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Using packaging material problems to promote student awareness about the role of mathematics in STEM

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Abstract

STEM learning systems in which the roles of all subjects are unequal, may have a detrimental impact on student learning in neglected subject roles. Therefore, STEM learning packages should have sub-activities that assist students to see the interdependence of all disciplines, especially in mathematics. The nature of the content makes it quite difficult to link it to the mission of STEM. As a result, both teachers and learners are not explicitly aware of the role of mathematics in STEM. Mathematics should not be seen as a simple component in the design of STEM activities, but rather as a vital and necessary aspect. STEM activities based on packaging material problems were developed in this study. The goal is to promote student awareness of the role of mathematics in STEM activities. Seventy-one students, aged 16 and 17 years old, participated in a one-day STEM camp. When the activities were completed, it was found that assessment of student awareness of the role of mathematics in STEM activities was positive. Moreover, teamwork was assessed by groupmates. The evaluation results showed that their behavior was satisfactory. These results indicate that the developed activities are useful for STEM learning in classroom contexts that lack clear tasks reflecting the role of mathematics. Interested instructors can integrate this activity into one sub activity in their own classroom STEM learning packages as appropriate.

Keywords: packaging material problem, STEM education, teamwork behavior, the role of mathematics in STEM

INTRODUCTION

STEM education is a learning management system to which the world pays great attention. This is because it helps develop many skills for learners to live in today's context. Four fields are included in STEM-based education, science, technology, engineering, and mathematics (S, T, E, and M). These four disciplines are united in harmony both for educators who must build missions for STEM learning activities and students who must depend on knowledge of all four disciplines to accomplish the objectives of an activity. In light of this, learning management according to the STEM education model is analogous to preparing students to do everyday duties in the actual world. It will be very useful to pupils (Abu Khurma et al., 2022; English, 2016; Hebebci & Usta, 2022; Koculu et al., 2022; Muhammad et al., 2022).

However, for those who want to create STEM activities, equal consideration must be given to all four fields. Of course, in reality, this may not be complete, but it should be noted that some parts of a STEM activity mission would not have been possible without the knowledge of a particular field. This is a serious concern because often allowing imbalances can result in students developing attitudes that place less importance on some subjects and this results in the need for extra learning, which in turn has long-term negatives outcomes. Therefore, designing a good STEM activity must enable learners to see the roles of S, T, E, and M. It has been discovered that the role of math in STEM is particularly difficult to manifest among these four sciences. The nature of mathematics is abstract. It will take a lot of understanding to connect it with real-world situations that support to STEM missions. It is therefore important to not see mathematics as just a supporting element, but

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Contribution to the literature

- An examination of STEM activities that have imbalanced roles among the subjects, especially mathematics. It is difficult to relate problems in STEM tasks, making students less aware of the value of learning mathematics.
- This research designed an activity to encourage student awareness of the role of mathematics in STEM.
- The developed activities can be integrated into sub-activities in STEM learning that will reduce the imbalance in the roles of the four sciences in STEM.

as an essential part of STEM (Fitzallen, 2015; Just & Siller, 2022; Maass et al., 2019; Man-Keung, 2022; Ring-Whalen et al., 2018). That is a problem that should be considered in developing STEM activities to promote student awareness of the role of mathematics in STEM. It is no less important than developing STEM activities to promote the cognitive (Acar et al., 2018; Chang et al., 2021; Rosli et al., 2019), affective (Fernández-Cézar et al., 2020; Lee et al., 2019; Leyva et al., 2022; Michaluk et al., 2018), or psychomotor domains (Dafik & Tirta, 2022; Nurhayati et al., 2021; Setyawati et al., 2022).

It is important to enable students to understand that the role of mathematics in STEM is no less important than other sciences. The elements of STEM are linked by the need to have good knowledge of mathematics both in terms of its use in STEM missions and in everyday life. Task design in STEM activities must make the role of mathematics in STEM clear and unambiguous (Maass et al., 2019). This research, therefore, develops STEM activities using optimization of packaging materials as a mission to promote student awareness of the role of mathematics in STEM.

Furthermore, it has placed a premium on student teamwork in carrying out the developed STEM activity. This comes with enhanced STEM activities as learning activities based on STEM education emphasize teamwork (Latip et al., 2020; Satchakett & Thana, 2019). The student teamwork is assessed by groupmates at the end of the event. The expected benefit is that the developed activities will be very useful in a classroom context that lacks tasks that clearly reflect on the role of mathematics. Interested persons can combine this activity as a sub-activity in a STEM learning package in their own classes as appropriate.

CONCEPTS UNDERLYING STEM LEARNING ACTIVITIES

Earlier STEM research provides a foundation for the concepts that define STEM tasks (Benacka, 2016; Leung, 2018; Pimthong & Williams, 2021; Tsai et al., 2017; Zendler et al., 2018). The packaging material problem, which requires students to design and create packaging under specific conditions, can link the STEM topics below.

Science

The scientific concepts used to design activities will entail environmental concepts with an emphasis on economical and efficient use of resources. The term "economical use of resources" here refers to the creation of packaging according to the specified design while using the least number of materials in its construction. The phrase "efficient use of resources" in this case refers to the design of packaging with the greatest volume from available materials.

Technology

Technology is unavoidable in today's world. Of course, technological tools are used in packaging design. This could involve technology for finding information, packaging design, or mathematical analysis. This clearly shows how technology is present at every stage of the work process.

Engineering

Packaging design engineers must consider the economical and cost-effective use of resources, according to the concept of environmental conservation. The main focus of this STEM activity is packaging design that optimizes the economical and cost-effective use of production resources.

Mathematics

For the design and construction of packaging according to the concept of environmental conservation, it is necessary to use mathematical information to help make decisions. Under the concept of economical and cost-effective use of packaging materials, mathematical parameters can be divided into two categories. Minimal use of packaging material to create a package of the required volume is consistent with mathematical consideration of the minimum value of a function. Production of packaging with the largest volume from a given amount of packaging material corresponds to the mathematical consideration of the maximum value of a function.

From the above, we can summarize concepts used in creating STEM learning activities, as shown in **Figure 1**.

Two STEM task activities were considered based on the aforementioned concepts.

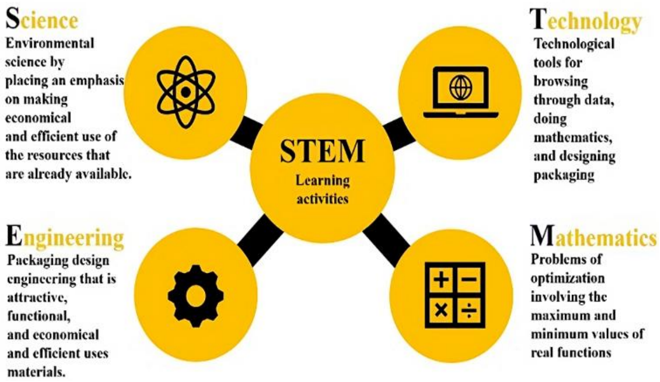


Figure 1. Key concepts underlying STEM learning activities (Source: Author's own elaboration)

Figure 2. Three distinct types of boxes, which consist of two components, a cover, & the box body (Source: Author's own elaboration)

Task 1: Creating the largest capacity box

Encouragement: Today, people all over the world are focusing on environmental conservation, particularly the efficient and beneficial use of limited resources. The use of packaging in our daily lives is also directly related to these environmental concerns. If packaging design considers the value of the materials used, the packaging must be designed to contain as much of a product as possible given a specified amount of packaging material. Consider boxes resembling those in **Figure 2**.

Figure 2 depicts boxes that consist of a cover and a box body. They are easy to use and ideal for storing and displaying products. Scarf, jewelry, and gift boxes are examples. In the majority of instances, 350 GSM art card paper or greater is used to create these types of boxes.

These packaging boxes are designed to be beautiful and usable, and we must also consider the value of the materials used to produce them. If students realize the importance of wisely using resources to promote environmental conservation, how should students design and build such boxes? Therefore, they must consider the most cost-effective use of materials in production.

Mission 1: Assign a sheet of rectangular paper to student teams. The exercise to collect research data necessitates a sheet size of 17×23 cm for construction of the box body.

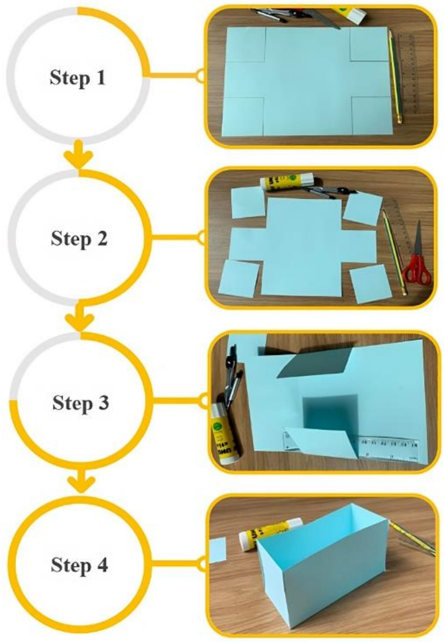


Figure 3. Plan for construction of the box body components of the cover box (Source: Author's own elaboration)

Figure 4. A three-part, three-color can consisting of a body, top, & bottom (Source: Author's own elaboration)

Figure 3 depicts the construction pattern. In this box design, it will be necessary to determine side length of the small square in the four corners of the paper that will maximize the capacity of the box.

Task 2: Creating cans that use the least amount of materials

Encouragement: Consider a can similar to those in **Figure 4**. The three cans shown in **Figure 4** are three-part cans because they are made up of a cylindrical body, with a circular top lid and bottom. Depending on the use of can, the materials used may be tin-plated steel, steel coated with a mixture of phosphate and chromate, aluminum-coated steel, galvanized steel, or aluminum. Electric welding is used today to assemble cans. In addition to being designed to be beautiful and usable, they have to use the least number of materials possible. If students realize the importance of saving resources to promote environmental conservation, how should they design and build their cans? Therefore, they must

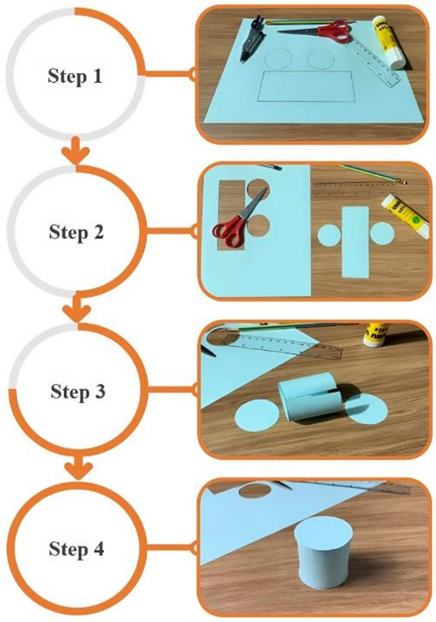


Figure 5. Packaging can construction model (Source: Author's own elaboration)

consider the most economical use of materials in production.

Mission 2: Assign a sheet of paper to be used as the material to create one can. The model is constructed in the sequence shown in **Figure 5**.

Consider the given can design to select rectangular and circle dimensions that allow for a custom-built can have a specified capacity. In the current learning activity, the can has a capacity of 140 cm^3 and is constructed using the least amount materials.

Of the STEM tasks proposed by the two missions, the design of the packaging may not be entirely realistic. However, the thought process of saving and using materials efficiently requires mathematics to analyze and make decisions. Use of knowledge in science, mathematics, and engineering will be more effective when technological tools are used.

Student Teamwork Behavior and Awareness of the Role of Mathematics in STEM Assessment

Since the design of STEM activities emphasizes student awareness of the role of mathematics in STEM and encourages student teamwork, these two assessment issues are presented in the following order in this section.

Awareness of the role of mathematics in STEM assessment

Assessing student awareness of the role of mathematics in STEM is an interesting study. Clearly demonstrating the importance of mathematics in STEM will increase interest in its study (Maass et al., 2019). previously presented (Fitzallen, 2015; Just & Siller, 2022; Maass et al., 2019; Man-Keung, 2022; Ring-Whalen et al., 2018) can be synthesized to create a Likert scale with the following evaluations:

1. **A1.** Executing STEM missions is required to understand the sections where mathematics can be employed.
2. **A2.** Executing STEM missions is required to convert the problem into mathematical form.
3. **A3.** Executing STEM missions is required to find the solution to a math problem.
4. **A4.** Executing STEM missions is required to interpret and evaluate mathematical results.
5. **A5.** Executing STEM missions is required to use mathematical results to make decisions.
6. **A6.** Executing STEM missions is required to use mathematical information as arguments.

The criteria for interpreting a mean score from the questionnaire can be divided into levels, as follows: 4.51-5.00 are the most aware, 3.51-4.50 are very aware, 2.51-3.50 are moderately aware, 1.51-2.50 are little aware, and 1.00-1.50 are the least aware.

Teamwork behavior assessment

Fostering teamwork is one of the primary goals of learning management through STEM education. Several studies have found that using STEM activities to promote teamwork in students has a positive effect (Latip et al., 2020; Satchakett & Thana, 2019). In conjunction with the research framework that studies teamwork behavior (Shofiyah et al., 2022; Strom & Strom, 2011), guidelines for assessing student teamwork will be used in this study. They will be used by group members to evaluate their own teams. The form employs the following assessments that are evaluated on a Likert scale:

1. **B1.** We listen to the knowledge and opinions of our team members.
2. **B2.** We help each other think and express our opinions about the activities.
3. **B3.** We will make polite comments on contentious issues.
4. **B4.** We always reach an agreement.
5. **B5.** We have defined roles and responsibilities in working as a team.
6. **B6.** We have time management to carry out activities efficiently.

Criteria for interpreting the mean score from the questionnaire are based on the following Likert scores: 4.51-5.00 very good behavior, 3.51-4.50 good behavior, 2.51-3.50 fair behavior, 1.51-2.50 behavior should be improved, and 1.00-1.50 behavior should be improved greatly.

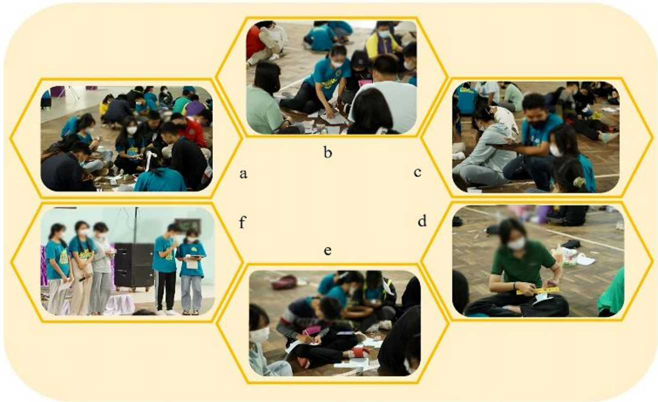


Figure 6. Overall atmosphere of two STEM activities: (a) the students sit in a circle during the activities; (b) the teacher observes and guides the students as they complete their tasks; (c) the students use tablets to assist them in carrying out the activities; (d) a student's attempt to make a box without using mathematics; (e) students design a can using mathematical analysis; & (f) presentation of student work and construction guidelines from a random group (Source: Author's own elaboration)

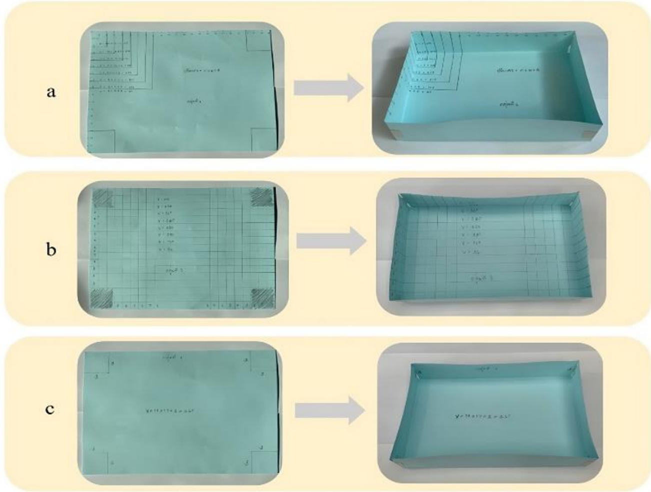


Figure 7. Ideas & work of some student groups: (a & b) student ideas are clearly visible on the workpiece, which shows drafting and consideration of the value and creation of a box; & (c) is different, pre-configured, & then sketched on paper to create a sample (Source: Author's own elaboration)

RESEARCH PROCEDURES

71 science class students, aged 16-17, were divided into 15 groups to participate in a one-day STEM camp.

Activities began with STEM education, where students completed two STEM tasks. Eight math teachers give advice on activities, preparing facilities, as well as providing snacks, and lunch. Upon completion of an activity, students completed an assessment questionnaire about their awareness of the role of mathematics in STEM and teamwork. The results of the assessment were used to create a chart showing mean, standard deviation and percentages based upon Likert scores from the team evaluation, followed by data interpretation. The results of the observations of student activities and the two questionnaire assessments are presented in the following section to guide conclusions about the research findings.

RESULTS AND DISCUSSION

Analysis of study results starts with observations of student activities, which have many aspects, as shown in Figure 6. This image shows the general atmosphere arising from student group activities.

Reflections on these exercises will center on the significant observations that have an impact on the issues studied in this research are presented, as follows.

Scenario 1: Workflow Process to Produce the Largest Capacity Box

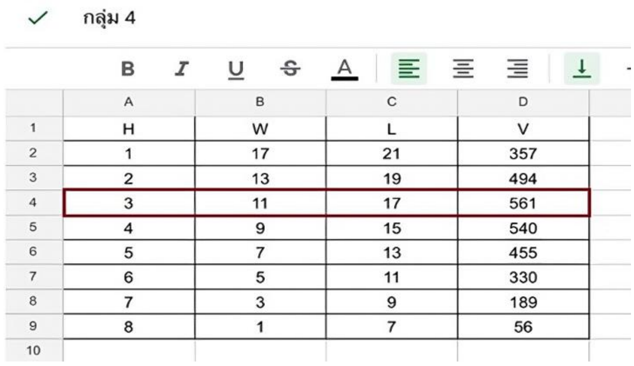
This section reflects group work process of students in task 1, which was to build the largest capacity box with a limited amount of packaging material.

Scene1: Workflow process

The instructor encourages the students to begin the first task of constructing a box by distributing the necessary materials and tools, with information about beverages and snacks that can be consumed during the activity. Each group of students attempts to understand the assignment. A team of instructors surveys each student group to assist them in understanding their mission and the procedure for creating the package according to the described pattern. It is restated that the objective is produce the largest capacity box from the available materials.

The majority of students concentrate on the design of the packaging by sketching directly on the paper that will be used to construct the given packaging. Using a calculator, which is a simple piece of technology, the length of a square is determined that will be cut from the corners of the sheet of paper to yield the greatest box volume. Trial and error calculations are performed to assist in decision-making. Based on environmental science concepts, design and creation of custom boxes is done to meet the goal of resource efficiency. Parts a, b, and c in Figure 7 illustrate examples of student concepts and work based on the aforementioned procedures.

According to Figure 7, the workflow process of most students is of the form seen in parts a and b, where the design is first drawn on a piece of paper. A ruler is used to measure and mark lines to determine the length of box edges that should be used to create the largest volume box. Therefore, it was drawn on paper to create the possible box types. Dimensions were expressed as integers since it is more difficult to draw lines with decimal distance measurements. Then all volumes are calculated to select the best. From parts a and b in Figure


กลุ่ม 4

	A	B	C	D
1	H	W	L	V
2	1	17	21	357
3	2	13	19	494
4	3	11	17	561
5	4	9	15	540
6	5	7	13	455
7	6	5	11	330
8	7	3	9	189
9	8	1	7	56
10				

Figure 8. A Google Sheets calculation table on a tablet to choose the most appropriate value (Source: Author's own elaboration)

7, at a superficial view, they seem to have different characteristics. However, the same workflow is used. This is seen using the design concept, which is clearly an engineering aspect. A box is designed that cost-effectively use construction materials, yielding the highest capacity. This is in line with environmental science concepts. While mathematics and technology play a very small role, it is not evident in the workflow process, which can be called an E-S workflow process.

After students submitted their work, random groups of students are also asked to present their ideas about the construction process and the volume of the resulting packaging. In general, the square size that must be cut at the corners of the paper is 3×3 centimeters, resulting in a box with dimensions of 11×17×3 centimeters and a capacity of 561 cubic centimeters.

There are few groups with concepts that differ from those shown in parts a and b in Figure 7, as illustrated in part c in Figure 7. Here, the selection of corner squares and box volumes are not different from those of the other groups. However, it is interesting to note that the concept shown in part c in Figure 7 does not have a line drawing like many groups do. The size of the square is three centimeters, and it is drawn on the paper to create a box. The instructor has this group present their ideas to the other students.

Scene2: Workflow process changes

In part c in Figure 7, the group shows that they first considered a construction model to define the variables. By forming the size of the cut-out square, then folding it up to a height H. The base width and length can be obtained by subtracting twice the height, which are given as variables W and L, respectively. Then, the box volume, V, is determined. This group used Google Sheets on tablet devices to calculate table dimensions and volumes, selecting the greatest value (Figure 8).

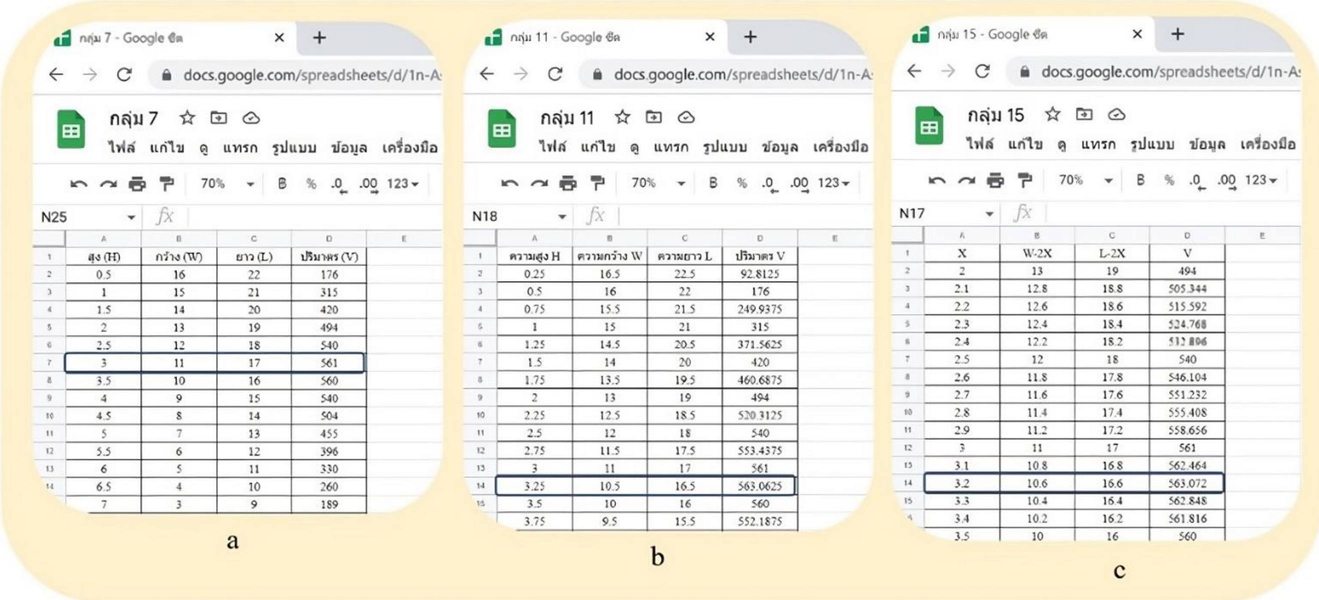
As a result of the group's presentation, the workflow process shifted from an original focus on design, which was E (engineering), with little assistance from M (mathematics) and T (technology), to creating a workpiece that aligns with the mission objectives. This stimulates student awareness of environmental issues, which is S (science). This was previously referred to as the E-S workflow process, where the M and T are not explicitly involved. The process was changed by considering the situation in terms of M (mathematics), although it was basic mathematics with variables and formulas. Then, the approach began to change. Google Sheets is a technological tool (T) that plays a prominent and important role in the process to determine important values in the design (E) to achieve the concept of (S). It can be seen that the process will change from an E-S workflow to on the follows an M-T-E-S process.

Numerous issues were discussed after sharing ideas. One of the most important was that the original workflow process was limited by not using decimal box dimensions, which was quite difficult. As a result, the students designed with integer values rather than decimals, as shown in Figure 8. However, the teacher could ask questions about the size of the square at the corner of the paper. Is it possible to use decimal values? Then, each group of students tried to adjust their work, where they changed their concept to use an M-T-E-S workflow process and used Google Sheets to calculate results, as shown in Figure 9. Using 0.5 increments, as shown in part a in Figure 9, shows an optimal value of 3 cm, which yields a volume of 561 cm^3, identical to the original workflow process.

Increments of 0.25 increments, as shown in part b in Figure 9, yields an optimal value of 3.25 cm. The measuring device is a millimeter-scale ruler. The result was estimated as close to 3.3 cm, giving a volume of 562.85 cm^3. Finally, using increments of 0.1, as shown in part c in Figure 9, yields an optimal value of 3.2 cm, which corresponds to a volume of 563.07 cm^3. Which of these three cases is the best? Figure 10 compares the student's work in all three cases.

From Figure 10, it can be seen that a tallest box has the narrowest base and the box with the widest base and shortest height are not boxes that give the desired volume. The box with the optimal volume has an intermediate sized height and base, which clearly shows the meaning of the word "optimum."

Achievement of the conceptual work shown in part c in Figure 7 by the students alters the activity's original plan. This is because the original plan required that the teacher explain the process in accordance with the M-T-E-S workflow process guidelines. The teaching team, on the other hand, linked what happened to the original plan and continued. At this point, the teacher asked whether we could clearly demonstrate to others that the value we had chosen was the most suitable. In this section, the instructor elaborated on the concept of the workflow processes, highlighting the significance of mathematics in the process.



สูง (H)	กว้าง (W)	ยาว (L)	ปริมาตร (V)
0.5	16	22	176
1	15	21	315
1.5	14	20	420
2	13	19	494
2.5	12	18	540
3	11	17	561
3.5	10	16	560
4	9	15	540
4.5	8	14	504
5	7	13	455
5.5	6	12	396
6	5	11	330
6.5	4	10	260
7	3	9	189

ความสูง H	ความกว้าง W	ความยาว L	ปริมาตร V
0.25	16.5	22.5	92.8125
0.5	16	22	176
0.75	15.5	21.5	249.9375
1	15	21	315
1.25	14.5	20.5	371.5625
1.5	14	20	420
1.75	13.5	19.5	460.6875
2	13	19	494
2.25	12.5	18.5	520.3125
2.5	12	18	540
2.75	11.5	17.5	553.4375
3	11	17	561
3.25	10.5	16.5	563.0625
3.5	10	16	560
3.75	9.5	15.5	552.1875

X	W-2X	L-2X	V
2	13	19	494
2.1	12.8	18.8	505.344
2.2	12.6	18.6	515.592
2.3	12.4	18.4	524.768
2.4	12.2	18.2	532.896
2.5	12	18	540
2.6	11.8	17.8	546.104
2.7	11.6	17.6	551.232
2.8	11.4	17.4	555.408
2.9	11.2	17.2	558.656
3	11	17	561
3.1	10.8	16.8	562.464
3.2	10.6	16.6	563.072
3.3	10.4	16.4	562.848
3.4	10.2	16.2	561.816
3.5	10	16	560

Figure 9. Google Sheets results filed for some groups: (a) a group of students who considered dividing integer values in half; (b) a group of students who considered dividing integer values a one-quarter; & (c) another group of students who divided integer values into tenths (Source: Author's own elaboration)

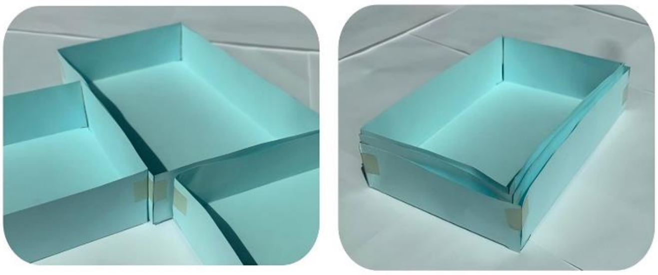


Figure 10. Image on the left side shows heights of 3.3, 3.2, & 3 cm arranged in order from left to right & the right-hand side image, compare the sizes of the box bases, showing that a taller box has a smaller base, which can be stacked on shorter boxes, but the base size changes accordingly (Source: Author's own elaboration)

Scene3: Workflow process refined

The instructor introduced concepts adapted from the previous workflow processes that started with M, mathematics, then applied T, technology, for assistance. Finally, the obtained value was used in design, which is E, engineering, to form a workpiece according to the target of S, science.

Figure 11 depicts the shape of the construction of the box. Let x represent the length of the square at the four corners of a 17×23 cm sheet of paper. When the corners are cut and folded to create a box, the width of the box base is the paper width minus $2x$ cm, or W-$2x$ cm. L=23-$2x$ cm is the length of the box's base, while H=x is the height of the box. The volume can be calculated V=W×L×H cm^3, which will give V=(17-2x)(23-2x)x cm^3. Changing the paper size was done to create an updated relationship. In this instance, the paper size is a mathematical constraint or condition.

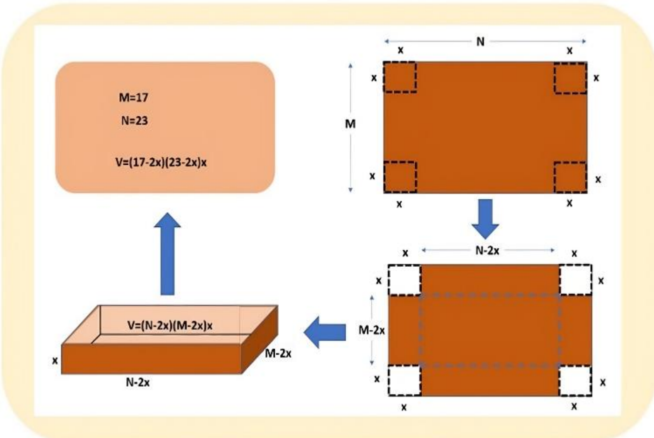


Figure 11. An image that teachers used to explain consideration of dimensions that must be understood to mathematically design a packaging box (Source: Author's own elaboration)

Relationship V=(17-2x)(23-2x)x was digitally plotted. In the graph command, V is represented by f. The relationship is f=(17-2x)(23-2x)x, as shown in **Figure 12**.

When we look at the resulting graphs, we can see the range of values for which the graph returns the maximum value when x falls within that range (1, 8). It was observed that f is has its maximum when x is on the interval (3, 4), as shown in part a in **Figure 12**.

Considering further by examining the (3, 4) range at a precision, it was found that f has the highest value when the value of x is in the range (3.2, 3.3), as in part b in **Figure 12**.

Refining the (3.2, 3.3) range into two decimal places, it was found that f had the highest value in the range (3.22, 3.23), as shown in part c in **Figure 12**. Since only

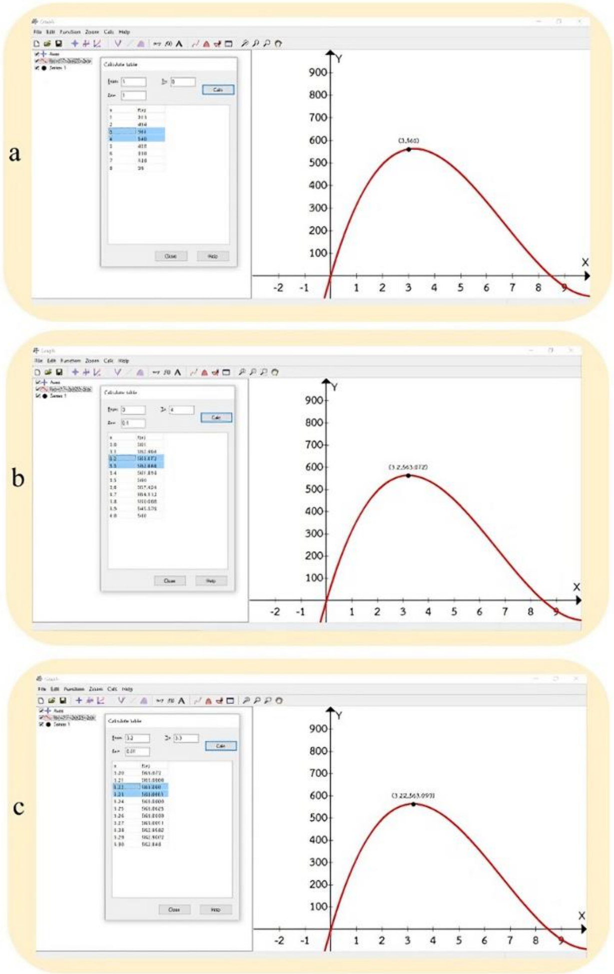


Figure 12. Determination of maximum value of a function from a graph & a reduced range of decimal places, respectively: (a) is a graph finds unit range that gives maximum value of a function; (b) considers one decimal to find one-decimal range that gives maximum value of function; & (c) considers two decimal places for maximum value of the function (Source: Author's own elaboration)

one decimal place is needed to work with a millimeter-scale ruler, verification can be completed to two decimal places. A close approximation yields x=3.2 cm, corresponding to a volume of 563.07 cm^3. The instructor has each group of students use this idea to create another workpiece. A team of instructors helped guide every group using a work process with an M-T-E-S workflow with this refined method. The boxes of all groups were identical, and no differences are seen (Figure 13).

Scenario 2: Applying Prior Workflow Process to Produce Cans With the Least Amount of Material

As with the first task, the instructor encourages students to move on to the second task. All student groups begin their initiation process by emphasizing problem analysis to translate the problem into a mathematical form. However, due to the lack of experience in this process, and the class required training, the instructor must expend much effort in this section. For students to create conditional volume

Figure 13. Boxes for all groups as a result of the workflow process adjustment using mathematical knowledge (Source: Author's own elaboration)

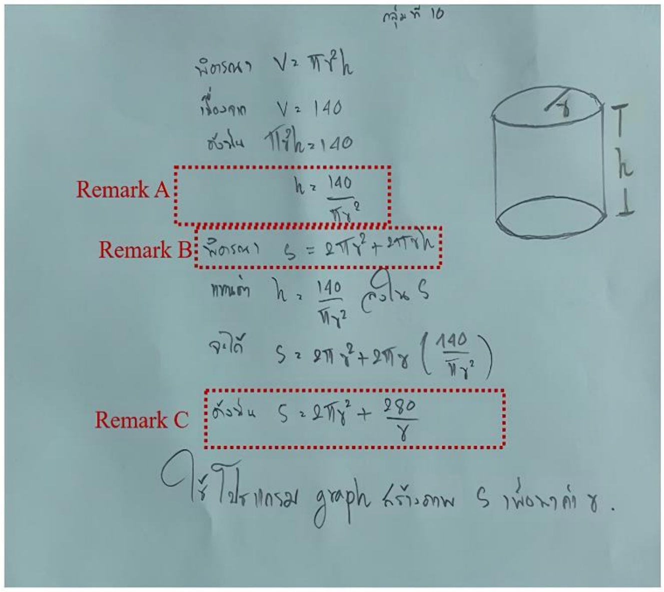


Figure 14. Learner's mathematical analysis, where remark A is a condition resulting from knowing the volume value given remark B as a surface formula. This is the target function to find a minimal value. Remark C is a formula resulting from a graph to analyze the desired value by substituting the conditions into the surface formula to create a relationship with one independent variable and one dependent variable (Source: Author's own elaboration)

formulas, the relevant variables must be defined. To minimize the use of materials, target surface formulas can be created to determine the minimum values for analysis. Incorporating these conditional volume relations into a target surface formula allows for mathematical analysis of the results. It took quite some time in this section before the students were able to obtain a formula, which is a relationship that would lead to the next step of finding , as shown in Figure 14.

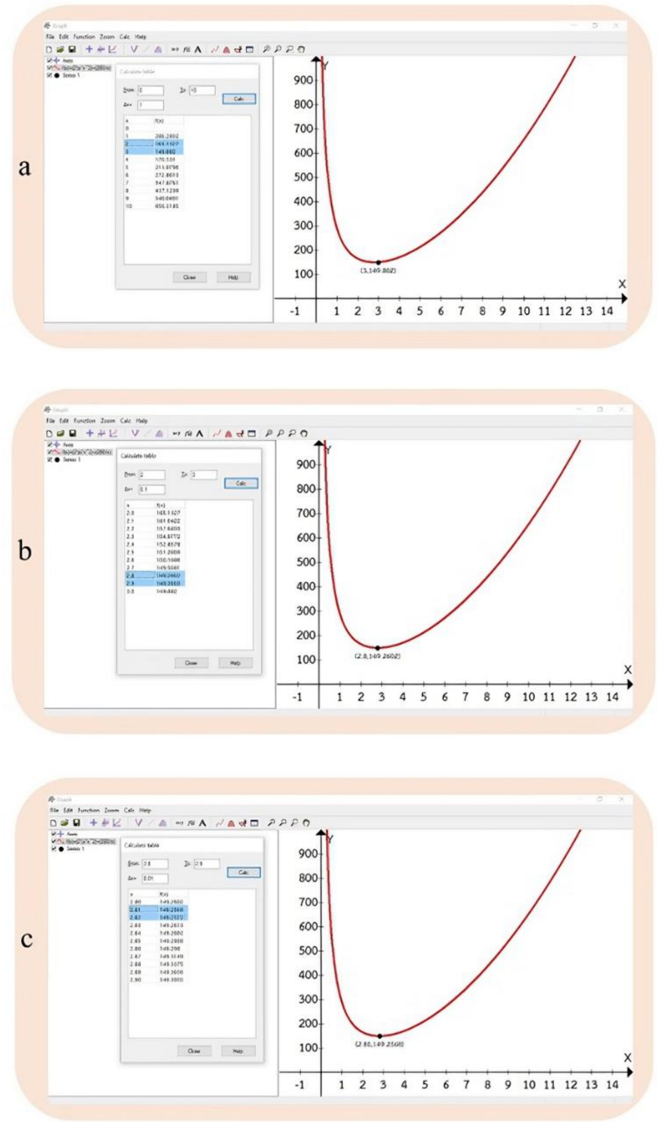


Figure 15. Outcomes of surface area minimization using a graphing program that considers a range of values to be narrowed from a unit range to a one-decimal & two-decimal ranges as graphs a, b, & c, respectively (Source: Author's own elaboration)

From **Figure 14**, each group of students calculated the formula obtained from the relationship of the surface variable S with the radius r of the cylinder according to Remark C using technological tools and a graph to help in analysis and consider the radius r that makes the can volume 140 cm^3 with the least surface area. In this case, the program uses f in place of S and x in place of r. The results of the analysis to obtain a value to one decimal place are shown in **Figure 15**.

Figure 15 has a resolution of two decimal places because it will be measured to one decimal place and estimated to two-decimal places, allowing workpieces to be created using a millimeter-scale ruler. **Figure 16** depicts the values used in the design to model the three components of the can.

When all three components were obtained, as shown in **Figure 16**, each group of students constructed a workpiece, a can container with a capacity of 140 cm^3 that used approximately 149.26 cm^2 of material. The values are the same because the workflow process involved analysis using the same approach. **Figure 17** displays the results of all 15 groups.

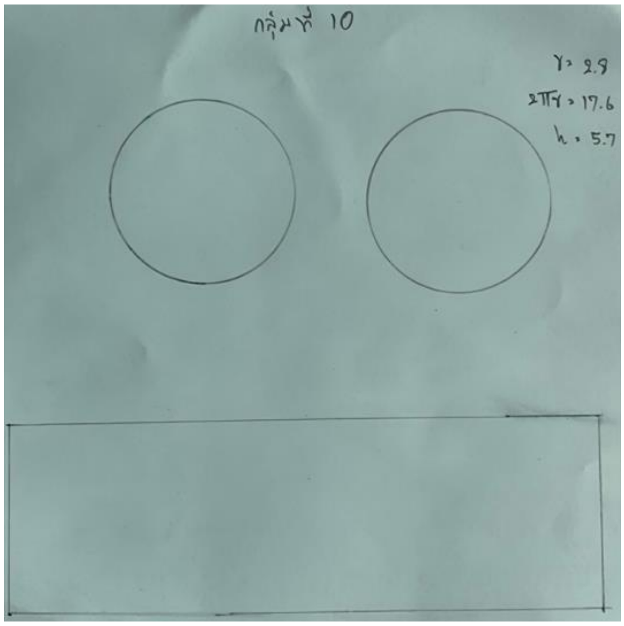


Figure 16. A design for all three parts of a can: all three dimensions are obtained through mathematical analysis using a graphing program (Source: Author's own elaboration)

Figure 17. 15 groups of student container-making projects are identical in size because they all follow the same construction procedure (Source: Author's own elaboration)

The instructor randomly selected two teams to review their ideas. As a result, the M-T-E-S workflow process is used again. Following the completion of activities, student awareness of the role of mathematics in STEM was assessed. Peer evaluation was used to evaluate teamwork. **Figure 18** depicts the findings of an assessment of student awareness of the role of mathematics in STEM.

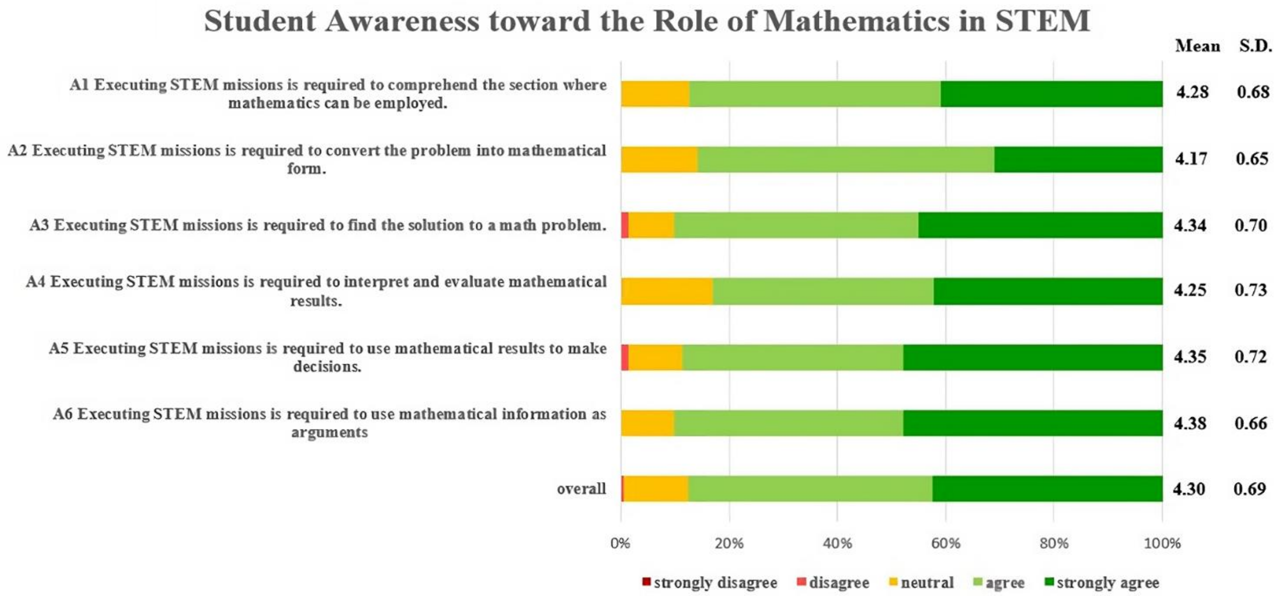


Figure 18. Results of an evaluation of student awareness of the role of mathematics in STEM (Source: Author's own elaboration)

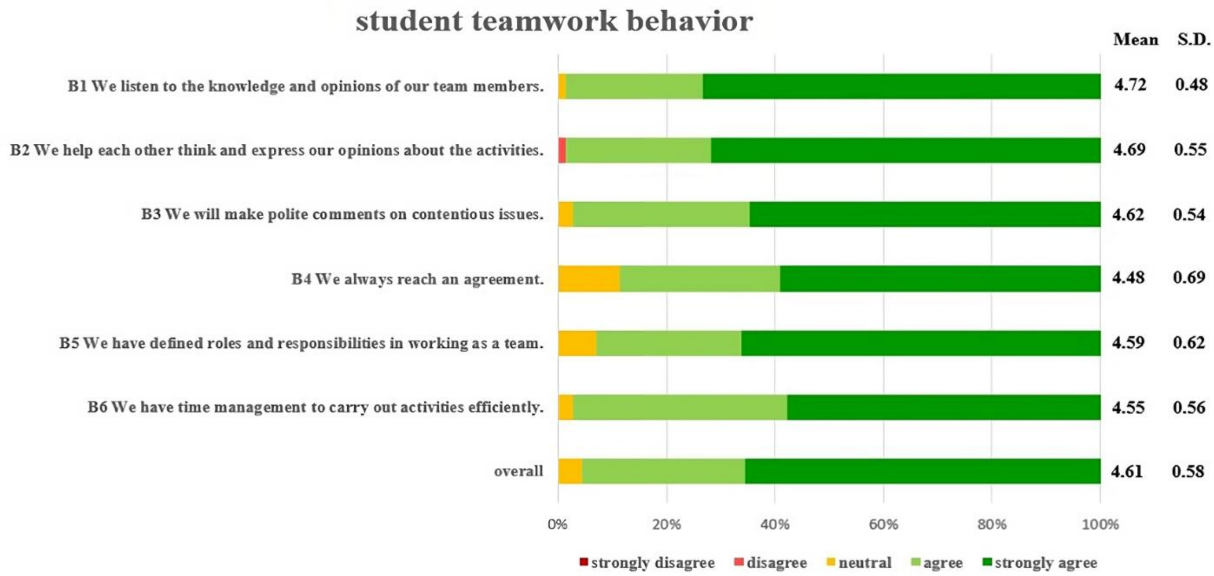


Figure 19. Assessment results of student teamwork in STEM activities (Source: Author's own elaboration)

Figure 18 shows Likert scale results with mean and standard deviation values displaying the results of an assessment of student awareness of the role of mathematics in STEM. According to the results interpretation criteria, the average scores of students across all topics ranged from 3.51 to 4.50, indicating that they were very aware of the roles of mathematics in STEM. An overall analysis yielded a consistent conclusion with a mean of 4.30 and a standard deviation of 0.69. The teamwork assessment results are summarized in **Figure 19**.

From **Figure 19**, it was determined that the majority of aspects were evaluated at a very good level, with the exception of the B4 aspect, which averaged 4.48. Overall, the analysis revealed that the student teamwork was exceptional.

For assessing student awareness of the role of mathematics in STEM, the activities were designed to emphasize that students were not only looking at mathematics as a component in STEM, but clearly pointing out that math is an important component of STEM activities. The workflow process that occurs is not a standard that STEM activities must use as well. However, the workflow process for student activities has resulted in students seeing the very important role that mathematics plays in completing assigned activities. The positive significance of the assessment of student awareness of the role of mathematics in STEM emerged. This is in line with the suggested guidelines that STEM activities must be designed so that students can clearly see the role of math in STEM (Maass et al., 2019).

Previous research indicates that teamwork is one of the primary objectives of learning management with STEM activities that teachers can employ to develop students (Latip et al., 202; Satchakett & Thana, 2019). The findings of this study regarding the evaluation of student teamwork are consistent with previous research.

Additionally, the mathematical foundation of students is very important in the design of the activity. Students participating in the activity had no knowledge of calculus, which would have greatly simplified their design activities. With very little time, students were able to construct functions and consider their derivatives to find their optimum values. At the same time, if this activity is applied to students who still have insufficient knowledge of mathematics to carry out the activity, it can also cause feelings of anxiety. Designing activities that fit the student knowledge level is therefore key to helping students achieve their goals.

CONCLUSIONS

This study has mathematical implications in the context of STEM education activities that lack clarity of their role in STEM. This may be due to difficulty in linking the content to build it into a STEM mission that focuses on real-world problems. When the role of mathematics cannot be clearly seen in an activity, its role may be neglected in the long term. Development of activities that highlight the role of mathematics in STEM was made in this research to encourage a group of seventy-one high school students who participated in STEM activities. Data was collected to assess the results of the developed activities. The overall assessment of student awareness of the role of mathematics in STEM was good at the end of these STEM activities. These students understand the importance of having strong math skills to complete STEM missions. This highlights the importance of learning mathematics. Additionally, teamwork was found at a very high level. This enables cultivation of the real-life skills needed in today's global context. These results indicate that the developed activities can be integrated into sub-activities in STEM learning by interested parties. This will reduce the imbalance in the role of the four STEM sciences.

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