Analysis of the Potential Use of STEM Approach in Biology Lessons Refers to Development of Science in Indonesia

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ABSTRACT

This study aims to determine the development and effectiveness of STEM in biology learning, referring to the development of STEM in science in Indonesia. This research is a literature study that examines some research articles that are compatible with the research theme. The research sample was taken purposively based on items related to the research theme, the research journal articles used came from searches on google scholar data, totaling 45 articles with a range of the last five years (2016-2020). The results of this study indicate that the most widely conducted research is to test the impact, influence, or effectiveness of 55.56%, the most commonly used research design is the quasi-experimental 44.90%, the data collection technique uses the 51.47% test, the most data analysis using N-gain 33.33%, the learning model that is most integrated with STEM is PjBL 31.11%, the effectiveness of STEM application in biology learning is dominated by the effectiveness of increasing learning outcomes 20%, 18% creative thinking, 14% understanding of concepts. Based on the analysis of the results, it can be projected that STEM will also be able to improve critical thinking skills, communication skills, mathematical skills, environmental literacy, scientific literacy, creativity, science process skills, argument skills, conservation character, misconceptions, scientific attitudes, and collaboration.

Keywords: STEM, Effectiveness of the STEM

1. INTRODUCTION

Entering the industrial revolution 4.0, the world has experienced relatively rapid development where information technology has become the basis of human life. This development also demands integrated and technology-based learning. The STEM (Science, Technology, Engineering, mathematics) approach is one of the updated topics following the 4.0 revolution era to compete globally and solve life issues through STEM literacy [1]. STEM literacy, as expressed by Bybee, shows concepts, principles, and techniques from science, technology, engineering, and mathematics that are used in an integrated manner in the development of products, processes, and systems in life[2]. The STEM approach can create a cohesive and active learning system because all four aspects are needed simultaneously to solve problems [3].

Learning objectives with the STEM approach are suitable for secondary school learning, where learning subjects require intricate knowledge [3]. Following curriculum 2013, the use of technology in biological, chemical, physical, and mathematical learning activities is also necessary to support active and innovative learning situations [4]. In recent years many have used STEM in learning at every level of education. This situation is shown from the research results that reveal that STEM application can improve students' academic and non-academic achievement.[5].

The application of STEM, which was initially only intended to increase students' interest in the STEM field, became wider. This situation arises because, after

applying in reapplying able to improve knocantery, apply knowledge to solve problems and encourage students to create something new. Various learning methods can support STEM application. Besides that, STEM, integrative STEM different learning methods can support its application[6], [7]. Apedoe, X. S., et al., 2008 said that the et al. rated STEM learning approach could equip students' 21st-century work skills through learning outcomes. [8]. Learning outcomes indicate the ability of student work skills, the extent to which the influence of STEM learning on learning outcomes in the form of creativity, problem-solving skills, and students' self-motivation to think critically.

Many researchers and academics in Indonesia have researched STEM. Various articles and research journals seek to find in-depth information about applying or using the STEM approach in Indonesia, especially in learning biology, chemistry, physics, and mathematics, provide information related to STEM. Based on this, researchers are interested in revealing the STEM approach's effectiveness if applied to biology learning based on the development of science in Indonesia by analyzing various STEM-related research articles and journals obtained from the google scholar database.

2. RESEARCH METHOD

This article is a literature study that discusses STEM (Science Technology Engineering and Mathematics) in learning biology, chemistry, physics, and mathematics in Indonesia to provide information about STEM-based and integrated learning in Indonesia. The literature study method examines previous studies similar to this research and is a literature study from reliable sources. The steps in this research can be explained as follows:

2.1. Preparation Phase

The preparation stage is collecting data in journal articles, National and International Seminars sourced from searches on google scholar indexed by SCOPUS, DOAJ, ISSN Journal, or other journal indexers regarding STEM in Biology, Chemistry, Physics, and Mathematics learning in the last five years. (2016-2020), The sample selection in this study used a purposive technique because the sample was adjusted to the research theme. Keywords used are STEM-based learning, STEM integration, Biology Learning, Chemistry, Physics.

2.2. Implementation Stage

At the implementation stage, the articles that have been collected are selected based on predetermined criteria, namely research objectives, research design, data collection techniques, data analysis techniques,

STEM implementation techniques, and STEM application in learning. The articles are grouped to facilitate data analysis. This study's data analysis is descriptive qualitative, with a total number of 45 items analyzed.

3. RESULT AND DISCUSSION

A literature study of 45 articles that discusses STEM in biology learning refers to the development of science in Indonesia. It is based on research objectives, research design, data collection techniques, data analysis, STEM implementation, and STEM's effectiveness in the learning process. The results of grouping based on these criteria can be presented as follows.

3.1. The Potential Use of STEM-based on Research Objectives

Based on the research objectives, the results obtained were as much as 55.56% of the research objectives used were to examine the impact, influence, or effectiveness of the STEM approach to the dependent variable. Research with this objective compares the results after treatment and before treatment, whether there is an increase or not. The research objective is to test the impact, influence, or effectiveness of being said to be useful if the experimental class shows better results than the control class, and it is said that there is an effect if there is a very significant difference between the practical course and the control class.

The purpose of STEM to describe is 20%, identical to literature studies that want to dig more in-depth about applying the STEM approach in education and find out which learning models and topics can be integrated with the STEM approach. STEM aims to develop 13.3%. The development carried out, in this case, is the product in the field of learning strategies, learning tools, and development of STEM-based learning media to be applied in learning biology, chemistry, physics, and mathematics. Research that aims to develop the average uses the R n D (Research and Development) design.

The research objective with the STEM approach in Indonesia, which is applied to learning, especially science learning, is dominated by research to examine the impact or effectiveness of the STEM approach on student learning outcomes or variables related to cognitive, affective, and psychomotor abilities. In addition to reviewing the result of research with the STEM approach in Indonesia, many also use development methods to develop teaching tools in ways, media, and other teaching materials that allow integration with a STEM-based system.

Table 1. Potential analysis based on research objectives

No	Research purposes	Frequency	Percentage (%)
1	Testing Impact / Effect / Effectiveness	25	55.56%
2	Develop	6	13.33%
3	Develop and test the impact	2	4.44%
4	Increase	3	6.67%
5	Describe	9	20%
	amount	45	100%

This objective-based analysis can reflect the development of research using the STEM approach that most researchers are interested in.

3.2. The Potential Use of STEM-Based Research Design

The research design most used in STEM research is Quasi-experimental with 44.90%. Quasi-experiments are experiments with a treatment, impact measurement, experimental unit but do not use random assignments to create comparisons to infer changes due to treatment[9]. This quasi-experimental study used a practical class and a randomly selected control class [10], [11]. The least research design used in STEM research was the mixed method [14] and the 2.04% survey. Meanwhile, the development design (R & D) was 18.37%.

Table 2. Potential analysis based on research design

No	Research design	Frequency	Percentage (%)
1	Experiment		
	a. Experimental	2	4.08%
	b. Pre-experimental	4	8.16%
	c. Quasi-experiment	22	44.90%
2	R & D	9	18.37%
3	Survey	1	2.04%
4	Mixed-Method	1	2.04%
5	Case study	2	4.08%
6	Classroom Action Riset	2	4.08%
7	Analysis	6	12.24%
	amount	49	100%

The tabulation of data based on the analysis presented in Table 2 shows that the research design is highly dependent and adjusted to the research objectives. Experimental research designs are the most suitable designs to determine the impact, influence, or effectiveness of a model, method, or approach to the variables the researcher wants to measure. The most widely used experimental design is the quasi-experimental design because it compares the control class and the practical class. With such a method, it will be easy to determine the effect or effect.

3.3. The Potential Use of STEM-Based Data Collection and Analysis Techniques

The results of the analysis showed that the most widely used test instrument was 51.47%. The test instrument in research related to the use of STEM in research used to measure critical thinking skills, creative thinking skills, conceptual understanding, mathematical abilities, scientific literacy, misconceptions, and student learning outcomes. The second most widely used data collection technique is a questionnaire used to look at communication skills, creativity, argumentative skills, conservation character, scientific attitudes, and collaboration. Overall, data collection techniques are tests, questionnaires, observation, documentation, field notes, literature study, and interviews.

The data analysis used the most N-gain, namely 33.33%, and the least used was the Anava test, Wilcoxon test, and the effect size of 2.08%. The data analysis used depends on the research objectives, the formulation of the problem, and the research hypothesis. In this study, the data analysis used was N-gain, t-test, qualitative descriptive, quantitative descriptive, MANOVA, z test, effect size, ANOVA, and Wilcoxon.

The N-gain test is the most widely used in this study. N gain is a test that aims to determine the effectiveness of a method or treatment in research using experimental designs in the form of real experiments, pre-experiments, or quasi-experiments. The N-gain test is performed by calculating the difference between pretest and post-test values before and after applying the method or treatment.

Tabel 3. Potential analysis based on data collection techniques

No	Data collection technique	Frequency	Percentage (%)
1	Questionnaire	20	29.41%
2	Observation	5	7.35%
3	Test	35	51.47%
4	Literature review	4	5.88%
5	Interview	2	2.94%
6	Documentation	1	1.47%
7	Fieldnotes	1	1.47%
	Amount	68	100%

Tabel 4. Potential analysis based on data analysis

No	Data Analysis	Frequency	Percentage (%)
1	Anava	1	2.08%
2	Uji-t	11	22.92%
3	Qualitative Descriptive	11	22.92%
4	Quantitative Descriptive	2	4.17%
5	N-Gain	16	33.33%
6	Manova	1	2.08%
7	Uji-z	2	4.17%
8	Validity	2	4.17%
9	Effect size	1	2.08%
10	Wilcoxon	1	2.08%
	Amount	48	100%

By looking at the difference in cost, it can be seen whether the technique or therapy is effective or not.

3.4. Potential Use of STEM Based on STEM Implementation

The implementation of STEM teaching in biology learning refers to the natural science approach in Indonesia can be seen in table 5. The results of 45 journal articles that have analyzed the implementation of STEM in learning show that 44.44% use the STEM approach alone in the application and the development of STEM in education. The integration of STEM that is integrative with the learning model is also carried out to increase STEM effectiveness in learning [15] because STEM as an approach does not have a syntax while the learning model has it.

Tabel 5. Usage analysis based on stem implementation

No	Implementation of STEM	Frequency	Percentage (%)
1	STEM only	20	44.44%
2	STEM with problem-based learning	9	20.00%
3	STEM with project-based learning	14	31.11%
4	STEM With Inquiry	2	4.44%
	Amount	45	100%

The integrated learning model is STEM with PjBl 31.11%, STEM with PBL 20.00%, and STEM with inquiry 4.44%. To achieve the learning objectives, the researcher combines STEM with other models such as PBL, PjBL, Inquiry to make it more suitable for the topic being studied so that the results are more effective.

3.5. Potential Use of STEM Based on The Effectiveness of The Application of STEM in Learning

The effectiveness of STEM in learning based on journals that have been analyzed is either STEM as a stand-alone approach or STEM combined with a learning model. The point of STEM in learning from this study can be seen in table 6.

Table 6. The effectiveness of the application of stem in learning

No	Implementation of STEM	Frequency	Percentage (%)
1	Critical Thinking Skills	5	10.00%
2	Creative Thinking Skills	9	18.00%
3	Communication skills	2	4.00%
4	Mathematical Ability	2	4.00%
5	Environmental Literacy	1	2.00%
6	Concept of Understanding	8	16.00%
7	Science Literacy	3	6.00%
8	Learning outcomes	10	20.00%
9	Creativity	1	2.00%
10	Science Process Insights	2	4.00%
11	Argument Skills	2	4.00%
12	Concert Characters	1	2.00%
13	Misconception	1	2.00%
14	The attitude of science	1	2.00%
15	Collaboration	2	4.00%
	Amount	50	100%

5.1.1. STEM Enhances Critical Thinking

STEM improves critical thinking; the STEM-based approach can improve students' critical thinking and increase students' critical thinking from students' post-test results after using STEM in learning. Some studies combine STEM with models or methods to improve critical thinking, as did I.mu'minah (2019) that ICT-assisted STEM can enhance critical thinking[12]. PjBl combined with STEM can enhance critical thinking due to scientific investigation steps to make students more active and creative [13].

5.1.2. STEM Enhances Creative Thinking

STEM can improve creative thinking. Creative thinking is one of the manifestations of higher-order thought because creative thinking can think creatively and with the highest cognitive competence. To find out, a person's creative thinking ability is shown through the product of his thought or creativity to produce something new[10]. STEM-PjBL can improve creative thinking because, in the STEM-PjBL learning process, there are stages of implementing testing. When conducting trials, students will determine whether the tool is made to function correctly or not; when something does not work, then the device is reviewed to be fixed. It will stimulate and improve the creative thinking of students [12]. Ariani (2019) states that STEM-PBL effectively improves creative thinking skills in good categories [14].

5.1.3. STEM Improves Learning Outcomes

STEM is effective in improving student learning outcomes, both cognitive, affective, and psychomotor. The effectiveness of increasing learning outcomes in biology, chemistry, physics, and mathematics is obtained based on hands-on activity in the STEM approach, which positively impacts students' understanding of the material. Several studies have been conducted by w. Nessa (2017)[15], Susanti (2018)[16], tiara Adelita (2017)[17], which integrates STEM with problem-based learning models, show that STEM-PBL can improve student learning outcomes. Learning using the STEM approach can increase the creativity and innovation of students[18].

5.1.4. STEM Improves Environmental Literacy

Environmental literacy provides students with an understanding of the main concepts of natural phenomena and the application of knowledge. The existence of a sense of ecological literacy makes it easier to solve environmental problems with unlimited sources through technology [19]. STEM provides meaningful learning in ecological literacy. STEM learning also offers a broad knowledge of

environmental issues. Environmental problem solving through STEM is determining environmental problems, initiating solution ideas, designing problem solutions, and creating products to overcome ecological problems [20]. The understanding of ecological literacy has better collaborated with STEM [21].

5.1.5. STEM Improves Scientific Literacy

Scientific literacy has an essential role in the 21st century. Scientific literacy is an important thing to master because of its complete application and almost all fields. [22]. STEM with scientific literacy provides maximum results on student learning outcomes [23]. Students become more aware of the environment, more critical in investigating and solving good results [24]. Learning using a virtual lab can also be a solution in the learning process to increase students' scientific literacy. Virtual labs with STEM are also useful in improving students' scientific literacy. The learning implementation becomes more attractive and valuable for students [25].

5.1.6. STEM Improves Communication Skills

The ability to communicate is a skill that must be possessed by students in the 21st century. Students have communication skills that support their success in problem-solving [26]. Problem-solving is done by conveying what he knows well and structured manner, either orally, in writing, with the media, or without the press. The ability to communicate with STEM provides a more diverse range of learning [27]. Students can take advantage of technology to develop vocabulary in their knowledge. The standard of learners in communication becomes higher. Communication will run better because students understand broadly through STEM knowledge [28].

5.1.7. STEM Improves Mathematical Abilities

The development of education has led to various breakthroughs and innovations, especially for mathematical abilities through STEM. Mathematical skills with STEM provide solutions to problems in life to Mathematical notation language. These problems will be solved using relevant mathematical concepts [29]. Learning with STEM allows students to construct their knowledge, collect facts, develop data, and present findings. The flow of thinking of students in mathematical abilities is better and orderly [30].

5.1.8. STEM improves Concept Mastery

Each student has their way of capturing and understanding learning material. The understanding of each student becomes heterogeneous. Mastery of concepts is needed in increasing students' knowledge of a material [31]. Mastery of concepts will increase when students learn on a STEM basis[32]. STEM-based learning provides students with solutions to difficulties in the understanding of division and problem-solving. The use of STEM-based teaching materials also significantly affects students' mastery of concepts [33]. Students will have extensive knowledge through access to technology in the form of the internet, then analyze with science and mathematics and project assignments by making simple props [34] available in teaching materials. Besides, STEM, which is applied in learning, can improve science process skills [13], argument skills [35], concert character, misconceptions[36], an attitude of science [37], and collaboration [12].

The STEM approach to education, especially in biology learning, has proven to improve students' skills in the cognitive, affective, and psychomotor domains. The STEM approach that is oriented towards technology, science, and engineering is constructive for the gifts of students and can increase the profile of 21st-century skills and is following the goals of the 2013 curriculum which emphasizes perfecting the mindset which discusses strengthening interactive learning, strengthening active learning seeking, strengthening multimedia learning that, of course, related to technology and critical learning emphasis. The most visible effect in this journal's analysis is that STEM can increase cognitive learning outcomes; besides that, the STEM approach is combined with a learning model, especially emphasizing project-based learning, problem-based learning, and inquiry resulting in active and interactive learning. Dynamic and interactive learning is obtained from students' activities, directly observing objects in their environment and combined with technology to produce products.

4. CONCLUSION

A discussion of this research can be concluded that the development of science and technology in Indonesia also has implications for the potential use of the STEM approach in Indonesia. The results of literature studies from articles and research journals related to the STEM approach to learning biology have increased significantly from year to year. Therefore,

the results of this study illustrate that STEM research is carried out by many researchers to determine the impact, influence, or effectiveness of learning by 55.56%, research designs that are widely used are 44.90% quasi-experimental, data collection techniques using 51.47% tests, implementation of the STEM-based approach. 44.44%, STEM combined with PjBL and PBL 51.11%, the effectiveness of STEM in learning biology to improve learning outcomes 20%, 18% creative thinking, 16% understanding of concepts, 10% critical thinking, STEM also enhances communication skills, mathematical skills, environmental literacy, scientific literacy, creativity, science process skills, argument skills, conservation character, misconceptions, scientific attitudes, and collaboration.

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