# Examining the Role of Mathematics in Primary School STEM Lessons: Insights from a Professional Development Course in Indonesia

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*Balai Besar Guru Penggerak Daerah Istimewa Yogyakarta (BBGP DIY)* conducted a professional development course aimed at enhancing primary school teachers' capacity to develop and implement STEM lesson plans in their classrooms. As part of the course, teachers were asked to record their lessons, which were later analysed to identify the mathematical content involved and how teachers delivered this content during the STEM lessons. The findings indicated that, although mathematics appeared to be less pivotal than other STEM disciplines in the lesson plans, the STEM activities provided rich opportunities for developing students' mathematical content knowledge. Most of the teachers realised this and were able to deliver the mathematical content within the context of STEM education. This paper presents an insight into how primary school teachers in Indonesia deliver mathematical content in their STEM lessons and highlights the role of mathematics in STEM education.

STEM education has gained attention around the world since the last decade, including from those within the mathematics education research community in Australia. An examination of MERGA publications during the last five years showed a number of papers reporting STEM education in various aspects. Anderson et al. (2017) reported a professional learning program to support secondary school teachers to design and implement the most appropriate STEM program for their students. Gervasoni et al. (2017) argued that focus on practices were more aligned with the play-based and intentional teaching objectives in the early years learning framework, rather than the traditional thinking concerning the integration of discipline content knowledge. Symposia papers by Clements et al. (2019) reported the use of digital technology to inspire preschool children's curiosity and engagement in STEM concepts. A study by Ferme (2018) indicated that STEM teachers have greater confidence and attitude towards numeracy than those of non-STEM teachers. Mulligan et al. (2022) reported an interdisciplinary approach to STEM subjects, namely mathematics and science and the role of mathematics in such approach.

Similar to the neighbouring country, there was also growing interest in STEM education in Indonesia during the last decade. A systematic review by Zainal Arifin et al. (2021) showed that the trend of STEM education research in Indonesia began in 2016 and has experienced significant growth afterwards. A Scoping review by Farwati et al. (2021) to map all articles on STEM education implementation published online found that research on this topic has been conducted in 19 out of 38 provinces in Indonesia. Those studies were dominated by West and East Java, the two most populous provinces in the country. STEM education has also been studied in all levels of education, and high schools were the most widely used research contexts. Regular courses for teachers on STEM education have also been conducted by several institutions in Indonesia, namely SEAMEO QITEP in Science, SEAMEO QITEP in Math, BBGP DIY (Professional Development Centre for Educators in D.I. Yogyakarta Province) and BBGP Jawa Barat (similar institution in West Java).

BBGP DIY is an institution under the Ministry of Education, Culture and Research in Indonesia that has responsibility to develop and empower teachers and education personnel in Yogyakarta Province. One way to carry out the duty is by conducting professional development courses to increase teacher competency and their teaching quality. There were four courses offered by BBGP DIY in 2022, namely courses on STEM Education, Differentiated Instruction, Literacy and Numeracy, and Computational Thinking. This paper discusses one of the courses, the course on STEM education. The paper also examines the mathematical content in the lesson plans developed by the course participants and how these were delivered during the lessons. The paper highlights the

(2023). In B. Reid-O'Connor, E. Prieto-Rodriguez, K. Holmes, & A. Hughes (Eds.), *Weaving mathematics education research from all perspectives. Proceedings of the 45th annual conference of the Mathematics Education Research Group of Australasia* (pp. 435–442). Newcastle: MERGA.

role of mathematics in STEM education and provides an insight on how teachers deliver mathematical content in their STEM lessons.

## The Professional Development Course on STEM Education

Ten Indonesian primary school teachers from five districts in Yogyakarta province completed an 82-hour professional development course on STEM Education in November 2022. The course aimed to introduce STEM education and equip teachers with skills to design and implement STEM lesson plans. The teachers, who had more than five years of experience, were generalist teachers teaching various primary school subjects except for physical and religious education. The course also encouraged knowledge and experience sharing among participants. The first author of this paper was the facilitator of the course.

Before the course, a survey was conducted to assess the teachers' understanding of STEM education. Results showed that none of the teachers had undergone professional development on STEM before, and half were not familiar with STEM at all. The other half had heard of STEM but were unsure of its meaning and how to incorporate it into their lessons. They had only encountered STEM through conversations with colleagues, news articles, or online searches.

The professional development course was divided into three phases: development, implementation and evaluation phase. The description of each phase was as follows.

### *Phase 1: Development of STEM Lesson Plans*

In the first phase, teachers participated in a three-day face to face workshop at BBGP DIY or equal to 30 learning hours (one hour was 45 minutes). Each day, the workshop started 7.30 am and finished at 5pm. The workshop covered a brief history of STEM education, the rationale of STEM education, the current trend of STEM education in Indonesia and other countries, and the definition of STEM according to a number of sources such as Tsupros et al. (2009), Bybee (2010), Brown et al. (2011) and Kelley and Knowles (2016). During the discussion, it was found that many participants were familiar with the traditional disciplines of science and mathematics, however they needed more time to discuss and established the definition of technology and engineering. Furthermore, teachers were introduced to the definition of STEM education according to Moore et al. (2014) who argues STEM education is an “effort to combine some or all of the four disciplines of science, technology, engineering and mathematics into one class, unit or lesson that is based on connections between the subjects and real world problems” (p.38).

The workshop introduced three approaches to teaching STEM: Silo, Embedded, and Integrated (Roberts & Cantu, 2012). With Silo, each discipline is taught independently, while Embedded uses one discipline as the anchor, with others providing support. Integrated treats STEM as a single subject, with a minimum of two disciplines involved. Participants shared that they previously taught math and science separately, so the facilitator encouraged them to adopt new approaches such as Embedded or Integrated with more than two disciplines, including Art or Reading, which could result in STEAM or STREAM education

In developing the lesson plans, teachers were free to choose any topic, any content, any real world problem or any situation for their lesson plan. They might choose teaching objectives in accordance with the curriculum used in their school, namely *Kurikulum 2013*, *Kurikulum Darurat* (emergency curriculum) or *Kurikulum Merdeka*. Teachers might use teaching methods such as problem-based learning, project-based learning or inquiry-based learning. Furthermore, to guide teachers to develop STEM lesson plans, the facilitator introduced a five step process which was a modification of the Engineering Design Process: *Empathy, Questions, Ideas, Prototype,* and *Experiment/Evaluation*.

*Empathy*. During this step, teachers presented situations or problems and discussed it with their students. Teachers might present the problem or situation in the form of news, videos, readings or free guided discussion with their students. Teachers were encouraged to foster students' empathy towards their surroundings or environment, understand other people's perspectives, care about others and cultivate students' willingness to help each other for the betterment of all.

*Questions*. This step was important to clarify the problems or situation and ask appropriate questions. During this step, teachers might guide students by asking questions such as "what do you notice?", "is there any problem?", "what happens if...". These questions might overlap with questions to collect ideas from the students.

*Ideas*. Teachers guide students to brainstorm ideas to solve the selected problem or situation. Teachers probed students with questions such as "what can we do in this situation?" "what can we do to solve this problem?" "what else has been done in this situation?' "can we solve this problem better than what other already did?". They might reflect on their experience and if possible undertake research to solve the problem. Several options might arise during the discussion, and teachers guide students to narrow down the options and finally agree on what they would do, for example creating a product, doing activities or conducting experiments.

*Prototype*. Teachers and students discussed tools and material that might be useful for creating the products, doing activities and conducting experiments. Because many teachers were afraid that STEM lessons might become an expensive lesson, they were encouraged to use tools and materials which were available and easy to find around them. This step was a time for them to realise their ideas. Teachers were encouraged to be open-minded and seriously listen to the students to accommodate their creativity as far as it is possible.

*Experiment/Evaluation*. Teachers guided students to test their solution. They might succeed or fail, but it was the opportunity for students to get a better perspective of the problem or situation, and to find better solutions in the future. Teachers guided students to present their work to the class. This was also an opportunity for students to improve their communication skills, one of the important skills needed in 21st century (Partnership for 21st century skills, 2007).

The product of the first phase was a draft of lesson plans which were ready to be implemented in the classroom during the second phase of the professional development course.

### *Phase 2: Implementation of the STEM Lesson Plans*

The second phase, which lasted for three weeks or 35 learning hours, involved teachers implementing the lesson plans in their schools while adhering to their usual teaching schedules. The teachers had the flexibility to create their own implementation schedules based on the lesson plans and school timetables. However, there was a weekly three-hour online meeting with the facilitator to discuss progress, challenges, and solutions to problems that arose during implementation. The online meetings also served as a platform for teachers to give and receive feedback from each other and the facilitator.

Teachers were asked to record the STEM lessons or activities using simple video recording such as mobile phone or any other recording device available in their school. Teachers were also asked to take pictures of students' worksheets and their products. Those recordings, pictures and products were reported to the facilitator and used to support the presentation and discussion at the third phase.

### *Phase 3: Evaluation of the STEM Lesson Plans*

In the third phase, a two-day face to face workshop or equal to 17 learning hours was conducted at BBGP DIY. This second workshop provided an opportunity for the participants to present their final lesson plans, to evaluate their implementation, to learn from other teachers' experiences and to reflect on what they have learnt during the professional development course. During the final workshop, teachers were also introduced to S-T-E-M Quartet Model (Tan et al., 2019; Tang Wee, et al., 2021), that is a framework that helps educators plan, develop, and assess their activities. This common framework provided structure to STEM education, it could improve professional conversations between teachers. In this study, the model was adopted as a tool to assist teachers to evaluate the levels of contribution and connection of each STEM disciplines in their lesson plans, whether it was low, moderate or high. However, due to the limited space for this paper, Table 1 only shows the science and mathematics components and their contribution in the STEM lesson plans identified by the participants.

**Table 1**

*Teachers' Ratings of the Science and Mathematics Components in the Lesson Plans and the Level of Their Contribution in Each Topic*

| Code | Project title | Grade | Science | Mathematics |
|---|---|---|---|---|
| A | Upgrading wasted goods | II | Understanding examples of solid material (Moderate) | Understanding 3D shapes (Moderate) |
| B | Water cycle diorama | III | Understanding the concept of changing the state of matter through rainwater cycle experiment (high) | Measuring the size of the material used for water cycle diorama (low) |
| C | Pretty pots from plastic waste | IV | Utilisation of the school waste, such as plastic bottles (moderate) | Measuring distance between pots, measuring distance of the rope used to hang the pots, frame of 3D shapes (low) |
| D | Fireball thrower | IV | Understanding type of force, elastic force and motion (high) | Measuring and comparing distance of the fireball after it is thrown (Moderate) |
| E | Changing shapes | IV | Understanding the change in state of an object when it is subjected to energy (high) | Measuring time (duration) needed for the shape to change (Moderate) |
| F | Elastic force rocket launcher | IV | Understanding type of force, elastic force and motion (high) | Measuring and comparing distance of the rocket after it is launched (Moderate) |
| G | Creative farming in a small garden | IV | Understanding generative /vegetative propagation of plants with hydroponic media or soil (high) | Understanding data collection by collecting data of the growth of plants, and presenting the data in table or diagram (Moderate) |
| H | Mini solar cell project | V | Understanding sustainable energy, application of series and parallel circuits (high) | Understanding nets of 3D shapes to create a solar cell container (Moderate) |
| I | Floating house | VI | Understanding the cause and effect of flood (high) | Measuring length and calculating area of 2D shapes (Moderate) |
| J | Lunar eclipse model | VI | Understanding the process of a lunar eclipse (high) | Measuring distance between the moon and earth, measuring angle (low) |

## The Research Questions and Data Analysis

The lesson plans, recordings, pictures of students' worksheets, students' products and facilitator's notes during the professional development course were the sources of data. The recordings were viewed multiple times and the other sources were examined to find common themes and differences as well. To reduce bias, the authors shared the data, its analytical process and the results with her colleagues. The data were analysed to answer the following research questions.

- What mathematical content is evident in the STEM lesson plans developed by the participating teachers?
- How do the participating teachers deliver mathematical content during the implementation of the STEM lesson?

## Results and Discussion

### *Mathematical Content in the STEM Lesson Plans Developed by the Participants*

Table 1 showed that measurement was a dominant mathematical topic that appeared in most (seven out of ten) of the STEM lessons. Two teachers used geometry content in their projects, *upgrading wasted goods* and *mini solar cell* project, and one teacher strengthened students' ability in data collection and presentation through the *creative farming in small garden* project. Study by Lasa et al. (2020) also showed that mathematical content in STEM activities is basic and utilitarian and being mostly related to the measurement.

Table 1 column 4 also showed the level of contribution of mathematics in the lesson plans according to the teachers. While eight out of ten teachers rated the level of contribution of science content in their projects as high, none of the teachers rated the contribution of mathematical content as the same. Three teachers rated the contribution of mathematical content as low, while the other seven rated as moderate. These data suggested that teachers put more emphasis in the acquisition of science rather than mathematical concepts during the STEM lessons. This may be because science sounds more closely related to STEM than other disciplines. One teacher associated science and STEM as follows "STEM would never be STEM without science". His opinion might be because science comes as the first letter in the STEM acronym and he was not too familiar with technology and engineering. The finding of this study is in line with study by Just and Siller (2022) that mathematics is often seen as minor matter or a means to an end in STEM secondary classrooms.

Although most teachers rated the contribution of mathematics as moderate or low in their STEM lessons, they still recognised the importance of mathematics as a discipline. They believed that STEM lessons provided rich contextual opportunities to enhance students' interest and understanding of mathematics and its value in daily life. According to one teacher, collaborative STEM lessons could promote a positive attitude towards mathematics, as students learn mathematics in a more friendly and less pressured way compared to traditional classroom settings. All teachers reported that their students were highly engaged and interested in their STEM activities, and they were proud of the products they created themselves.

### *Delivering Mathematical Content During the STEM Lessons*

Observation into STEM lesson plans and the lessons' recordings suggested that teachers used two different approaches in implementing the STEM lesson plans. The first approach (used by teachers A, C, G, H, and I) was started by presenting science related problems or situations, continued by guiding discussion to clarify the problems and then giving students a task to create a product to solve the problem. The second approach (used by teachers B, D, E, F and J) was started by presenting science concepts followed by a science experiment or building a model to enhance students' understanding of the concepts. Further examination of the recordings showed that even though mathematics was not the central role in those STEM lessons, there were opportunities to deliver mathematical content which appeared throughout the lessons and most teachers used those opportunities accordingly. The authors named the opportunity as a “mathematical moment”. Figure 1 shows the mathematical moments that appeared in the STEM lessons.

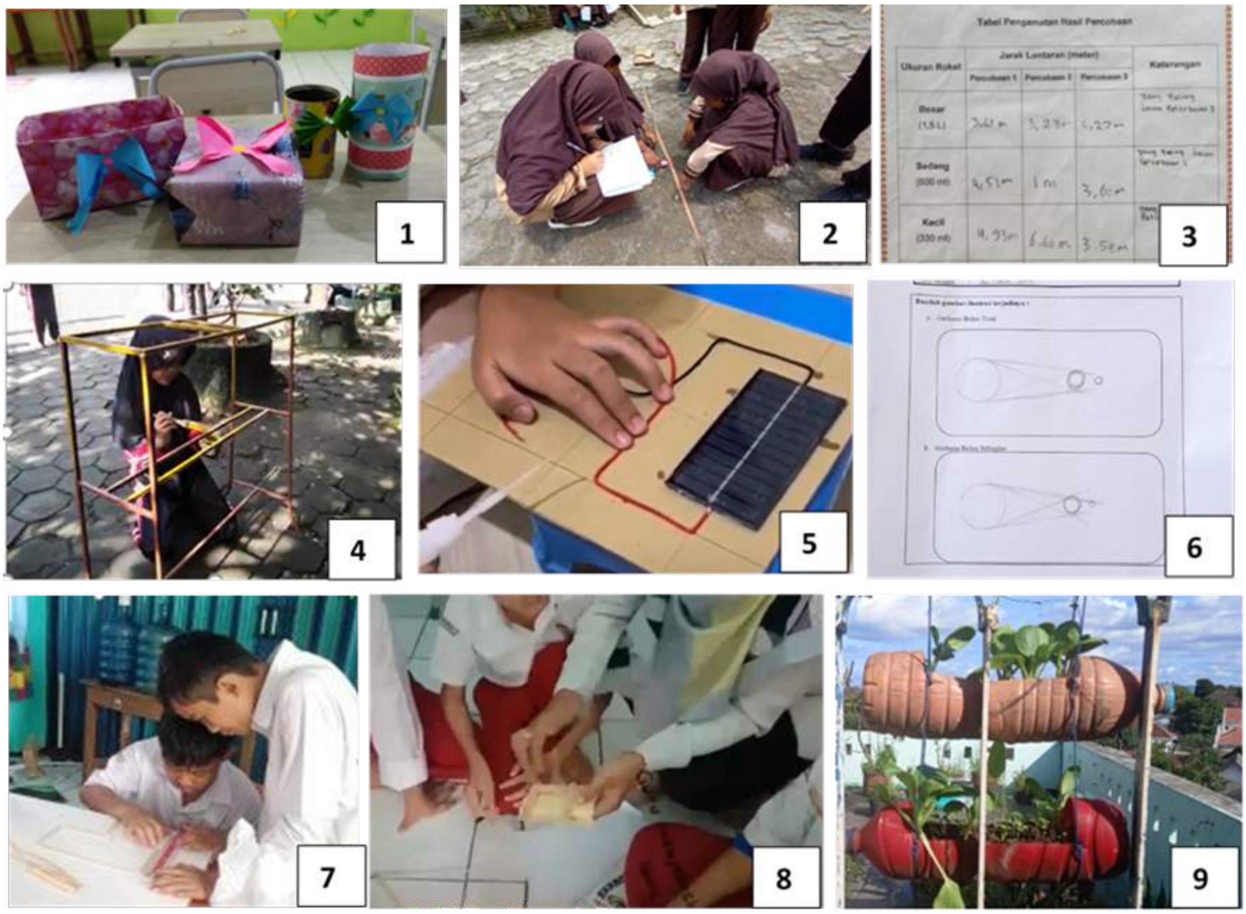


Figure 1. Mathematical moments during STEM lessons.

Figure 1 number 1 showed the moment from *upgrading wasted goods* project. At the end of the project, students were asked to present their work. During the presentation, Teacher A deliberately asked her students questions, such as “what is the name of 3D shape that you made?”. She saw the opportunity to strengthen students’ mathematical knowledge of various 3D shapes and their properties and she used the moment to push mathematical content to the front. Similar moments were found during lessons by Teacher F (Figure 1 Numbers 2 and 3), Teacher C (Number 4), Teacher H (Number 5), Teacher J (Number 6) and Teacher I (Numbers 7 and 8).

Pushing mathematics to the front during the STEM activities was suggested by previous studies (Fitzallen, 2015; Nu’man, 2022) in order to strengthen mathematics during STEM lessons. The participants of the course used this suggestion. However, this effort has its weakness. It could interrupt students’ activities, and the students might not give full attention to teachers’ explanations. It remains a challenge for teachers to push mathematics content accordingly to gain maximum benefit.

Teacher G did not find mathematical moment similar to other teachers. She created mathematical moments to happen. Figure 1 Number 9 captures *creative farming in small garden*. Teacher G gave tasks to her fourth grade students to observe the growth of the plants. Students measured the height of the plants periodically and noted the results. The data collected were used in the mathematics learning spaces in which she guided the students to learn about presenting data in tables and diagrams. Teacher G strengthened mathematics in STEM lessons by integrating real world problems from STEM activities in the mathematics learning space.

## Conclusion, Limitations and Further Studies

This study found that mathematical content was not the main focus of the STEM lesson plans developed by the participants. However, STEM lessons still provided opportunities for teachers to enhance students' mathematical content knowledge by recognising and prioritising mathematical moments. Teachers could then bring those moments into the next mathematics lesson to demonstrate the connection between mathematics and the real world and to enhance students' interest in mathematics. Further professional development initiatives that can help teachers better integrate mathematical concepts and skills into their STEM lesson plans, as this can lead to more engaging and effective STEM instruction for students

The study's results may only be relevant to primary school teachers and their students, and may not be generalisable to other levels of education. The study did not address factors such as curriculum limitations, appropriate mathematical content, and students' developmental levels. Future research is needed to explore effective approaches for promoting mathematics within the framework of STEM education.

## Acknowledgments

The authors wish to thanks to teachers who participated in the professional development course and their students, Dr. Adi Wijaya, M.A, the head of BBGP DIY for his support during the professional development course and Rhonda Faragher for providing feedback during the writing process of the paper.

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