

Integrated STEM Approach to Improve 21st Century Skills in Indonesia: A Systematic Review

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Abstract

21st-century skills are important for students to be equipped to face the challenges of the 21st century. So it needs an appropriate approach to be able to provide resources that are by the demands of the 21st century. This study aimed to determine the influence of STEM approaches in science learning to improve students' 21st-century skills and determine the indicators of STEM elements in science learning. The method used in this study is a literature study or a study of research results from several journals. The instrument used is a Paper Classification Form (PCF) table. The data were analyzed using percentages and descriptive calculations. The study results showed that n methods are often used in STEM approaches to improve century skills by using a STEM approach only, followed by a combination of various learning models such as inquiry, PBL, and PjBL. K21st century skills most often studied are students' critical thinking skills. Indicator of STEM approaches in science learning includes Science, which is related to natural symptoms and observation; technology is related to the use of tools; Engineering is related to designing to make solutions; and Mathematics is related to linkage analysis. The STEM approach is very influential in improving students' 21st-century skills: communication, creativity, critical thinking, and collaboration.

Keywords: Science Research, STEM, 21st Century Skills, Indonesia

INTRODUCTION

At least that consists of the aims and rationale of the study. Science is one of the sciences that studies all the natural symptoms on Earth, ranging from biotics and antibiotics. Science knowledge can be obtained through scientific activity to find the results. There are several essences of Science: Science as a process, a product, and Science as an attitude (P. Rahayu et al., 2012). Science learning emphasizes direct experience more so that learners can discover, discover, and scientifically understand the surrounding environment. So that in science learning, an approach is needed that can present learning through the experience of the scientific process and the understanding of science products presented in the form of direct experience (Ministry of Education, 2003). So Science learning in schools can be applied with the scientific method, where students will be accustomed to solving a problem and finding a solution.

Science learning can improve the abilities of learners, such as cognitive abilities, skills, and attitudes so that they can increase the resources they have (Zubaidah, 2011). With science learning, learners can discover new things (Das et al., 2014). However, unfortunately, there are several problems with science learning in Indonesia, namely the role of teachers in science learning is still lacking (P. Rahayu et al., 2012), the use of inappropriate learning models and

the existence of guidance teacher learning outcomes to students (Sulthon, 2017). Learning still applies to teacher centres and conventional methods, so students become passive (Dewi, 2018).

The current conditions have undergone changes seen in the development of Science and technology, which is so rapid that it is called the 21st century (Hasibuan & Prastowo, 2019). Learning skills in the 21st century are called 4C skills: creativity, critical thinking, communication, and collaboration (Muhali, 2019). High-quality human resources are needed to face the challenges in the 21st century (Hasibuan & Prastowo, 2019). A balance between cognitive knowledge and skills is necessary for students to face the times, especially in the 21st century (Mardhiyah et al., 2021).

The importance of 21st-century skills in learning aims to make learning more qualified (Junedi et al., 2020). By applying 21st-century learning, it will have an impact on Science and technology which will affect all aspects of life because 21st-century learning is an implication of the development of society from time to time (R. Rahayu et al., 2022). So school learning activities must fulfil 21st-century skills (Rawung et al., 2021). In fulfilling 21st-century skills in students, there is still a problem, namely educators who are still unable to adapt to the development of the 21st century; learning methods are still conventional such as lectures and teacher centres, so students become passive (Junedi et al., 2020).

The material contained in Science is still mostly abstract, so it is necessary to have a representation of the material so that students understand it easily (Zheng et al., 2022). Based on the results of data from The Program for International Student Assessment (PISA), which consists of developed industrial countries, the science literacy ability of students in Indonesia still needs to improve (Schleicher, 2019). So, there is a need for the right approach to learning, namely with a STEM approach that can integrate the material in the form of STEM learning objectives will be achieved. STEM goals are designed to improve people's ability to science and innovate technological products to compete globally (Utami et al., 2017).

STEM learning is an approach by combining Science, technology, engineering, and mathematics to help students acquire their knowledge independently and skillfully overcome real-life problems (Lestari et al., 2018). The STEM component consists of 3 aspects: competence or knowledge, skills related to their abilities in practice, and recognition (Carlone & Johnson, 2007). The STEM approach to learning aims to improve the ability of students to be creative and innovative, and able to solve problems creatively because STEM combines learning from various aspects of the surrounding environment (Simeon et al., 2022). The STEM approach can train the digital literacy of learners and teachers (Ziatdinov & Valles, 2022).

The application of STEM in learning in Indonesia is relatively high, as seen in several STEM studies over the decade (Ardwiyanti et al., 2021). Some of the studies that have been carried out to improve the abilities of students in facing the 21st century with STEM learning are the application of a STEM approach with formative assessment in PjBL to improve students' critical thinking skills (Parno et al., 2022), application of project-based STEM methods to increase student creativity (Alifa et al., 2018). learning with STEM approaches to improve students' science literacy (Khaeroningtyas et al., 2016), virtual STEM media labs for improving science literacy (Ismail et al., 2016), STEM approaches to build 21st-century literacy skills (Yulianti et al., 2022), development of stem animation media with feedback to facilitate critical thinking skills (Lafifa et al., 2022).

Based on the description presented about literature studies that combine STEM research in Indonesia and internationally, it also systematically analyzes research in Indonesia. Thus, this study aims to examine more deeply related to the results of STEM research analysis in Indonesia in improving 21st-century skills with problem formulation (1) what methods are most often used in improving STEM-based 21st-century skills?; (2) what 21st-century skills are enhanced in STEM research?; (3) what are the indicators of the components of the STEM approach that are appropriate to science learning?; (4) how does the STEM approach affect science learning to deal with the challenges of the 21st century?

METHOD

The subject of this study is a research article on the use of STEM in science learning in Indonesia to improve 21st-century skills. The method used is a literature study or reviewing research results. The instrument used is a Paper Classification Form (PCF) table. The data were analyzed using percentages and descriptive calculations.

This type of research is qualitative research using a content analysis approach based on the study of research results to analyze STEM approach research in improving 21st-century skills in Indonesia. It then combines findings from various studies to answer research questions (Newman & Gough, 2019). This study aims to determine the influence of STEM approaches in science learning to improve 21st-century skills in Indonesia and indicators of STEM approaches in science learning. The object of this study is STEM research articles in Indonesia, both nationally and internationally with a publication period of 2012-2022.

The instrument used is the pcf adaptation coding developed by (Kizilaslan et al., 2012), which has been tested for validity and reliability requirements. Then the data is analyzed using percentage calculations. Twenty articles meet the PCF coding requirements, which can be viewed in Table 1.

Table 1. Classification of articles by journal identity

Journal Type	Status	Journal Name	Sum
National	Accredited by Sinta 1 and Scopus Q2	Indonesian Science Education Journal	3
		Journal of Science Education Innovation	1
		Journal of Chemistry and Chemistry Education	1
		Indonesian Journal of Education	2
	Accredited by Sinta 2	Indonesian Journal of Science Education	6
		Journal of Science Research and Learning	1
		Journal of Science Learning	2
		Journal of Science Education Research	1
	Accredited by Sinta 3	Journal of Physics Learning Research	1
		Journal of Physics: Conference Series (JPCS)	1
International Journal of Research in STEM Education (IJRSE)		1	
International	DOAJ Indexed	European Journal of STEM Education	1

The method used is a review process with steps to formulate research questions, establish inclusion criteria that can be seen in Table 2, search for articles on various databases such as Scopus, Google Scholar, DOAJ, Scimago, journal websites by typing in the keywords "STEM", "21st-century skills", and "Indonesia", coding articles using the Paper Classification Form (PCF), identifying the pattern of the entire article, and analyzing articles to answer research questions (Sharif, 2019).

Table 2. Inclusion criteria of the Articles

Criterion	Inclusion Indicators
Type of Publication	Scientific articles published in journals
Journal specifications	National peer-reviewed journal accredited minimum grade 3 (Sinta 3), international peer-reviewed journal indexed minimum DOAJ
Publication year	2002-2022
Research setting	Indonesian
Researcher's nationality	Indonesia, the combination of Indonesian and foreigners
Independent variable	STEM and all kinds of integration patterns
Field	Science, physics, chemistry, biology
Type of Study	Empirical and theoretical

Criterion	Inclusion Indicators
Research subject	Students and teachers at all levels (elementary, junior high school, senior high school, college)

Data analysis in this study was carried out through several stages. The first stage is to group articles by grade. Then the results of the grouping of articles are classified again based on every aspect of the methods and skills of the 21st century. Then, each article is reviewed for the results of their research. Then, the number of articles of each aspect is calculated and added up. The researcher then converts the result of the summation of the score into a percentage. The final stage is the drawing of conclusions. The percentage level of each aspect of the study is described to determine the influence of STEM research in Indonesia in improving 21st-century skills. Then compare the percentages on each observed aspect based on the existing categories. The greater the percentage rate, the more the use of STEM approaches in improving 21st-century skills in Indonesia. Then conclude, the results of the analysis of each article related to STEM indicators in science learning. At least that consists of the discussion; it is suggested to strengthen it using the relevant previous studies.

RESULT AND DISCUSSION

STEM Approach Methods in Science Learning

STEM research in Indonesia conducted to improve 21st-century skills in students is carried out by various methods. Table 3 shows that learning carried out with a STEM approach is higher by 35% compared to STEM approaches integrated with learning models or teaching materials and media. In an integrated STEM approach, Problem-Based Learning is 15%, Inquiry 5%, Project Based Learning 10%, and Discovery Learning 5%. For the use of student worksheets, it is 10% STEM adjacent, while with learning media, it is 15%.

Based on the literature states that the absorption of STEM in learning in Indonesia is relatively high, which can be seen from several STEM studies over the decades (Ardwiyanti et al., 2021). With the application of several STEM approaches, it can make learning more quality and directed. This is because the STEM approach is an approach that combining Science, technology, engineering, and mathematics in their learning so that it can help students gain their knowledge independently and skillfully overcome problems in real life (Basu et al., 2021; He et al., 2021; Lestari et al., 2018). Applying the STEM methodology from the basic level to practical use can motivate students to learn and improve their skills and see Science as a way of life (Imbach-Diaz et al., 2023; Stonier & Adarkwah, 2023). For example, STEM-based enrichment books can support STEM education in Indonesia to develop further STEM in Indonesia (Azalia & Wisnuadi, 2020; Triayuni et al., 2023). With STEM learning, the class will become more active (Burke et al., 2020).

Table 3. Results of Classifying Articles by Method

Method	Sum	Percentage
STEM-Problem Based Learning (PBL)	3	15%
STEM-Inquiry Pendekatan STEM	1	5%
STEM-Project Based Learning (PjBL)	7	35%
STEM-Discovery Learning	2	10%
STEM-Blended Learning	1	5%
STEM-Student Worksheets	1	5%
STEM-Learning Media	2	10%
Total	3	15%
	20	100%

STEM is implemented as a learning strategy and approach, integrated with other learning models, used as a learning assessment, and developed into teaching materials, modules, and learning media to improve 21st-century skills (Farwati et al., 2021; Widiawati et al., 2022). The problem-based Learning learning model is a problem-based learning activity. So that students will be trained in finding solutions to solve the problems faced. Meanwhile, STEM-PBL is a problem-based learning model integrated with STEM elements. The purpose of this learning model is so that learning can be meaningful and systematic, starting from concepts, knowledge, and skills so that learning will become more active so that learning able to create knowledge and can improve the analytical skills of students (Hasanah et al., 2021; Matawali et al., 2019)

The STEM approach is learning by combining four elements: Science, Technology, Engineering, and Mathematics. The STEM approach to learning aims to improve the ability of students to be creative and innovative, and able to solve problems creatively because STEM combines learning from various aspects of the surrounding environment (Simeon et al., 2022).

The learner models and using inquiry means training learners to find concepts independently. This is so that learning becomes more active and creative. By adding a STEM approach to the inquiry, after finding the concept independently, students can apply the concept in their daily lives, such as solving problems (Fadlina et al., 2021).

The PjBL learning model is project-based, while the STEM-PjBL is a learning model whose learning is project-based by integrating STEM approaches. The PjBL model has several benefits. Namely, it can improve problem-solving skills, collaboration, learning motivation, creative thinking, and critical thinking. The appropriate approach to support achieving the PjBL model objectives is to combine it with a STEM approach. This is because the STEM approach also aims to create creativity skills, namely in the Engineering process where students will try to design and make innovations in designing things. This is in line with research that STEM-PjBL can improve the creative thinking ability of students (Allanta & Puspita, 2021; Kristiani

et al., 2017). In addition, STEM approaches can improve critical thinking skills (Mutakinati et al., 2018)(Mutakinati et al., 2018). Critical thinking skills can be seen through science activities, where students will make observations, problem-solving, and produce conclusions. The STEM-integrated PjBL model can foster and develop students' creative thinking abilities (Hendriyani et al., 2023).

Blended learning is a synchronous and asynchronous learning debate. By using blended learning, students will be motivated to learn and make students able to create independently. Blended learning combined with STEM learning will improve higher-order thinking skills, such as the Discovery of technological innovations to solve a problem (Haryadi et al., 2021).

Student worksheets contains a summary of the material and practice questions for students. The student worksheets presented must be by the material and learning objectives to be achieved. Student worksheets presented by integrating STEM approaches can improve students' creative thinking skills. Because STEM, in its presentation, secures the structure and intimates the direct life of the learner. Thus, upbringing participants will feel motivated and interested in learning which makes students creative in developing and finding solutions to the problems presented (Krisdiana et al., 2020). Flipped learning can facilitate teachers' learning and contribute (Mai et al., 2022). STEM is the learning that faces the most challenges during virtual learning due to the nature of these courses and the use of mathematics and associated practice. STEM-based electronic modules can also help students learn independently (Al-Ansi & Al-Ansi, 2023; Ruliyanti et al., 2020; Zakiyah & Sudarmin, 2022). Lesson Plans that implement STEM can determine the increasing impact on student learning outcomes (Ceylan & Ozdilek, 2015; Haerani & Erna, 2022).

The virtual lab is interactive multimedia-based software that contains simulations of practicum activities so that students can explore and visualize abstract concepts into concrete. Combining the STEM approach can improve higher-order thinking skills because it will train students in the Science process and solve problems in the presented practicums (Sari et al., 2022). Media combined with STEM, such as STEM-based loose part play, can increase STEM understanding to find solutions to problems faced by teachers example, mobile learning and web (Abadi et al., 2023; Jeong & González-Gómez, 2020; Mutambara & Bayaga, 2021).

The 21st Century Skills with STEM Approaches in Science Learning

STEM learning has always been associated with several skills, including 21st-century skills. Table 4 shows the 21st-century skills of learners who are enhanced through learning with a STEM approach. The most frequently improved skill is the ability to think critically, with a percentage of 60%. Several 21st-century capabilities are enhanced through learning with STEM

approaches, such as a 15% increase in problem-solving, 5% in collaboration, 15% in creativity, and 5% in communication.

The data shows that the STEM approach emphasizes more on higher-order thinking abilities than learner-learning outcomes (Agussuryani et al., 2022; Richardo et al., 2023). This is in line with research that STEM approaches can facilitate students to think critically in solving problems in daily life, such as the presence of air and water pollution events, global warming, and the availability of clean water(Reeve, 2015).

Table 4. Results of Classifying Articles with 21st-Century Skills

21 st -century skills	Sum	Percentage
Critical Thinking	12	60%
Troubleshooting	3	15%
Collaboration	1	5%
Creativeness	3	15%
Communication	1	5%
Total	20	100%

The 21st century is a very advanced and digital-based era. The skills of the 21st century that need to be possessed are the ability to think critically, think creatively and innovatively, solve problems, and cooperate or collaborate.

Critical thinking skills are the ability to analyze, evaluate, and logically and rationally. At the same time, reactivity is a skill in finding something original, developing various new solutions to each problem and generating various ideas (Leen et al., 2014). Communication skills are skills in conveying ideas to others orally or in writing. Collaboration skills work together to achieve common goals effectively (Greenstein, 2012). STEM learning can increase students' creativity in class so that their skills will increase (Anh et al., 2022).

Indicators of a STEM Approach in Science Learning

Based on the analysis of literature reviews on short a tan STEM in Indonesia, several indicators can include STEM. STEM itself is an approach that combines elements of Science, Technology, Engineering, and Mathematics. Indicators of STEM elements can be seen in Table 5.

Table 5. STEM Approach Component Indicators

STEM elements	Information
Science	(1) Research related to events around the environment involving observation and measurement. (2) The use of knowledge and skills of the process of science in researching natural symptoms
Technology	4. There are innovations to make and modify tools to overcome problems and make it easier for humans. 5. Systems governing society, organization and knowledge

STEM elements	Information
Engineering	6. Skills in designing and operating developed technologies
Mathematics	7. Formulate, interpret, and analyze data and calculation results.
	8. Thinking logically in relating things

Science in STEM uses knowledge and skills in the science process to understand natural phenomena in everyday life (Siswanto, 2018). *Technology* in STEM consists of all organized human systems, knowledge, processes, and devices that can be used (Bahrum et al., 2017). Components *Engineering* on STEM elements that are more towards operating, designing, or assembling based on previously developed Science and technology. The *Mathematics* element is more about analyzing by showing evidence and solving problems to interpret a solution from the data obtained and calculation results (Siswanto, 2018).

The Influence of STEM Approaches in Science Learning to Face the Challenges of the 21st Century

Based on studies from several articles, the STEM approach is the right approach to be used in science learning to improve the skills of 21st-century students in facing the challenges of the 21st century in the future. The STEM approach is an approach that, in its learning, integrates four aspects, namely Science, Technology, Engineering, and Mathematics. With the use of STEM in Science, learning will make learning conditions active because learning using a STEM approach is always associated with real problems in everyday life, so students will directly practice and apply the knowledge they have in their activities. That way, students' skills will continue to improve, including the 21st century 4C skills, namely Creative, Critical, Collaboration, and Communication.

STEM-based learning design in the science curriculum is very important to understand learning easily (Aberilla et al., 2021; Perdana et al., 2021). Learning using STEM greatly impacts students; students' abilities will continue to increase with learning that links Science to STEM elements (Kara et al., 2021). STEM learning can also improve student outcomes (Rohali et al., 2023). However, the success of STEM learning is also influenced by several factors, such as gender, socioeconomic, and the digital divide (Kufi, 2023; Saw et al., 2019; Sharma, 2023; Tam et al., 2020).

These 21st-century skills include critical thinking and problem-solving, creativity and innovation, communication, and collaboration. 21st-century skills are indispensable because in the 21st century, technology will develop very rapidly, and there will be changes globally. A STEM approach affects learning activities and outcomes, such as the success of students'

cognitive, motivation, and interest in learning, problem-solving skills, critical thinking skills, and scientific process skills. Several articles that have been studied show that STEM approaches have proven to be effectively used in learning and assist learners in improving 21st-century skills.

CONCLUSION

Based on the study of the results of the research, it can be concluded that the method most often used in the STEM approach to improving the skills of 21st-century students in science learning is only using a STEM approach, then followed by the combination of various kinds of learning models such as inquiry, PBL, PjBL. K21st century skills most often studied are students' critical thinking skills. Indicator of STEM approaches in science learning includes Science, which is related to natural symptoms and observation; technology is related to the use of tools; Engineering is related to designing to make solutions; and Mathematics is related to linkage analysis. The STEM approach is very influential in improving students' 21st-century skills: communication, creativity, critical thinking, and collaboration.

SUGGESTIONS

Recommendations for subsequent researchers to be able to develop this research for the better and review more journals.

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