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THE IMPACTS OF STEM ON MATHEMATICS AND SCIENCE THROUGH LESSON STUDY: A SYSTEMATIC LITERATURE REVIEW

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ABSTRACT

STEM-based mathematics learning is required to assist learners in developing 21st-century skills, including creativity, critical thinking, communication, and cooperation. However, the application of STEM-based Mathematics and Science learning in Indonesia is relatively new and rarely done due to some obstacles. One alternative is the implementation of lesson study for the learning community. This study determines the positive impacts of STEM on Mathematics and Science learning through lesson study for the learning community based on the findings of a systematic review of current research. The results show that applying the STEM approach through lesson study positively impacts teachers and students. Positive impacts for teachers include improving lesson quality and teaching professional competency as well as improving critical and creative thinking skills, information, media and technology abilities, life and career capability, problem-solving, basic questioning skill, learning achievement, science literacy, concept understanding, and motivation as advantages for students. Nonetheless, further research is necessary to investigate the best method for applying STEM-based learning in Mathematics and Science through lesson study.

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INTRODUCTION

The main focus of Mathematics and Science education is improving 21st-century skills (Nisrina et al., 2020). 21st-century learning needs to master communication, collaboration, critical thinking, and problem-solving skills (Van Laar et al., 2020). So that students can have adequate mathematical and scientific literacy skills. By mastering mathematical literacy skills, students can use mathematics in everyday life (Jannah, Putri & Zulkardi, 2019; Genc & Erbas, 2019; Hwang & Ham, 2021). A student is said to have good literacy skills if he can analyze, reason, and communicate his mathematical knowledge and skills effectively and solve and interpret mathematical problems (OECD, 2019). Likewise, with scientific literacy, students use their knowledge to create a new idea, a new concept for a problem scientifically (Wulandari, & Sholihin, 2016) so that it supports students to create their procedures based on the investigations carried out (Irmita, & Atun, 2018).

However, the results of 2002–2018 PISA, a program that measures the mathematical, scientific, and reading literacy abilities of 15-year-old students, showed that Indonesian students' rankings were consistently ranked in the 12 lowest countries of the countries participating in PISA (Stacey, 2011). In 2015, Indonesia was ranked 63 out of 75 countries, and in 2018, out of 79 countries, Indonesia was ranked 73. The ability of Indonesian students to answer PISA questions is still in the low category compared to previous years since joining the program. The survey places Indonesia in the 10th position with the lowest mathematical literacy rating (Nugrahanto & Zuchdi, 2019).

Therefore, we need an approach that engages students in acquiring and practicing 21st-century skills through STEM-based education. STEM, an acronym for Science, Technology, Engineering, and Mathematics, is a current instructional approach designed to equip learners for an unforeseeable hereafter (Jung et al., 2020). The objective of STEM, a learning method heavily promoted by the United States since the late twentieth century, seeks to accelerate science and mathematics learning, emphasize the integration of scientific fields, to increase pupils' passion for science, technology, engineering, and mathematics, and to progress technical literacy (Breiner, et al., 2012).

STEM education is viewed as a strategy capable of bringing about significant change in the 21st century (Kusumaningrum, 2020; Widarti et al., 2020). With STEM learning, scientific literacy skills, which are part of 21st-century skills, can be achieved (Afriana et al.,

2016; Ismail & Zenobia, 2018; Knowles et al., 2018). In line with this, an integrated STEM education offers a chance for enhanced skills associated with integrating students in real-world situations that are realistic, open, and structured to boost the significance of the subject to be studied (Thibaut et al., 2018; Furner & Joseph, 2018). Numerous studies have also shown that learning with a STEM framework in Indonesia can significantly improve learners' abilities in a subject (Khaeroningtyas et al., 2016; Wisudawati et al., 2018).

However, STEM-based learning in schools is still relatively new for teachers, so some teachers are still experiencing problems in implementing it (Suprapto et al., 2019). Teacher difficulties in implementing STEM-based learning include: (1) the most significant challenge mathematics educators encounter in implementing mathematics in STEM for a variety of abstract themes owing to its characteristics that are unrelated to the real-world application (Milaturrahmah et al., 2017; Rosikhoh et al., 2019), (2) the time constraint on deploying a STEM curriculum (Winangun et al., 2019; Wahono & Chang, 2019; Susilo & Sudrajat, 2020), (3) teachers expected to possess a thorough understanding of the science, technology, engineering, and mathematics subjects they instruct (Eckman et al., 2016), (4) fostering a school culture and environment supporting the teaching process of STEM-based education could be prohibitively expensive and time-intensive (Nadelson and Seifert, 2017).

Based on the teachers' problems in implementing STEM learning in their classes, the concept was presented, for instance, because only most mathematics and science instructors comprehend STEM. As a result, other educators cannot assist them in integrating STEM. Moreover, STEM integration would be beneficial if a well-defined and supporting curriculum (Suwarma dan Kumano, 2019). So, we need a learning community helping teachers to share in the design, implementation, and evaluation of learning. Lesson Study for learning community is one of the learning community models that can build teacher abilities to the fullest (Mahardika dan Putri, 2020). Teachers will learn from each other how to optimize STEM-based learning.

Lesson study is a model for fostering the educational profession through collaborative and sustainable learning studies based on collegiality and mutual learning principles to build a learning community (Hendayana et al., 2006). “Lesson study is a simple idea. If you want to improve instruction, what could be more obvious than collaborating with fellow teachers to plan, observe, and reflect on the lesson?" (Cerbin, B and Kopp, B, 2015). Lesson study

implementation emphasizes three activities: (1) planning (plan), (2) implementation (do), and (3) reflection (see) (Hidayat, 2015). The learning process can run effectively and systematically through lesson study (Nuha, Waluya, & Junaedi (2018).

Therefore, in light of the stated background, this article explores the impact of implementing STEM using lesson study. This systematic review focuses on the positive impact of STEM in lesson study. The results are expected to inspire the teacher to design their mathematics and science lessons using the STEM-based approach lesson study.

METHOD

A systematic review technique was utilized to discover, critically assess, and synthesize the outcomes of all actual studies highlighting the influence of STEM-based Mathematics and Science learning on learning communities (Gopalakrishnan and Ganeshkumar, 2013). A systematic review is different from a narrative review. Narrative reviews typically concentrate on a group of publications chosen based on availability or researcher preference and tend to be descriptive. Hence, elements of selection bias often have the potential to occur. On the other hand, Uman (2011) stated that systematic reviews strive to decrease partiality by locating, evaluating, and summarizing all supporting documents on a specific topic and using a rigorous and exhaustive search method determined a priori. In this article, a systematic review is conducted employing electronic databases: ERIC and Google Scholar. The database was accessed via four distinct search keyword combinations: "STEM + Mathematics and Science learning" (n = 100), "Lesson Study + Mathematics and Science learning" (n = 75), "STEM + Lesson Study + Mathematics and Science learning" (n = 59), resulting in a total of 234 articles.

The data set was then filtered following four indicators after the identical findings were eliminated. First, all papers considered should be peer-reviewed journal articles or book chapters published in both Indonesian and English, except conference proceedings and dissertations. Second, the papers should highlight the significance of STEM education, encompassing at least three areas. Articles combining only two fields were omitted, particularly interdisciplinary mathematics and the incorporation of science or engineering into mathematics. Third, the article should focus on the impact of learning Mathematics and Science using lesson study for the learning community. Fourth, all articles must describe the impact of STEM-based Mathematics and Science learning through lesson study for the

learning community. One rater verifies that the article satisfies the criteria, and if there is any doubt, the paper is reviewed with the other two raters up to an agreement established. Following the application of the criterion, only 20 articles remained in the sampling. Supplemental articles were obtained using the "snowball approach" (Doust et al., 2005). All eligible papers' references were examined, and five related articles that fulfilled the indicator were incorporated into the data, giving 25 articles published in 2016-2020.

Miles and Huberman (1994) argued that it is necessary to do in-case and cross-case analyses to analyze articles in a data set. For the analysis stage in the case, each article is assessed independently and reported in a table consisting of two indicators: (1) STEM-based Mathematics and Science learning and (2) STEM-based Mathematics and Science learning through lesson study. Moreover, during the cross-case analysis step, the influence of STEM-based learning on learning communities was reorganized using data from all papers. Relating factors were classified collectively, resulting in the formation of two distinct groupings. Besides, the conceptual model is developed by emphasizing the effect of STEM-based instruction and the influence of lesson study on the learning community, which are the most frequently addressed topic in systematic review papers.

RESULT AND DISCUSSION

The review will be elaborated on three main results: (1) STEM-based Mathematics and Science Learning and (2) STEM-based Mathematics and Science learning through lesson study. All of them can be elaborated as follows.

STEM-based on mathematics and science learning

Based on the literature review from a selected article published in 2016-2020 used in this study, there are some positive impacts of implementing STEM in Mathematics and Science learning, both for students and teachers. Additionally, Table 1 describes the overview of the influence of STEM-based on Mathematics and Science education across all papers, divided into two categories: student and teacher.

Table 1. Overview of STEM-based Mathematics and Science learning impact

Category	Impact of STEM-based on Mathematics and Science learning (extracted from papers)
student	- Critical thinking skills - Creative thinking skills - innovative abilities in terms of creativity - knowledge of information, media, and technology - interpersonal and career capabilities

Category	Impact of STEM-based on Mathematics and Science learning (extracted from papers)
	- Basic questioning skill - Learning achievement - Science literacy skill - Concept understanding - Motivation
teacher	- The positive view of STEM learning

It needs to examine the articles in the dataset to explain the impact of STEM-based education on Mathematics and Science learning. Only 18 of 25 papers mentioned the impact of STEM-based. Furthermore, fourteen publications discussed the effects of STEM-based mathematics and science education on students, while four studies addressed the impact on teachers. As mentioned above, STEM-based Mathematics and Science learning can positively impact students and teachers. In addition, Table 2 describes an overview of the impact of two categories in each paper.

Table 2. Overview of the influence of STEM-based on Mathematics and Science Education for two categories present in each paper

Authors	Student										teacher
	Critical thinking	Creative thinking	information, media, and technology skills	life and career skills	Problem-solving	Basic questioning skill	Learning achievement	Science literacy	Concept understanding	Motivation	
Oonsim, & Chanprasert, (2017)	√										
Rosikhoh et al., (2019)	√										
Almahida et al., (2020)	√										
Evcim, I., & Arslan, M. 2021	√										
Sumarni & Kadarwati, (2020)	√	√									
Amiruddin et al., (2019)		√									
Tunkham et al., (2016)		√	√		√						
Astuti et al., (2021)						√					
Purwaningsih et al., (2020)						√					
Ilma et al. (2019)							√	√			

Authors	Student											teacher
	Critical thinking	Creative thinking	information, media, and technology skills	life and career skills	Problem-solving	Basic questioning skill	Learning achievement	Science literacy	Concept understanding	Motivation		
Prasetyo et al., (2021)								√				
Adiwiguna et al., (2019)	√							√				
Afni et al. (2019)	√								√			
Julia et al. (2019)										√		
Kim & Lee (2018)											√	
Kim et al. (2019)											√	
Park et al. (2016)											√	
Wahono & Chang, (2019)											√	

The influence of STEM education on mathematics and science learning was abstracted from all studies, and elements with a common aspect were put into one category, as seen in table 2. This resulted in two classifications: impact for students and implications for the teacher. The implications for students are reasoning skills, creative thinking skills, information, media and technology capabilities, life and career skills, problem-solving abilities, essential questioning competencies, academic achievement, science literacy, concept understanding, and motivation. A resume of those impacts found in each article can be shown in table 2 and explained more.

The first impact on students is improving students critical thinking skills (Oonsim & Chanprasert, 2017; Rosikhoh, 2019; Almahida, 2020; Evcim & Arslan, 2021; Sumarni & Kadarwati, 2020; Adiwiguna & Gunamantha, 2019; Afni & Ilmiyati, 2019). According to those references, learners that obtain STEM learning could strengthen their critical thinking abilities. Integrating diverse fields concurrently while creating products is critical for developing pupils' critical thinking abilities in STEM education. As a result, educators must design this procedure efficiently.

The second effect is improving creative thinking skills (Sumarni & Kadarwati, 2020; Adiwiguna & Gunamantha, 2019; Afni & Ilmiyati, 2019; Amiruddin et al., 2019). The ethnomathematics-STEM Project Based Learning (PjBL) substantially influenced the pupils'

creative thinking skills, and all parts of those talents rose following the implementation of STEM PjBL (Sumarni & Kadarwati, 2020). Moreover, by incorporating STEM education into theme teaching, learners could become accustomed to analyzing issues and challenges extensively. Additionally, it can equip learners with investigative skills and integration skills, leading to the establishment of an idea capable of developing pupils' competencies and capacity for creative thinking capabilities (Sumarni & Kadarwati, 2020).

The third impact is enhancing information, media and technology capabilities, and life and professional abilities (Tunkham et al., 2016). They found that their information media and technology experts were rated exceptional after students completed STEM activities. At the same time, their life and career competence, specifically their teamwork and communication, their correlation to listeners, and their capacity to verify the group work, along with leadership and commitment, were highly satisfactory.

The next impact is developing students' ability in problem-solving (Astuti et al., 2021; Purwaningsih et al., 2020). Astuti et al., (2021) found that STEM-based education enables students to enhance their problem-solving skills. Besides, STEM-PjBL instruction prepares and challenges pupils to tackle difficulties encountered in daily situations (Purwaningsih et al., 2020).

The sixth impact is improving basic questioning skills and learning achievement (Ilma et al., 2019). In line with that, STEM education could aid learners in strengthening their fundamental questioning ability. Students have also dared to ask the teacher about material or technique that has not been understood when doing a STEM practice.

Then the impact is improving science literacy skills (Adiwiguna & Gunamantha, 2019; Prasetyo et al., 2021). The advancement of a STEM-based electronic module for milieu pollution content is successful in improving class VIII pupils' scientific literacy abilities, particularly science as a knowledge base, science as a method of inquiry, science as a line of thinking, and the interplay of science, technology, and community (Prasetyo et al., 2021).

The subsequent impact is enhancing concept understanding. The STEM-based PjBL approach could improve comprehension of ideas (Afni dan Ilmiyati, 2019). Moreover, STEM-based learning of Mathematics and Science can improve students’ motivation. Based on (Juli & Antoli, 2019), the STEM program is through a natural learning process that provides an exciting and practical educational experience for pupils. Furthermore, based on teacher

perspective on implementing STEM in their classroom also have a favorable view of STEM learning (Kim & Lee, 2018; Kim et al., 2019; Park et al., 2016).

STEM-based on mathematics and science learning through lesson study

The development of teachers' quality is a primary aspect that can make the success of an educational system. Therefore, teachers' professional development should be an essential point to be paid attention. One way to reach it is through lesson study for the learning community. The teacher faces several challenges in implementing STEM using lesson study: time constraints, trouble adapting STEAM courses, and problems designing a meaningful STEAM lecture (Boran et al., 2018).

However, some findings indicate that teachers could benefit from lesson study. Referring to Wahono & Chang (2019) and Lewis & Perry (2017), the advantages of lesson study for both teacher and students namely: (1) capable of using mathematical ability, (2) developing the students' mathematical skills through group work, (3) the process of teaching and learning be more active, and (4) improve teachers' and students' knowledge learned. According to (Jung & Shin, 2018), through lesson study, the teacher could work together to develop a good quality lesson plan STEAM-based to plan a better lesson by discussing, cross-checking, and overcoming difficulties. If the teacher can design a more effective lesson, pupils can accomplish their learning objectives and benefit from the session. In addition, the teacher can grow through a series activity by observing and learning from each other lessons. In addition, implementing lesson study can help the teacher improve their pedagogical content knowledge (Akerson et al., 2017). Furthermore, integration between STEM and lesson study for the learning community can positively impact the quality of STEM lesson planning and teaching process (Aykan & Yildirim, 2021).

CONCLUSION

Based on the literature review, it can be concluded that there are several impacts of implementing STEM on mathematics and science learning using lesson study for students, namely: critical thinking skills, creative thinking skills, information, media and technology capabilities, and life and professional abilities, problem-solving, basic questioning skill, learning achievement, science literacy, concept understanding, and motivation. In addition, implementing the STEM approach in mathematics learning using lesson study also positively impacts teachers: improving lesson quality and teaching professional competency.

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