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Meta-Analysis: The Effect of Implementing the STEM (Science, Technology, Engineering, Mathematics) Approach on Biology Learning

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Abstract: Biology learning is a field of science that requires students to think critically, creatively, and analytically in order to solve problems in each material they study. It is important for students to have the right strategies for learning, and teachers as professionals who teach students must be able to develop effective and efficient learning for students. According to various research, the implementation of STEM (Science, Technology, Engineering, and Mathematics) based learning has a significant impact on students' learning skills. STEM is a suitable alternative for 21st century learning. Through the interconnections of science, technology, engineering, and mathematics, students can solve real-life problems in a systematic manner. The purpose of this article is to analyze the effect of implementing the STEM approach on biology learning. The method used in this article is a literature review method through a review of literature from various sources relevant to the discussion. The results obtained from this article are the influence of the implementation of the STEM approach on biology learning, namely, in improving students' learning outcomes, students' science literacy skills, students' critical thinking skills, students' creativity, and students' scientific thinking skills. Therefore, the application of STEM-based learning can be used as an alternative solution to empower 21st century skills of students, especially in biology learning.

Keywords: Biology Learning, STEM Approach, 21st Century Skills

INTRODUCTION

21st century biology learning is oriented towards students' critical thinking, creativity, and innovation skills. In addition, students are also required to be able to communicate and collaborate in solving problems from the material they are studying. The goal of 21st century biology learning still refers to achieving a competence that has been designed in a curriculum so that students can become lifelong learners and can realize a learning society. Simply put, a learning society can be interpreted as a group of people who are willing to learn on their own, thereby influencing their emotions, intellectual, and spiritual and behavioral changes. According to Syah (2010), learning is an experience and interaction with the environment involving cognitive processes that cause a person's behavior to change relatively permanently. Meanwhile, the perspective of 21st century biology learning should be able to answer the challenges and demands of real life, such as the ability to work together in problem solving, self-control, critical, creative, and innovative technology mastery, and the ability to process information and communicate effectively.

Simarmata et al. (2020) mention that STEM is a learning approach that combines several aspects of science consisting of Science, Technology, Engineering and Mathematics. Where the STEM approach is able to create a integrated learning system and active learning, so that learning can train students to apply the knowledge obtained at school, in overcoming phenomena that occur in the real world. According to Nugraha & Syafi'ah (2020), the integration and implementation of the STEM approach in the curriculum in Indonesia is not easy, requiring the

creativity and competence of teachers as educators in combining the learning process based on the curriculum with STEM aspects, so that learning outcomes can create students who are ready to face the 21st century world of work. This is because the skills needed in the 21st century are not yet depicted in the majority of students.

In facing the 21st century, the teacher's task is to train and educate students so that they have good character and skills that support them to face the world of work. Yanuar (2018) suggests that 21st century learning has characteristics or principles, namely, a student-centered learning approach, students are taught to be able to collaborate, learning materials are associated with problems faced in everyday life, and in an effort to prepare students to become citizens. responsible. Learning biology in the 21st century emphasizes the importance of mastering 4C skills, such as critical thinking skills, creative and innovative thinking, communication and collaboration in problem solving. This is the biggest challenge for teachers in conditioning students to learn actively, creatively and innovatively in solving learning problems. Therefore, teachers must be prepared to provide learning media that support these 4C skills for students, so that the learning objectives expected by the curriculum can be achieved as effectively and efficiently as possible.

The STEM approach as an alternative learning solution can be analyzed based on several criteria, starting from the learning model that is applied with the STEM approach, the material chosen and the influence that will be given to students, as well as the learning media that will be used in biology learning. Several models that can be used in implementing the STEM approach that have been tested and identified are Problem Based Learning (PBL), Project Based Learning (PjBL), Inquiry Based Learning, Discovery Learning and Blendead Learning. Furthermore, teaching materials are an important composition of learning media and are always used in the teaching and learning process in the classroom. By using teaching materials based on the STEM approach in learning biology, students can improve their learning outcomes and mastery of 4C skills, namely critical thinking skills, creative and innovative thinking, communication and collaboration in problem solving. According to Santosa et al. (2021), teaching materials are a tool designed consciously and systematically that teachers use to make it easier to teach students so that student competence is achieved in the learning process. Teaching materials such as modules, worksheets, books, e-books and others can be used to achieve effective and efficient learning objectives. The development of these teaching materials can be developed by the teacher according to the needs of students in learning. Meanwhile, the material to be selected using the STEM approach can be adapted to the characteristics of the biology material that will be taught to students.

The application of the STEM approach to biology learning has a positive impact on students, that is, it has a good influence on the learning process so that it occurs effectively and efficiently, and forms students who are ready to face 21st century life. According to Permanasari (2016) the application of STEM in learning is able to increase mastery of knowledge, apply knowledge to solve problems, and encourage students to create something new. The purpose of STEM learning itself according to Bybee (2013) in the context of primary and secondary education is to develop STEM literate students who have the knowledge, attitudes and skills to identify questions and problems in life and draw conclusions based on evidence related to STEM issues. Understanding the characteristics of the features of STEM disciplines as a form of knowledge, explaining natural phenomena, designing human ideas, awareness of how STEM disciplines shape the material, intellectual and cultural environment or being involved in studying STEM-related issues.

Based on existing facts and various studies that have been conducted by previous researchers, the purpose of this article is to explain the meta-analysis of the effect of implementing the STEM approach on biology learning, so that it influences student learning outcomes and their skills in mastering 21st century learning. The problem seen is in terms of the learning model used with the STEM approach, the selected material and the teaching materials used are STEM-based.

METHOD

The method used in this article is a literature review method, through a review of literature from various sources such as books, journal articles, theses, and websites relevant to the discussion of the meta-analysis of the effect of the implementation of the STEM approach on biology learning written in a descriptive-analytical manner. In conducting the literature review, various databases such as Google Scholar and Scopus were searched using keywords such as "STEM," "biology learning," "21st century skills," and "critical thinking." The inclusion criteria for the selected sources were studies that were published in the last 10 years and related to the topic of the meta-analysis. The data collected from the selected sources were analyzed qualitatively to identify the main themes and patterns related to the effect of the implementation of the STEM approach on biology learning. The strengths and limitations of the selected studies were also discussed. By using the literature review method, this study aims to provide a comprehensive overview of the current state of research on the topic and to identify any gaps in the literature that can be addressed in future research.

RESULTS AND DISCUSSION

Syarah (2021) reveals that the analysis of the implementation of the STEM approach on biology learning can be seen from the learning model applied with the STEM approach, the selected materials, and the impact that will be given to students in the implementation of STEM used in biology learning. STEM is connected with learning models such as PBL, Discovery Learning, PjBL, Inquiry Learning, and Blendead Learning. Meanwhile, the teaching materials used include e-books, modules, LKS, LKPD, and books. The STEM approach has an impact on student learning outcomes and various student skills in the 21st century such as critical thinking skills, creative thinking skills, analytical thinking skills, and others. STEM requires a change in the learning model from teacher-centered learning to student-centered learning, from individual learning to collaborative learning, and emphasizes the application of scientific knowledge, creativity, and problem solving. The implementation of the STEM approach will have a positive impact on biology learning if done well. Therefore, Fadhilah (2022) suggests that STEM is often paired with problem-solving learning models, both in the form of observation and projects. The results obtained from the literature review of various relevant journal articles can be seen in the Table 1.

From Table 1, it is clearly seen that the implementation of the STEM approach has been widely studied with different types and criteria. From these studies, it has been proven that the implementation of the STEM approach significantly improves the 21st century biology learning skills of students. This also confirms that the STEM approach is suitable for use in 21st century biology learning. This is because almost all studies show a significant improvement in student skills before and after implementing STEM learning. As explained by Baharin et al. (2018), STEM can provide meaningful learning experiences for students in 21st century learning because it integrates science literacy, knowledge, technology utilization, and mathematical literacy. Ritonga & Zulkarnaini (2021) also explain that learning with STEM makes students discuss each other to realize their ideas and thoughts to answer questions in LKPD based on the steps in learning.

The aspects that are always studied in the implementation of the STEM approach to biology learning are student learning outcomes, critical thinking skills, creative thinking skills, science literacy skills, analytical thinking skills, and scientific thinking skills. This can be seen from the summary table of sample data results of the articles that have been analyzed previously. These studies prove that the implementation of the STEM approach greatly supports student learning, which is oriented towards 21st century skills. With the STEM approach, student learning skills significantly increase, as seen from the analysis of data on the pretest and posttest of students before and after the STEM approach was applied in learning. The analysis of the aspects that are often studied by researchers in the implementation of the STEM approach to 21st century student skills can be seen in Figure 1.

Table 1. Recapitulation of Sample Data from Analyzed Research Articles

Article code	Article title and translation	Author (year)
A1	*Penerapan Project Based Learning Terintegrasi STEM untuk Meningkatkan Literasi Sains Siswa Ditinjau dari Gender* (Implementation of STEM Integrated Project Based Learning to Improve Student Science Literacy in terms of Gender)	Afriana et al. (2016)
A2	*Bahan Ajar Berbasis STEM (Science, Technology, Engineering, and Mathematics) untuk Meningkatkan Penguasaan Konsep Siswa SMA* (STEM (Science, Technology, Engineering, and Mathematics) Based Teaching Materials to Improve Mastery of High School Students' Concepts)	Pangesti et al. (2017)
A3	*Pengaruh Project Based Learning Terintegrasi Stem Terhadap Literasi Sains, Kreativitas dan Hasil Belajar Peserta Didik* (The Effect of Stem Integrated Project Based Learning on Scientific Literacy, Creativity and Student Learning Outcomes)	Lutfi et al. (2018)
A4	*Implementasi Model PJBL Berbasis STEM untuk Meningkatkan Penguasaan Konsep dan Kemampuan Berpikir Analitis Siswa* (Implementation of the STEM-Based PJBL Model to Improve Students' Concept Mastery and Analytical Thinking Ability)	Tipani et al. (2019)
A5	*Implementasi Pembelajaran Stem Pada Materi Sistem Reproduksi Tumbuhan Dan Hewan Terhadap Kemampuan Berpikir Ilmiah Peserta Didik SMP* (Implementation of Stem Learning on Plant and Animal Reproductive System Material on the Scientific Thinking Ability of Junior High School Students)	Agustina et al. (2020)
A6	*Implementasi Model Problem Based Learning Dipadu LKPD Berbasis STEM untuk Meningkatkan Keterampilan Berpikir Kritis pada Materi Pencemaran Lingkungan* (Implementation of Stem Learning on Plant and Animal Reproductive System Material on the Scientific Thinking Ability of Junior High School Students)	Hasanah et al. (2021)
A7	*Efektivitas Model Inquiry dengan Pendekatan STEM Education terhadap Kemampuan Berfikir Kritis Peserta Didik* (The Effectiveness of the Inquiry Model with the STEM Education Approach to Students' Critical Thinking Ability)	Santoso & Arif (2021)
A8	*Penerapan Pendekatan STEM untuk Meningkatkan Keterampilan Berpikir Kritis Peserta Didik* (Application of the STEM Approach to Improve Students' Critical Thinking Skills)	Ritonga & Zulkarnaini (2021)
A9	*Penerapan Model Discovery Learning Berbasis STEM pada Materi Sistem Gerak Untuk Meningkatkan Keterampilan Berpikir Kritis* (Application of the STEM-Based Discovery Learning Model in Motion Systems Material to Improve Critical Thinking Skills)	Fadlina et al. (2021)
A10	*Pengembangan E-Book Berbasis Stem Pada Materi Ekosistem Untuk Melatihkan Kemampuan Literasi Sains* (Development of Stem-Based E-Books on Ecosystem Materials to Train Science Literacy Skills)	Andaresta & Rachmadiarti (2021)

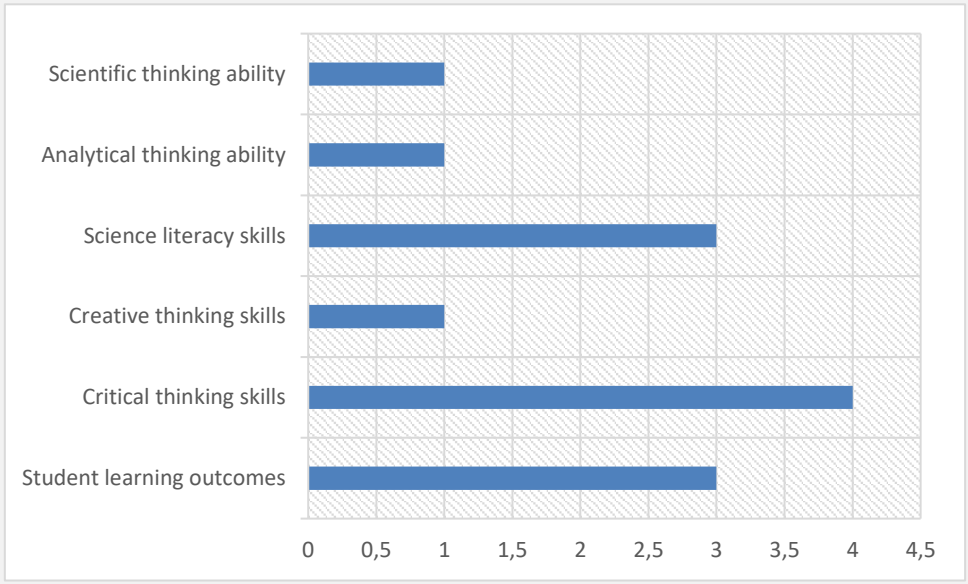

Figure 1. Analysis of the aspects studied in the implementation of the STEM approach

Agustina et al. (2020) conducted research on the implementation of STEM learning in the material on the reproductive system of plants and animals that can affect the scientific thinking abilities of class IX junior high school students. There are four aspects of this research, namely inquiry, analysis, inference and argumentation. The application of the STEM approach used is integrated STEM and silo STEM, and from his research it is explained that the average score obtained by students in each aspect is higher when using integrated STEM. Because in the integrated STEM approach students are given the freedom to develop their own creativity in solving problems, students are directly involved in the observation process, students experience learning to design designs as an engineering process, and excellent students argue according to the results of investigations and analogy logic, so that the four aspects mentioned have been fulfilled well.

At the beginning it was stated that the implementation of the STEM approach in learning is often juxtaposed with problem-solving learning models. According to Sukmawijaya et al. (2019) STEM-PJBL learning can influence students' creative thinking skills in environmental pollution material. Where the results of the recapitulation of students' creative thinking ability test scores show that there is an increase in students' creative thinking abilities, with the control class and the experimental class showing different values. Tipani et al. (2019) also revealed that the STEM-based PJBL model gave good results on students' mastery of concepts and analytical thinking skills, because it is a learning model that is applied to material presented in the form of a problem, question, and facilitates investigation by students by way of discussion to produce a project. Furthermore, the products resulting from the use of PJBL-STEM in biology learning can become student participation in improving the quality of life in the 21st century era.

Fadlina et al. (2021) in his research explained that the STEM-based discovery learning model was used to improve students' critical thinking skills in motion system material. The results of increasing students' critical thinking skills were included in the high category. It was shown that the average N-gain for the experimental class was 67.57 and the N-gain for critical thinking skills was 0.85. The learning process using the STEM-based discovery learning model on motion system material provides an opportunity for students to practice their level of activity first, then seek knowledge according to discovery using sources that can facilitate problem solving. Also, students are active in learning by conducting experiments on skeletal system material by making posters of the human body frame.

The application of the STEM-based 5E learning cycle learning model can also be applied in biology learning, which influences student learning outcomes and scientific literacy. Salma et al.

(2022) explained that learning the 5E learning cycle combined with the STEM approach to mushroom material can improve learning outcomes and scientific literacy skills in students. That is, the value of scientific literacy in the experimental class is higher than the control class. Likewise with student learning outcomes, with students' scientific literacy abilities, they not only gain knowledge but also encourage them to explore knowledge so they are able to solve problems. By finding a concept for themselves in answering these problems so that students' understanding of the material becomes good, which then has a good impact on their learning outcomes. This is reinforced by Putri et al. (2019) that the implementation of STEM-based learning with the 5E learning cycle model can improve students' ability to solve problems, namely an increase in students' scientific literacy and critical thinking abilities.

Furthermore, the application of the STEM approach can be combined with the blended learning model. Banila et al. (2021) found that blended learning interventions incorporating the STEM approach can enhance students' scientific literacy, particularly in the form of a significant increase in students' scientific literacy during learning activities. The blended learning approach with the STEM approach consists of three stages: the first stage focuses on developing students' scientific knowledge, the second stage focuses on cultivating an empirical attitude in students, and the third stage involves students working and collaborating together. These three stages incorporate elements of science, technology, engineering, and mathematics and utilize both synchronous and asynchronous technology. Santoso & Arif (2021) found in their research that the inquiry learning model incorporating the STEM approach resulted in higher critical thinking skills compared to the control group using conventional learning. Similarly, Fitriansyah (2021) found that the STEM-inquiry approach has a positive impact on students' scientific work because it fosters critical, honest, and conscientious attitudes in students. The STEM-PBL model also showed similar results, improving students' critical thinking skills in learning.

In addition to the use of learning models, the development of STEM-based teaching materials is also very important in improving students' abilities in learning. For example, e-books based on the STEM approach can improve students' scientific literacy skills if trained optimally. As revealed by Andaresta & Rachmadiarti (2021) that the development of STEM-based E-books on ecosystem material is stated to be valid and feasible theoretically and empirically, because it has features that support learning to train students' scientific literacy abilities. The main features contained in the E-book are the STEM zone in which there is reading relevant to the material sub-chapters that have been prepared by the researcher, so as to be able to encourage students to study STEM-based ecosystem material. Retnowati (2020) in Andaresta & Rachmadiarti (2021) also believes that learning using STEM-based e-books will greatly affect learning outcomes. Where, STEM learning can train students in applying knowledge of making designs as a way to solve problems related to the environment using technology and encourage increased student scientific literacy.

According to research conducted by Santosa et al. (2021) regarding the meta-analysis of the influence of teaching materials based on the STEM approach on ecological learning, it explains that the measurement of effect size is based on educational levels such as high school, junior high school, and elementary school, the effect size price is in the high category, where the use of STEM-based teaching materials is more effectively applied at the high school and junior high school levels. For teaching materials used in the form of modules, LKS/LKPD, and teaching materials also obtain Effect size prices with high categories and are effective when using modules in the application of learning. In addition, this STEM-based ecology teaching material greatly influences students' scientific processes, student learning outcomes, student competencies, critical thinking, and problem solving by students, with the average effect size of each component being in the high to medium category. So, the application of STEM-based ecological teaching materials is very suitable for elementary and middle school levels.

In addition, Fauzi & Hayya (2022) in their research tried to describe the process of developing interactive e-modules on high school ecology material. In this study, the results obtained from the validity and practicality test of STEM-based interactive e-modules on ecological

material were declared valid and suitable for use in the field. Apart from that, this research also measured the increase in student test results, so that overall the product has a valid, practical, and effective category. This supports the statement of Santosa, et al about the application of STEM-based ecological teaching materials which are very suitable for use at the elementary and middle school levels.

Oktavia (2022) also explained that the use of integrated teaching materials with the STEM approach to learning science is very much in line with the demands of the 2013 curriculum. Because integrated teaching materials with the STEM approach have been proven to be able to improve student learning outcomes, and it is hoped that they can also improve students' creative thinking skills. The presentation of teaching materials is carried out using science, technology, engineering (engineering), and mathematics approaches. It is intended that with the existence of STEM-based teaching materials in integrated science learning, it can increase students' interest in studying science further and will also indirectly improve learning outcomes, creative thinking skills, and students' critical thinking skills.

CONCLUSION

From the results and discussion it can be concluded that the analysis of the implementation of the STEM approach in biology learning can be seen from several categories such as, the learning model applied with the STEM approach, the material chosen and the influence that will be given to students, and the STEM-based teaching materials used in learning biology. Several models that can be used in implementing the STEM approach that have been tested and identified are Problem Based Learning (PBL), Project Based Learning (PjBL), Inquiry Based Learning, Discovery Learning and Blendead Learning. While the teaching materials used are in the form of e-books, modules, LKS, LKPD, and books. The application of the STEM approach is very good for learning biology in the 21st century. Because of the four components contained in the STEM approach such as science, technology, engineering, and mathematics, students can solve problems by utilizing technology and assemble them into experiments that can prove scientific concepts, supported by data. which has been managed mathematically. Furthermore, learning and teaching materials using the STEM approach are proven to be able to improve student learning outcomes, students' critical and analytical thinking skills, increase student creativity, student scientific literacy, and students' scientific thinking abilities.

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