an effect size (ES) value of 1.47 and an N-gain of 0.86 in the high category.

Keywords: 21st Century Skills; Generation Z; Science; STEM Learning

Introduction

The industrial revolution 5.0 has had such a big impact on the field of education (Oktarina et al., 2021). Education is the most important thing for a country to improve human resources. Competent human resources will easily boost the quality of a country's education (Finlay et al., 2022). The world of education is currently based on technology to assist the learning process (Yani et al., 2020). Learning that uses technology makes it easier for students and teachers to access subject matter (Everett et al., 2019; Dueñas, 2021). Students and teachers are the main factors in carrying out the learning process in schools (Fradila et al., 2021). Therefore, students must be guided to be able to master technology (Yoshida et al., 2022; Rapanta, 2021; Al-kahtani et al., 2022).

Students who are able to master technology will find it easier to understand learning, as well as encourage digital literacy (Purnama et al., 2022; Yusuf et al., 2020). Student digital literacy is the main thing in improving the quality of learning (Kumar et al., 2022; Hakim et al., 2022; Rachmani et al., 2022). In addition, a teacher must also understand technology to convey subject matter to students (Faux-nightingale et al., 2022);. Not only that, technology-assisted learning increases students' creativity and independence in learning (Wiyanto et al., 2022; İncİk & İncİk, 2022; Serin & Bozdağ, 202). Furthermore, teachers are more helpful if their students can access information more quickly about the subject matter being taught (Abdoh, 2022; Santosa et al., 2021).

Natural Science subjects are subjects that are still difficult for students to understand (Razak et al., 2021;

Suhaimi et al.,2022). Science learning is a very important subject for students to develop a scientific attitude (Wulandari & Raharjo, 2020). Furthermore, science learning becomes a compulsory subject in schools. Science learning is learning that consists of chemistry, physics and biology (Elsigini, 2021). Problems in science learning generally occur in teachers who still use traditional learning patterns (Asmara et al., 2016). Therefore, it makes students bored in learning, less motivated and creative. This problem occurs in generation Z. Generation Z is the main factor that accesses a lot of information in the world. The number of generations Z ± 34.05% of the world's population and 33% of Indonesia's population (Christiani & Ikasari, 2020).

The learning system for generation Z is generally based on technology (Demirbilek, 2022). A professional teacher must master digital literacy, so that he is able to adapt to the times. Learning for generation Z is directed at encouraging 4C skills (Creativity, Calaboration, Critical Thinking and Communication). 4C skills are indispensable for generation Z to solve various phenomena in life (Çoklar & Tatli, 2021; Yalçı et al., 2020; Moore et al., 2017; Halisdemir, 2019). The science learning system applied by teachers is not optimal to encourage students' 21st century skills (Suharyat et al., 2022). 21st century skills are very necessary for generation Z to develop a mindset in learning (Liu, 2022). So, we need an approach that is able to encourage 21st century skills for generation Z.

The STEM approach is a learning approach that combines science, technology, engineering and mathematics in the teaching and learning process. (Parker et al., 2020; Rais et al., 2021; Johnson et al., 2021). This STEM approach is able to improve 21st century skills in science learning. This STEM approach encourages students to think more scientifically (Benek & Akcay, 2022; Zorlu et al., 2021). The ability to think scientifically is needed in learning science (Santosa et al., 2021). This is because scientific thinking skills can encourage more problem solving (Morales-obod et al., 2020). In addition, the STEM approach can encourage students to think critically and creatively in learning.

In research by Castro & Jimenez, (2022) the STEM approach is able to improve students' 21st century skills in science learning. In addition, this STEM approach encourages students to increase motivation and student learning outcomes (Kuloğlu & Karabekmez, 2022). Research by Deniş Çeliker (2020) STEM approaches are highly effective for enhancing students' 21st century skills. According to Wang & Chiang (2020) explained that the STEM approach was effective in cultivating student attitudes in learning. Based on these problems, this study aims to identify the effectiveness of STEM-based learning to train 21st century students' skills in science learning.

Method

This research is a kind of meta-analysis research. Meta-analytical research is research that collects literature that can be processed statistically(Santosa et al., 2021). The research data in the study came from an analysis of 16 reputable national or international journals. Searching research data through the google scholar database, Sciencedirect, Wiley, Springer and Eric. The sampling technique is a purposive sampling technique. The data criteria used as samples must have a relationship with research variables, namely the effectiveness of STEM-based learning on the 21st century skills of Generation Z students in learning science (chemistry, biology and physics). Data analysis is a descriptive statistical technique by calculating effect size (ES), mean and N-gain with SPSS 16. Effect size calculation techniques are 1) collecting relevant literature, 2) coding samples, 3) calculating the effect size of the study outcome size and 4) calculating the moderating effect of the characteristics of the literature is clearer in table 1. Furthermore, the effect size criteria can be seen in Table 2.

Table 1. Effect Size Calculation Steps

Statistics	Formula
Average in one group	$ES = \dfrac{X_{Postest} - X_{Pretest}}{SD_{Pretest}}$
Average in each group	$ES = \dfrac{X_{Eksperimen} - X_{Kontrol}}{}$
Chi-Square	$ES = \dfrac{2r}{\sqrt{1-r^2}}; r = \sqrt{\dfrac{X^2}{n}}$
t-count	$ES = t \sqrt{\dfrac{1}{n_{eksperimen}} + \dfrac{1}{n_{Kontrol}}}$

Source: Miterianifa et al., (2019)

Table 2. Effect Size Criteria

Effect Size	Criteria
0 ≤ ES ≤ 0.2	Low
0.2 ≤ ES ≤ 0.8	Medium
ES ≥ 0.8	Hight

Source: Cohen in (Santosa et al., 2021)

Resultand Discussion

Result

A search of 16 reputable national and international journal articles related to the effectiveness of Science Technology Engineering and Mathematics (STEM) learning on the 21st century skills of Generation Z students in learning science Table 3.

Based on Table 3, Shows 16 national and international journals taken as research samples. The sample relates to the effect of STEM learning on the 21st century skills of Generation Z students in learning science (biology, chemistry and physics). The relationship between the independent variable is STEM learning with the dependent variable students' 21st century skills consisting of critical thinking skills and problem solving, creative, communication and collaboration. To find out more clearly the effect of the two variables can be seen from the effect size in Table 4.

Table 3. Tracing 16 Research Samples

Author	Variabel X	Variabel Y	Journal Type
Pertiwi et al. (2017)	The effectiveness of STEM worksheets	Creative Thinking	National
Benek & Akcay (2022)	STEM learning	21st Century Skills	International
Hacioğlu (2021)	STEM learning	21st Century Skills	International
Nurhayati et al. (2020)	Digital Literacy and STEM	21st Century Skills	International
Deniş Çeliker (2020)	STEM learning	21st Century Skills	International
Peters-burton & Stehle, (2019)	STEM learning	21st Century Skills	International
Han et al. (2021)	STEM learning	Learning outcomes 21st Century Skills	International
Seage et al. (2020)	STEM-integrated Blended Learning	21st Century Skills	International
Abdurrahman, (2019)	STEM learning	21st Century Skills	IOP International Proceedings
Yavuz, (2020)	STEM learning	21st Century Skills	Internasional
Latip et al. (2020)	STEM learning	Collaboration Skills	Prosiding IOP International Proceedings
Hacioğlu & Gülhan (2021)	STEM learning	Critical Thinking Skills	International
Alatas & Yakin (2021)	STEM learning	Problem Solving Skills	National
Triana et al. (2020)	STEM-PJBL Learning	21st Century Skills	National
Nugent et al. (2010)	STEM learning	Attitude Skills	International
Sari et al. (2017)	STEM learning	Problem solving skill	International

Table 4. Sample Effect Size

SD	Effect Size	Criteria
4.03	0.78	Medium
3.17	0.12	Low
2.19	0.80	Medium
9.70	2.44	Hight
1.50	3.90	Hight
7.01	1.8	Hight
6.66	0.6	Medium
10.70	0.90	Hight
11.20	1.7	Hight
9.76	3.49	Hight
4.29	1.92	Hight
5.31	0.88	Hight
7.02	0.64	Medium
8.10	0.82	Hight
18.98	2.77	Hight
Average *ES = 1.47*		Hight

Based on table 4. The average effect size of this research sample is 1.47 high criteria. This means that STEM learning has a positive influence on the 21st century skills of Generation Z students in learning science. To find out the distribution of research subjects in science learning in Table 5.

Table 5. N-Gain Effectiveness of STEM Learning > 21st Century Skills in Learning Science

Class	Critical Thinking	Creative	Calabora-tion	Comuni-cation	Mean N-Gain
Experiment	80	84	83	85	0.86
Control	77	75	70	70	

Based on Table 6, Explains that STEM learning is very effective for improving the 21st century skills of Generation Z students in learning biology. This can be seen from the N-Gain value of 0.86. Not only that, the average value of Critical thinking skills in the experimental class is 80 and the control class is 77 on average, the experimental class's Creative skills are 84 on average and the control class is 75, the experimental class's Calaboration skills are 83 on average and the average control class is 70 and the communication skills of the experimental class are on average 85 and the control class is an average of 70.

Discussion

STEM-based learning effectively trains the 21st century skills of generation Z students in science learning. This can be seen from the value of the effect size (ES) of 1.47 and the N-gain of 0.86. This research is

in line with Ješkov & Luk (2022) explained that Science Technology Engineering and Mathematics (STEM)-based learning gave positive results in developing students' thinking skills. STEM-based learning helps students and teachers in the learning process (Pathoni et al., 2022). In addition, STEM-based learning optimizes Generation Z's learning understanding in science learning (Sagala et al., 2019). Generation Z is the person who spends the most time with technology to learn.

Learning in the industrial era 4.0 students are directed to learn more with technology. Furthermore, a teacher is able to apply various models and learning methods based on the use of technology. The application of STEM technology in learning is able to improve the 21st Century skills of Generation Z students in learning science. In addition, teachers must be able to improve higher professionalism in the science learning process in generation Z (Zorlu & Zorlu, 2021). Science learning students must have critical thinking skills, scientific, creative, communication and collaboration (Kuloğlu & Karabekmez, 2022).Because learning science for generation Z students trains them in developing knowledge and thoughts to face the world of the future.

Learning is a teaching and learning process that is carried out between students and teachers to achieve certain learning objectives. Learning will run optimally if a teacher is able to apply a good learning model in class. Technology-based learning helps teachers and students to be more creative and effective in learning (Hasibuan et al., 2022). STEM-based learning really helps generation Z students to be more creative and innovative in the learning process in science learning. Science learning for generation Z is needed to solve various scientific phenomena in life (Zulirfan & Yennita, 2022; Demirbilek, 2022; Ding et al., 2017).

21st century skills are the main thing that must be improved in generation Z (Sanalan & Taşlıbeyaz, 2020). The quality of science learning for Generation Z students in Indonesia is relatively low. This can be seen from the PISA score, Indonesia is ranked 74th out of 78 member countries (Zulyusri et al., 2022; Santosa et al., 2021). Therefore, Indonesian education needs to be rehabilitated towards progress so that students are able to compete with the outside world. STEM-based learning is an alternative for Indonesian teachers to improve the quality of science learning for Generation Z in Indonesia. STEM-based learning is a solution to encourage the potential of enduring skills-21 generation Z students in science subjects.

Conclusion

From the research above, it can be concluded that the application of STEM-based learning effectively trains the 21st century skills of Genera Z students in science

learning with an effect size (ES) value of 1.47 and an N-gain of 0.86 in the high category. In addition, STEM-based learning is a solution for developing 21st century skills in generation Z in Indonesia.

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