



FUN CLASSROOM: HOW SEVEN GRADERS AND SCIENCE TEACHERS RESPOND TO STEM LEARNING AS THE FIRST EXPERIENCE IN SUBURBAN AREA?

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ABSTRACT

STEM learning is now being implemented at science schools. After a STEM training session, a group of science teachers in West Java implemented STEM learning in secondary school, a heat and energy topic. The school where STEM learning is implemented is in the suburban area of West Java, Indonesia. The research aims to elaborate on how STEM learning can lead students to learn actively and interactively by using all their modalities as expected by the Merdeka Belajar curriculum. The qualitative research was conducted through profound learning observation. The impact of learning with the STEM approach was then investigated through the STEM Literacy of students. The observation was done directly by some science teachers, and video recording was used to complete the observation. The tests were also conducted to determine the quantitative picture of student achievement (STEM literacy assessment). The results of interviews with teachers and students revealed that this STEM learning was their first experience. Many interesting things were found during the learning process, which significantly provided prospects for the future of STEM learning. STEM learning does not necessarily improve student learning outcomes as expected. However, the characteristics of STEM learning in accelerating the Merdeka Belajar program are evident. All teachers involved agreed that if this learning was applied to at least three more topics, they were optimistic that students could achieve STEM literacy.

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Keywords: STEM learning; merdeka belajar; students' modality

INTRODUCTION

STEM learning emphasizes developing students' abilities to integrate cross-disciplinary or meta-disciplinary knowledge and learn problem-solving skills directly (Lou et al., 2011; Newhouse, 2017), both in facing the world of work and solving problems globally (Gonzalez & Kuenzi, 2012). One of the essential learning values in STEM is interdisciplinary integration;

in other words, students can overcome real-world challenges by making meaningful connections and integrating knowledge across disciplines (Johnson, 2012). STEM refers to integrating science, technology, engineering, and mathematics at all grade levels, from pre-school students to post-doctoral programs and in informal and formal education settings. Achillos et al. (2019) stated that the four core elements of STEM learning are interrelated. The aim is to train students to become interdisciplinary experts. STEM learning helps students to think about cross-disciplinary

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knowledge and learn cross-disciplinary professional skills (Lou et al., 2011; Ritz & Fan, 2015; Newhouse, 2017; Lai et al., 2021). For example, mathematical equations are often used to solve problems in science, technology, and engineering. Ritz & Fan (2015) found that most people believe in the importance of exploring the meaning of STEM learning and propose appropriate cross-disciplinary educational directions. Learning STEM separately can cause students' knowledge systems to be isolated and affect their learning outcomes. STEM is closely related and must be integrated and studied (Kelley et al., 2020; Awad, 2023).

Another goal of STEM learning, especially in science learning, is to motivate students to practice using integrated skills to solve problems and make learning more meaningful (Wai et al., 2010; Moore et al., 2014; León et al., 2015). STEM can also develop students into innovators, inventors, logical thinkers, independent thinkers, and people who can use technology (Stohlmann et al., 2012). Another goal is to develop a STEM-literate society, which means that in this century, students need to become future citizens who can apply knowledge from STEM disciplines in real life (Kennedy & Odell, 2014; Tati et al., 2017). It can be referred to as STEM literacy.

STEM literacy can be defined as the ability to identify, apply, and integrate science, technology, engineering, and mathematics concepts to produce innovative products and the ability to solve complex problems (Balka, 2011). STEM literacy refers to knowledge, attitudes, understanding of STEM characteristics, awareness of how STEM-related disciplines, and a willingness to engage in STEM-related issues (Bybee, 2010). STEM literacy is driven by literacy from each subject incorporated into STEM. Scientific literacy can be interpreted as an understanding of scientific concepts and processes. Technological literacy is understanding and evaluating technological principles and strategies to solve problems. Engineering literacy is an understanding of how technology develops through engineering design and how to make something based on the scientific concepts that have been obtained. Mathematical literacy is the ability to identify, understand, and use the role of mathematics in personal, work, and social life (Zollman, 2012).

Students' STEM literacy can be achieved by a learning process using projects (Tati et al., 2017; Aninda et al., 2020). This project emphasizes engineering designs that can make students achieve their creativity (Ergül & Kargin, 2014; Vaidya, 2015; Sookpatdhe & Soranastaporn,

2016). Students are tasked with solving a problem integrating science, engineering, technology, and mathematics concepts. Project-based learning collaborating with STEM learning can encourage students to think at a higher level in designing solutions to their problems. Decision-making is critical when creating a project. Project-based learning through STEM can also develop students' learning competencies (Baran & Maskan, 2010), attitudes (Kilinc, 2010; Tseng et al., 2013), and science process skills (Özer & Özkan, 2012; Septiani & Rustaman, 2017). Thus, STEM-based learning will lead to effective learning (Cook et al., 2012).

STEM learning has become a significant trend worldwide, including in Indonesia. STEM learning can also support the Merdeka Belajar Curriculum, developed to anticipate global developments and science for the 21st century. This century is marked by the accelerated implementation of digital transformation in learning innovations that can encourage students in Indonesia to think critically, creatively, communicatively, and collaboratively. The Merdeka Belajar curriculum framework was developed to be more flexible while focusing on essential material, character development, and competencies. The Merdeka Belajar Curriculum provides an appeal by using a student-oriented learning model or approach to accommodate these competencies and make learning more enjoyable and meaningful. Some recommended models are inquiry, discovery, problem-based, and project-based learning, which can train scientific literacy and higher-order thinking skills and improve learning outcomes (Nawalinsi, 2016; Ramadhan & Sutrisnawati, 2023). The application of this model or approach is undoubtedly familiar to teachers.

However, there are still many obstacles and challenges in STEM learning. One of them is that these models are designed to not accommodate problem-solving activities by integrating cross-disciplinary knowledge (Riani et al., 2017; Mislinawati & Nurmasiyah, 2018). STEM should be a student-oriented approach that integrates various disciplines into problem-solving activities. It can be an alternative to make learning more relevant, fun, connected, and meaningful (Stohlmann et al., 2012), improve scientific attitudes and conceptual understanding (Thahir et al., 2020), and enhance students' high-level skills (Mutakinati et al., 2018).

Another problem in STEM learning is the range of implementation areas. STEM learning has been implemented in Indonesia and has various benefits for students. STEM learning has

been implemented in Indonesia at various levels: elementary school (Nuragnia et al., 2021; Sumaya et al., 2021), secondary school (Khaeronytyas et al., 2016; Firda et al., 2021; Amalia et al., 2023), and universities (Fathoni, 2020; Khairani et al., 2018). However, most STEM learning cases are only implemented in big cities and have not touched many schools in remote villages. This happens because the understanding of teachers in the regions related to STEM learning is still inadequate. Because they are very far from the center of activity, science teachers in remote areas rarely participate in various professional trainings. Through this research, it is hoped that students and teachers in the suburban area will gain learning experience with the STEM approach. Besides that, this research will detail how STEM learning can lead students in suburban areas to learn actively and interactively by using all the modalities they have, as expected by the Merdeka Belajar curriculum. Learning from experience, the skills of students in suburban schools have the potential to improve through learning innovations. It is just that the opportunity to gain innovative learning experiences is infrequent because of the teacher's weaknesses in innovative learning. Innovative learning using the STEM approach is expected to change the paradigm of learning science. Many students still think that learning science is difficult and scary. In addition, the research also aims to picture how STEM learning in suburban areas occurs, how students' potential modalities can be explored, and what challenges and obstacles science learning faces.

METHODS

This research is qualitative and quantitative. Qualitative research was conducted to picture STEM learning through observation and in-depth analysis. Several science teachers did the observation directly using video recordings. Qualitative research was also conducted to see student activity, such as how many students asked questions, discussed, answered, and argued in learning using the STEM approach. Quantitative descriptions related to learning outcomes in the form of students' STEM literacy and STEM literacy assessments were also carried out in the test questions. The test was initially composed of 25 multiple-choice questions, then validated by experts and tested. Finally, it had 20 multiple-choice test items, including scientific literacy, technological literacy, mathematical literacy, and engineering literacy. The test was given to students before and after learning temperature and energy materials using the STEM approach.

Analysis of STEM literacy questions using the *Stacking* and *Racking* techniques with the *RASCH* model approach was employed to see the effect of STEM learning on improving students' learning outcomes. *Stacking* is an analysis showing increased students' abilities based on the pretest and posttest results. *Racking* analyzes changes at each test item level (Laliyo, 2021). The analysis results using the *Stacking and Racking* techniques are presented with a scatter plot graphic image to see shifts and trends in improving students' abilities (Laliyo et al., 2022). The results of learning recordings were transcribed first to get an accurate portrait of learning, and the results of observations became additional data to support quantitative data.

The research was conducted on 32 seventh-grade students of a suburban school in West Java, consisting of 14 males and 18 females. Learning was carried out in six meetings in six weeks. The meeting began with giving pretests to students individually. In the second meeting, the teacher initiated and gave challenges related to material on how to convert heat into energy (using an example of how a fireboat works). Students are divided into several groups to discuss it. In the initial group, students must discuss how energy changes produce motion energy. A jigsaw strategy was applied to maximize the role of students in their groups. Group experts (two students from each group) were appointed to study the concept of energy change and energy change technology. The experts then discussed finding relevant concepts. Each student from the expert group then returned to the initial group, presenting the results of the discussion from the expert group.

Students were asked to design and make a group project at the third and fourth meetings: the otok-otok boat. It is a toy boat they often play in daily, made of cans. It runs on oil and starts by filling it with water and burning its wick. The teacher determined the criteria for the otok-otok boat: it does not capsize while passing through the set route, and the travel time for one route is not less than a minute. Based on their understanding of the concepts, students were asked first to describe their designs on a sheet of manila paper, specify the materials used, and design the boat to be made. After designing, students started making boats according to the designs. They tried, improved, and tried again until the product met their expectations. In the fifth meeting, students were asked to present the results of their respective boat designs and test their otok-otok boats in the school's botanical pond. At the last meeting, students took the STEM literacy posttest.

RESULTS AND DISCUSSION

In the initial predictions, the research team felt they would face difficulties building student-student, student-teacher, and student-teaching material interactions. This is because teachers' interviews revealed students' low involvement in learning in general. Based on the interviews, it was also revealed that the teacher had never taught students a variety of innovative learning methods. Therefore, the research team asked science teachers with expertise in STEM learning. The teacher has five years of teaching experience, has carried out STEM learning, and has attended STEM learning training organized by SEAMEO STEM in 2022. Meanwhile, some science teachers from the target school became observers.

The results of the learning observations surprised the research team. Overall, the STEM learning activities on temperature and energy materials significantly contribute to students' active learning. Students interacted intensely with others, even with the teacher they just met. The

jigsaw technique encouraged students to seek information about the material to be discussed. It happened because students were responsible for providing the best for their group. According to students, the STEM learning they experienced was delightful. The choice of the STEM project in the form of an otok-otok boat is very appropriate because students are familiar with it. Their lives on the coast are very close to the otok-otok boat. Involving students as experts from each group made students feel responsible. Before discussing it with the expert team, some students searched through the Android or their book. Once the expert team returned to the initial group, they confidently explained their discussion results. Thus, each contributed actively according to his expertise when making a boat design. For example, students designed and built boats systematically, wrote footnotes, discussed possible failures, and discussed the boat's shape so that it is aerodynamic. Figure 1 is an example of authentic evidence of their boat design with the various considerations listed in the draft design.



Figure 1. Students' Otok-otok Boat Project Design

It was fascinating when groups of students tried their designs in the school pool, as shown in Figure 2. They looked highly enthusiastic. They looked, tried, and improved until they got a design they think is right. Living on the beach makes them feel close to this project. They felt that

learning using contexts close to their lives is like learning while playing. This aligns with what Sudarmin et al. (2023) stated: using local wisdom-based learning ideas or contexts will increase students' interest in learning.



Figure 2. Students Trying Otok-Otok Boat They Designed

Students were also more active in collaborating during discussions. Their creativity was trained when designing projects, and their critical thinking was trained when identifying problems and determining project designs during learning by asking several questions. For example, one of the students asked: “Why does this otok-otok boat have to be filled with water, while water can extinguish fires as the main source of the boat’s engine?” Another student asked about the design: “Why does the boat hull we make have to be wide? What will happen if the tip of the boat is not sharp? What effect does it have on the speed of the boat?” These curiosity questions appeared from the students as a form of practicing critical and creative thinking skills. It has also been revealed that engaging learning experiences motivate students to learn better. As stated by previous researchers, students’ skills can be explored optimally (Safitri & Sontani, 2016; Solanki & Xu, 2018; Trevino & DeFreitas, 2014; Wahyuningsih, 2021). According to Aninda (2020), learning that focuses on the growth and development of interactions between students and students, students and teachers, and students with teaching materials will occur if learning is designed innovatively.

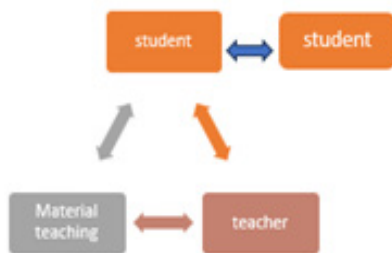


Figure 3. Classroom Interactions with Innovative Learning

Even though the overall implementation of the learning process is excellent and fosters learning motivation in each stage of STEM learning, some students still feel awkward and confused. At the time of the presentation, they still felt shy and lacked confidence. It was understandable because this was the first time STEM learning was implemented in the class.

An innovative and meaningful learning process can impact students’ learning outcomes. The quantitative research showed that the students’ average STEM literacy increased after STEM learning. The average logit value calculated based on statistical item data shows an increase. This increase can be seen from the positive difference between the pretest and posttest logit average values (mean), as illustrated in Table 1.

Table 1. Mean (Logit) of STEM literacy

Items	Mean of Students’ STEM Literacy		
	Pretest (Logit)	Post-test (Logit)	The difference between Pretest and Posttest (Logit)
20	-0.02	-0.01	0.01

The data describes the results of students’ STEM literacy in general. There is a slight shift in students’ STEM literacy. Furthermore, does every student have a shift in a positive direction? Or vice versa? So, a stacking analysis was carried out to see shifts in student abilities.

The Stacking analysis shows increased students’ abilities based on the pretest and posttest results, as shown in Figure 3. There is a significant shift in the increase in students’ STEM literacy. Student number 23, a female, has a good shift in increasing STEM literacy, while student number 22 also has a negative shift in STEM literacy skills. Besides that, the average male students showed good improvements, such as numbers 31, 14, 15, and 21. However, it can be seen that their pretest scores were deficient, and their posttest scores were quite good. The results of the student interviews were based on how they answered the pretest and posttest questions was not serious, so the results were not optimal. These results are seen from the position of students based on the cut-off diagonal line, namely the line of change. Students approaching or above the line of change have an increased shift in STEM literacy skills in a positive direction.

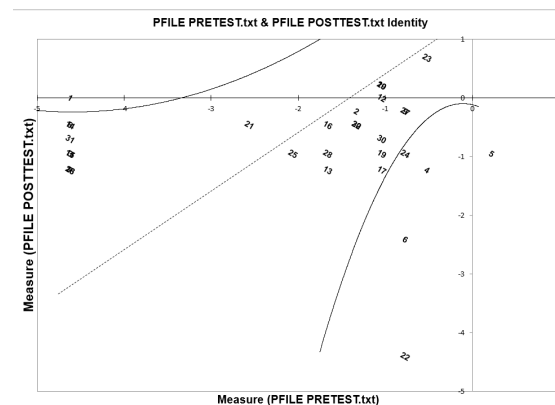


Figure 4. Stacking Scatter Plot of Students’ STEM Literacy

Based on Figure 5, the difficulty level of the questions is shifted to make it easier for students to answer. The closer to the center diagonal line or beyond the center diagonal, the more efficiently the student can answer the question. The

average difficulty level of the questions decreased in scientific literacy questions, such as numbers 20, 6, 13, and 16. Numbers 8 and 9 are mathematical literacy questions, while number 12 is engineering literacy questions. This shows that literacy questions in science experienced a decrease in difficulty because students had accepted and understood the concepts of temperature and energy in science learning.

Several questions are still relatively difficult; students still find them difficult after learning, causing a negative shift. Most of these questions include those related to mathematical literacy, engineering literacy, and technological literacy. Mathematical literacy is dominated by counting activities. Students still pointed out weaknesses, especially when asked to calculate the ideal size for a boat to have maximum aerodynamic properties. The research results show that technological and engineering literacy still needs to be improved. Based on interviews with students, it was revealed that they were still stuttering when making technology and engineering designs. They only know how to develop the design step by step in the learning that has been implemented. However, there is great hope for increasing engineering and technology literacy, considering that based on interview results, students understand technology related to the internet, cellphones, laptops, and other devices well. Meanwhile, related to engineering literacy, with several lessons that raise contexts related to activities such as electricians, car mechanics, and builders (activities that are close to their daily lives), it is believed that students can grow well.

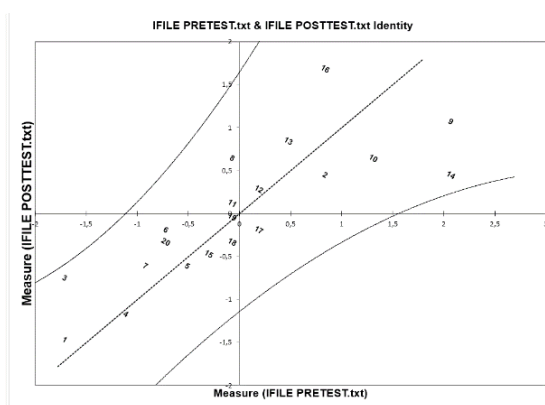


Figure 5. Racking Scatter Plot of Students' STEM Literacy

Regarding gender issues, most male students answered questions related to mathematical, technological, and scientific literacy correctly. For female students, data indicated that

female students' interest and understanding were better for questions related to scientific and mathematical literacy. This is corroborated by the observations during the design and project design stages that male students are more precise when calculating the size of an otok-otok boat. In addition, male students are more appropriate in using technology during learning practices than female students. One of them is when the male student uses a funnel to fill the water into the boat. They did this by placing a funnel on top of the boat's pipe so that the water would go right inside, while the female students used a funnel to collect water and then poured it into the pipe so that much water was wasted.

Another thing revealed in this study was that female students were more adept at drawing and adding color to designs, giving directions, being disciplined, and following the steps and rules that the group had agreed upon. Meanwhile, male students prefer to think outside the habits and rules that the group agreed upon with the desired result, namely the creation of an otok-otok boat. This aligns with research on project-based learning, which shows differences in results based on gender. Male students can show their best performance in mathematics, engineering, and computing (Hyde & Mertz, 2009). While girls perform best in art, science, and memorization, they do not perform well enough in technical subjects (Kulturel-Konak et al., 2011; Nurramadhani, 2020).

The results of subsequent research show that science teachers also feel that their understanding of STEM learning is very inspiring in developing methods and approaches, especially for learning science material, which they find difficult. Teachers find it helpful to innovate in designing interesting and student-centered science learning through STEM. According to the teachers, learning science with STEM clarifies the direction of implementing independent learning in schools and is clearly illustrated. Under its characteristics, STEM learning allows students to learn in-depth, meaningfully, and have fun by identifying problems, finding and designing solutions to these problems, and creating prototypes based on designs that have been made. Teachers can also focus more on the process and development of student learning, not just results. For teachers in rural areas, teaching science through STEM using local context materials is a new thing that is very likely to be developed because it uses materials that can be easily found around and are affordable. The science teachers participating in this study are optimistic that students' STEM lite-

racy and higher-order thinking skills can improve significantly if learning is carried out consistently and continuously.

CONCLUSION

Based on the research results, science learning with the STEM approach is very promising and will be developed to support the Merdeka Belajar curriculum. STEM learning can embody the spirit of the Merdeka Belajar curriculum or learning that accommodates as many students' initiatives as possible in learning and accommodates the diversity and differences in students' characteristics. STEM learning with a local context provides added value for students to understand better the phenomena they often encounter daily. Studying at a school far from the city is no longer an obstacle to teaching students with a STEM approach. Many local contexts that can be used in STEM learning are relevant to the school situation, even for schools in remote areas.

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