JRPM, 2026, *11*(1), 70-83
JRPM (Jurnal Review Pembelajaran Matematika)
http://jurnalftk.uinsa.ac.id/index.php/jrpm

STEM-Based Hypothetical Learning Trajectory: The Context of Ice Cream Making in Algebraic Multiplication Material

Arvin Efriani[1*], Sujinal Arifin[2], Dea Ananda[3]

[1,2] Universitas Islam Negeri Raden Fatah Palembang, Sumatera Selatan, Indonesia
***Corresponding Author:** arvinefriani_uin@radenfatah.ac.id

ARTICLE INFO

Article history:
Received 24 Jun 2025
Revised 7 Mar 2026
Accepted 13 Mar 2026

Keywords:
Learning Design;
STEM; HLT

ABSTRACT

This study addresses students' limited understanding of algebraic multiplication and the limited integration of the STEM (Science, Technology, Engineering, and Mathematics) approach in mathematics learning. The aim is to design a STEM-based Hypothetical Learning Trajectory (HLT) for algebraic multiplication and analyze student responses. Using a design research method, the study comprised three stages: preparation, design experiments (pilot and teaching), and retrospective analysis. The participants were seventh-grade students at SMPLTI Indo Global Mandiri Palembang. Data were collected through observation, tests, interviews, and documentation. Results show that STEM-based HLT, grounded in simple ice cream-making, improved students' understanding of algebraic multiplication, their critical thinking, and their engagement and interest. Students also responded positively to contextual learning that integrates STEM components.

© 2026 The Author(s)
Published by JRPM (Jurnal Review Pembelajaran Matematika)
This is an open-access article under CC BY-SA license
(https://creativecommons.org/licenses/by-sa/4.0/)

How to cite:
Efriani, A., Arifin, S., & Ananda, D. (2026). STEM-Based Hypothetical Learning Trajectory: The Context of Ice Cream Making in Algebraic Multiplication Material. *JRPM (Jurnal Review Pembelajaran Matematika)*, *11*(1), 70-83.

INTRODUCTION

Mathematics learning at the junior high school level often presents its own challenges for students, especially in algebra. One part of algebra that students still find difficult is algebraic multiplication. This difficulty is not only due to the abstract nature of mathematical symbols, but also to the lack of connection between the material and real-life contexts that are easy for students to understand (Lestari & Suryadi, 2020). This is in line with the findings (Mutaqin et al., 2023) that algebra learning requires a contextual learning path in order to be logically accepted by students. Based on observations at Indo Global Mandiri Information Technology Life Skills Junior High School, it was found that some students had difficulty understanding the concept of algebraic multiplication, especially when they had to relate it to with phenomena in everyday life. In addition, learning still rarely utilises technology-based

ISSN 2503–1384 (*online*)
DOI: https://doi.org/10.15642/jrpm.2026.11.1.70-83

or digital media approaches such as live worksheets and Zep Quiz, creating a gap between the development of educational technology and classroom practice (Andriani, 2020). In fact, technology-based interactive media has been proven to increase the attractiveness of learning and students' process skills (Asmita et al., 2022).

To address these issues, a learning approach is needed that integrates mathematical concepts with the real world, one such approach being STEM (Science, Technology, Engineering, and Mathematics). STEM is an interdisciplinary approach that combines the four scientific fields to improve students' critical thinking, creativity, and problem-solving skills (Ibáñez & Delgado-Kloos, 2018; Murnawianto et al., 2017; Saputri & Herman, 2022).

For STEM-based learning to be more focused and tailored to students’ characteristics, a systematic learning design is required: the use of the Hypothetical Learning Trajectory (HLT). HLT is a learning design framework comprising learning objectives, learning activities, and predictions of students' thinking processes during activities (Hendrik et al., 2020a; Simon, 2020). Through HLT, teachers can design a learning sequence that gradually guides students in understanding the concept of algebraic multiplication through contextual, meaningful activities. In addition, HLT allows the development of didactic designs based on learning obstacles identified through initial assessments (Suwarto & Purnami, 2018).

The purpose of this study was to develop and apply a STEM-based Hypothetical Learning Trajectory (HLT) design to algebraic multiplication material with the context of making simple ice cream as a real phenomenon. This design aimed to improve students' understanding of algebraic concepts, develop critical thinking and problem-solving skills, and facilitate the integration of technology in the learning process.

STEM learning integration has great potential in encouraging student engagement, improving understanding of mathematical concepts, and developing 21st-century skills (Ai'syah et al., 2022; Milaturrahmah et al., 2017; Uzun & Şen, 2023; Villaruz et al., 2019). Previous studies have demonstrated the effectiveness of the STEM approach in improving mathematical skills and in visualising geometric concepts (Saputri, 2023; Saputri & Herman, 2022), but few have focused specifically on STEM-based HLT learning design for algebraic multiplication.

This study offers a novel contribution by developing a STEM-based Hypothetical Learning Trajectory (HLT) specifically for algebraic multiplication using a contextual approach grounded in the real-life activity of ice cream making. While previous studies have explored the integration of STEM in mathematics learning and the application of HLT in various mathematical topics, limited research has focused on systematically integrating STEM components within an HLT design for teaching algebraic multiplication at the junior high school level. Furthermore, this study incorporates the Engineering Design Process (EDP) as a structured framework to support students' conceptual understanding through meaningful and sequential learning activities. Therefore, the purpose of this study is to design and implement a STEM-based HLT for algebraic multiplication and to analyze students' responses and understanding during the learning process. The findings of this study are expected to contribute both theoretically and practically by enriching the literature on STEM-integrated learning design and providing teachers with a contextual and applicable learning trajectory that can enhance students' conceptual understanding, critical thinking skills, and engagement in mathematics learning.

RESEARCH METHOD

This study used a Design Research approach to develop a Hypothetical Learning Trajectory (HLT) for STEM-based algebraic multiplication material. Referring to (Gravemeijer & Cobb, 2006), this study consisted of three stages:(1) preparing for the experiment, (2) designing the experiment, and (3) retrospective analysis.

In the initial stage, researchers designed HLTs that included learning objectives, student activities, and assumptions about student thinking. The design experiment stage was conducted in two cycles: a pilot experiment (small-group trial) and a teaching experiment (classwide trial) to observe the actual learning trajectory (ALT). The final stage, the retrospective analysis, was used to examine the data and refine the Local Instructional Theory (LIT).

The research subjects were 25 seventh-grade students of the Indo Global Mandiri, Palembang, Sumatera Selatan, Indonesia. Informatics Technology Life Skills class in the even semester of the 2024/2025 academic year, who were selected purposively because the school had not yet implemented STEM learning, and the students still had difficulty understanding algebraic multiplication.

Data collection techniques include observation, tests, interviews, and documentation. Observation is used to assess learning, tests (pre-tests and post-tests) to measure improvement in understanding, interviews to explore students' thinking, and documentation (student worksheets) to assess progress and conceptual errors.

Data analysis in this study was carried out using both qualitative and quantitative approaches in accordance with the research design. Qualitative data obtained from observations, interviews, and students' worksheets were analyzed using the interactive model of Miles and Huberman, which includes data reduction, data display, and conclusion drawing/verification. This analysis aimed to describe students' learning processes, identify learning obstacles, and examine the alignment between the Hypothetical Learning Trajectory (HLT) and the Actual Learning Trajectory (ALT) during both the pilot experiment and the teaching experiment.

Quantitative data were obtained from students' pre-test and post-test results to measure the improvement of their understanding of algebraic multiplication concepts. The data were analyzed using the N-Gain test to determine the level of students' learning improvement after the implementation of the STEM-based HLT. The results of the N-Gain analysis were used to support the findings from the qualitative data, particularly in showing the effectiveness of the designed learning trajectory in improving students' conceptual understanding.

Furthermore, the overall analysis was conducted through retrospective analysis, which is a key stage in design research, to evaluate the learning process and refine the HLT based on the comparison between the predicted learning trajectory and the actual learning outcomes.

RESULT AND DISCUSSION

This study aims to develop a STEM-based Hypothetical Learning Trajectory (HLT) for algebraic multiplication material and to determine students' responses and understanding of its implementation.

Preparing for the experiment

Hypothetical Learning Trajectory (HLT) Design

In this design stage, the researcher outlined the learning objectives, the sequence of student activities in the learning process, the students' conjectures, and the tools used to support the learning process within the HLT.

Activity 1

In Activity 1, the Engineering Design Process stages of defining the problem (identifying the problem) and researching (gathering information related to the problem) are used. Students identify problems in the context of making ice cream and understand the roles of salt, milk, and ice cubes.

- Low conjecture: students do not yet understand the problem and the role of the ingredients.
- Medium conjecture: students begin to understand the function of salt, but still need additional information.
- High conjecture: students can explain the role of ingredients scientifically and relate it to the freezing process.

Activity 2

In Activity 2, the Engineering Design Process stage of imagining (determining ideas from problems) is used—students compile illustrations of the relationship between the number of ice cream servings and the ingredients needed.

- Low conjecture: the illustration does not match the amount of ingredients required.
- Moderate conjecture: students begin to draw pictures, but they are not yet accurate.
- High conjecture: students create accurate tables and illustrations based on the pattern.

Activity 3

In Activity 3, students use the Engineering Design Process stages of planning (planning or designing ideas from the previous stage) and creating (implementing or creating ideas that have been planned or designed). Students arrange patterns in the form of algebraic expressions of the relationship between the amount of material and the portion.

- Low conjecture: students do not yet understand the use of variables and pattern formation.
- Moderate conjecture: students begin to use variables but are not yet consistent in arranging patterns.
- High conjecture: students can use variables to simplify calculations in algebraic form.

Activity 4

In Activity 4, the Engineering Design Process stages of testing and evaluating (testing and evaluating ideas that have been created), redesigning (redesigning ideas), and communicating (communicating or summarising the results obtained) are used. Students apply algebraic models to contextual problems, adjust the models when there are changes in materials, and summarise the learning outcomes.

- Low conjecture: students are not yet able to connect the algebraic model to the problem's context.
- Medium conjecture: students can solve problems, but are not yet able to communicate

their results comprehensively.

- High conjecture: students can correctly construct algebraic calculations, understand the use of algebraic multiplication, and relate learning to the benefits of mathematics in everyday life.

Researchers designed learning hypotheses in the form of HLT and student learning paths in the form of icebergs to illustrate the process of student understanding, starting from real contexts to reaching abstract mathematical understanding. The following are the HLT and icebergs that have been designed.

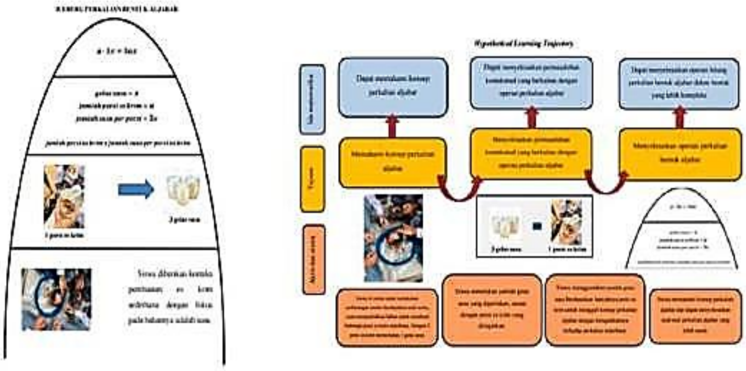


Figure 1. Iceberg and Initial HLT

During the Preparing for the experiment stage, the HLT results were validated by experts, suggestions were obtained, and improvements were subsequently made. The suggestions and input from the validators during the expert review stage will serve as a reference for improving the previously designed HLT and Iceberg, especially the comments and suggestions they provided on the previously compiled designs. The researcher will carefully consider the validators' suggestions and implement relevant improvements to the HLT.

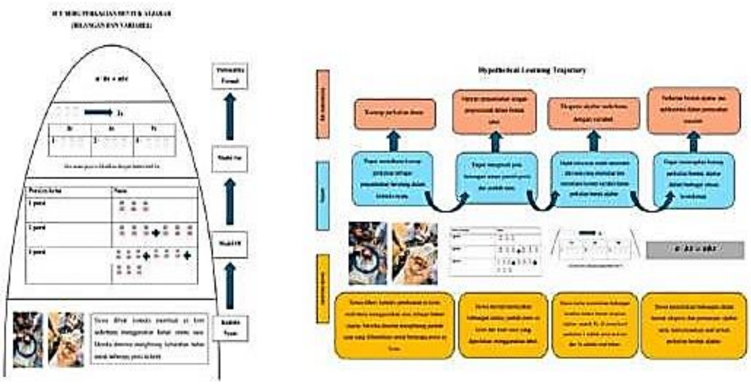


Figure 2. Final Iceberg and HLT

Pilot Experiment

A pilot experiment was conducted with six seventh-grade students at Ahmad Yani

SMP LTI Indo Global Mandiri Palembang to test the feasibility of the designed Hypothetical Learning Trajectory (HLT). Students were given Student Activity Sheets (SAS) in four stages, aligned with the Engineering Design Process (EDP) from STEM.

Activity 1 (define the problem and research)

In this stage, students were introduced to the basic concepts of making simple ice cream, including the important roles of salt, milk, and ice cubes in making ice cream.

Activity 2 (imagine)

In this stage, students are asked to compile pictures in a table by understanding the relationship between the number of servings and the amount of ingredients.

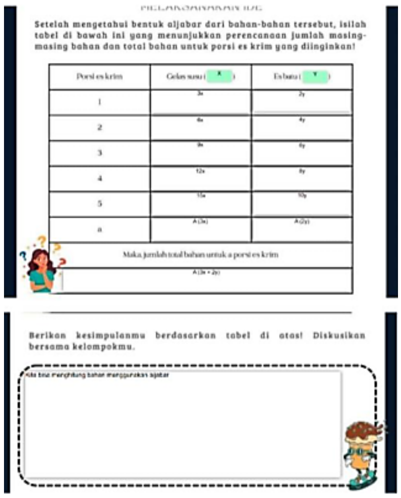
Activity 3 (create and plan)

In this activity, students in the create stage were asked to convert the material into variable forms and write down the patterns they had created from the previous table. In the planning stage, they were asked to identify previous patterns, construct mathematical models from contextual situations, and begin thinking symbolically. In the plan stage, it was found that one group wrote "3x + 6x" outside the conjecture formulated by the researcher.

Teacher : Why did you use the sum 3x + 6x in the three parts? Why didn't you use repeated sums such as 3x + 3x + 3x?
Student : Because we want to try writing other forms, such as 3x + 6x, so it is faster and still correct.
Teacher : What is the difference between the two forms?
Student : 3x + 3x + 3x consists of three identical terms, whereas 3x + 6x has only two terms, so it is simpler.
Teacher : Okay, please proceed to the next question.

Table 1. Results of the Pilot Experiment on Algebraic Form Multiplication

<table>
<tr><th colspan="2">Plan</th></tr>
<tr><td>Conjecture fulfilled</td><td>
</td></tr>
<tr><td>Outside the conjecture</td><td>
</td></tr>
</table>

	Create
Conjecture fulfilled	

Activity 4 (test and evaluate, redesign, communicate)

In this activity, students in the test-and-evaluate stage begin using mathematical models from the previous stage in contextual situations. In the redesign stage, they are asked to redesign if there are changes in the required materials. In the communication stage, students summarize their learning results.

Teaching Experiment

In the teaching experiment stage, the researcher involved 25 students, divided into 5 groups, each with 5 people. Learning was carried out through four LAS activities adapted to the Engineering Design Process (EDP) stages of STEM.

Activity 1 (define the problem and research)

At this stage, students were introduced to the basic concepts of making simple ice cream and the important roles of salt, milk, and ice cubes in the process.

Activity 2 (imagine)

At this stage, students are asked to arrange images in a table by understanding the relationship between the number of servings and the amount of ingredients.

Activity 3 (create and plan)

In this activity, students in the highest age group are asked to convert ingredients into variable forms and write down the patterns they have created based on the previous table. In the planning stage, they are asked to identify previous patterns, compile mathematical models from contextual situations, and begin to think symbolically. During the planning stage, one group did not use repeated addition in the image patterns they created. Therefore, it was interesting for the teacher to question this group's answer. The conversation was as follows:

Teacher : Why did your group not use repeated addition to write down the image pattern from the previous stage?

Student : Excuse me, miss. We don't quite understand the instructions. We don't understand what you mean by writing patterns such as 3x + 3x, like that, miss.

Teacher : I gave you instructions before you started working on the problem. Didn't you listen to the explanation?

Students : We listened, Miss, but we didn't understand the explanation, so we just wrote down the results and couldn't apply them correctly.

Activity 4 (test and evaluate, redesign, communicate)

In this activity, students in the test-and-evaluate stage begin using mathematical models from the previous stage in contextual situations. In the redesign stage, they are asked to redesign if there are changes in the required materials. In the communication stage, students summarize their learning results.

Retrospective Analysis

The retrospective analysis stage 1 evaluates the activity sheets created and tested by researchers in the previous pilot experiment. It was found that students faced an obstacle: difficulty understanding the instructions on the LAS, which led them to give incorrect answers when asked to explain the concept. This finding is consistent with research (Hendrik et al., 2020b), which noted that predictions of student difficulties must be mapped in detail using HLT. The following is a comparison of the HLT designed with ALT based on the pilot experiment.

Table 2. HLT and ALT (Pilot Experiment)

Question	HLT	ALT
Algebraic Form Multiplication		
<u>**Activity 1**</u> **Define the problem:** Understand the main problem from the given context.	Students can identify that the main problem is calculating the total ingredients when the number of portions changes.	All groups can understand and identify the main problems of the issue. However, they have not specifically mentioned the proportional relationship between the ingredients.
Research 1. Conclude the function of salt in the ice cream freezing process based on the video. 2. Explain how milk and ice cubes contribute to the texture of ice cream	1. Students can conclude the role of salt in the ice cream freezing process from the video. 2. Students write down the results of the discussion on the role of milk and ice cubes in ice cream texture.	All groups accurately recorded the results of their discussions and understood the functions of the ice cream ingredients.
<u>**Activity 2**</u> **Imagine** Determine ideas for calculating the ingredients needed for more servings of ice cream using illustrations.	Students present the relationship between the amount of ingredients and the number of portions needed using illustrations in a table.	All groups can accurately arrange the images in the provided table according to the number of ingredients and their portions.
<u>**Activity 3**</u> **Plan** 1. Plan a way to solve problems using algebraic expressions. 2. Arrange patterns using addition	1. Students represent material with variables. 2. Students can create patterns using addition operations.	1. All groups used variables to express the ingredients. 2. There is 1 group that uses the pattern of repeated addition. And there was one group that did not use repeated addition.

Question	HLT	ALT
Algebraic Form Multiplication		
operations.		
Create Write down the total material requirements for several servings of ice cream	Students calculate the number of materials and the total materials using algebraic multiplication and the distributive property.	All groups can use algebraic multiplication to calculate the amount of each ingredient.
<u>**Activity 4**</u> **Test and evaluate** 1. Calculate the ingredients for 5 and 12 servings of ice cream via the Zep quiz. 2. Draw a conclusion: "Does algebraic form make calculations easier?"		However, there is still confusion in using the distributive property for the total amount of material. 1. All groups calculated accurately, but in the total ingredients, they used standard algebraic multiplication. Therefore, emphasis on the distributive property is needed again. 2. All groups were able to write down the conclusion accurately.
Redesign Recalculate if the ingredients change to 4 cups of milk and 3 ice cubes for 1 serving of ice cream.	Students reused the distributive property.	All groups are still confused about how to write the formula for the distributive property of multiplication.
Communicate Provide conclusions about the use of algebraic multiplication, the benefits of mathematics and technology in everyday life.	Students draw conclusions about algebraic multiplication and the benefits of mathematics and technology in everyday life.	All groups accurately summarized the results of their discussions.

Table 2 presents the comparison between the Hypothetical Learning Trajectory (HLT) and the Actual Learning Trajectory (ALT) during the pilot experiment. The results indicate that, in general, students were able to follow the designed learning stages and identify the main problems presented in the contextual situation. However, several discrepancies between the HLT and ALT were identified. For instance, although students could represent mathematical situations using variables and perform algebraic multiplication, some groups experienced difficulties in applying repeated addition patterns and understanding the distributive property. In addition, students tended to focus on obtaining final answers rather than explaining the underlying concepts. These findings reveal that the initial HLT design had not fully anticipated students' learning obstacles, particularly in interpreting instructions and connecting contextual problems to formal algebraic representations. Therefore, revisions were necessary, especially in simplifying instructions and providing more structured guidance to support students' conceptual understanding.

Table 3. HLT and ALT (Teaching Experiment)

Question	HLT	ALT
	Algebraic Form Multiplication	
Activity 1 **Define the problem:** Understand the main problem from the given context.	Students can identify that the main problem is calculating the total ingredients when the number of portions changes.	All groups can understand and identify the main problems of the issue. However, they have not specifically mentioned the proportional relationship between the ingredients.
Research Conclude the function of salt in the ice cream freezing process based on the video. Explain how milk and ice cubes contribute to the texture of ice cream	1. Students can conclude the role of salt in the ice cream freezing process from the video. 2. Students write down the results of the discussion on the role of milk and ice cubes in ice cream texture.	All groups accurately recorded the results of their discussions and understood the functions of the ice cream ingredients.
Activity 2 **Imagine** Determine ideas for calculating the ingredients needed for more servings of ice cream using illustrations.	Students present the relationship between the amount of ingredients and the number of portions needed using illustrations in a table.	All groups can accurately arrange the images in the provided table according to the number of ingredients and their portions.
Activity 3 **Plan** Plan a way to solve problems using algebraic expressions. Arrange patterns using addition operations.	1. Students represent material with variables. 2. Students can create patterns using addition operations.	1. All groups used variables to express the ingredients. 2. There is 1 group that uses the pattern of repeated addition. And there was one group that did not use repeated addition.
Create Write down the total material requirements for several servings of ice cream	Students calculate the number of materials and the total materials using algebraic multiplication and the distributive property.	All groups can use algebraic multiplication to calculate the amount of each ingredient.
Activity 4 **Test and evaluate** Calculate the ingredients for 5 and 12 servings of ice cream via the Zep quiz. Draw a conclusion: "Does algebraic form make calculations easier?"		However, there is still confusion in using the distributive property for the total amount of material. 1. All groups calculated accurately and understood how to calculate the total ingredients using the distributive property, as they had been guided in the previous stage. 2. All groups were able to write down the conclusion accurately.
Redesign Recalculate if the ingredients change to 4 cups of milk and 3 ice cubes for 1 serving of ice cream.	Students reused the distributive property.	All groups are still confused about how to write the formula for the distributive property of multiplication.
Communicate Provide conclusions about the use of algebraic multiplication, the benefits of mathematics and technology in everyday life.	Students draw conclusions about algebraic multiplication and the benefits of mathematics and technology in everyday life.	All groups accurately summarized the results of their discussions.

Table 3 shows the comparison between the Hypothetical Learning Trajectory (HLT) and the Actual Learning Trajectory (ALT) during the teaching experiment after the revision of the initial design. The results demonstrate a significant improvement in the alignment between the HLT and ALT. Most students were able to understand the given instructions, construct algebraic models using variables, and apply the distributive property more accurately in solving contextual problems.

Although a small number of students still encountered difficulties in interpreting repeated addition patterns, overall, students showed better engagement and more systematic thinking in completing the learning activities. Furthermore, students were able to draw appropriate conclusions and relate algebraic concepts to real-life contexts. These findings indicate that the revised HLT was more effective in facilitating students' learning processes and in addressing the obstacles identified during the pilot experiment.

The retrospective analysis of the stage 2 evaluation of the teaching experiment shows good progress: students, as a whole, are able to carry out learning activities with greater proficiency. This marks a significant difference from the results obtained in the previous pilot experiment stage. During the pilot experiment, students struggled in respond to and complete the activities. However, after the teaching experiment, they showed significant improvement in understanding and completing learning activities. The following table compares the HLT created and the ALT during the teaching experiment.

The results of this study indicate that the implementation of a STEM-based Hypothetical Learning Trajectory (HLT) in algebraic multiplication learning can effectively support students' conceptual understanding and engagement. During the pilot experiment, several learning obstacles were identified, particularly in students' difficulties in interpreting instructions, using variables consistently, and applying the distributive property. These findings highlight the importance of carefully designing learning trajectories that anticipate students' thinking processes, as emphasized in previous studies on HLT (Hendrik et al., 2020a; Simon, 2020).

After revising the learning design based on the pilot experiment, the teaching experiment showed a significant improvement in students' performance and participation. The alignment between the Hypothetical Learning Trajectory (HLT) and the Actual Learning Trajectory (ALT) became more evident, indicating that the revised design was more effective in guiding students through the learning process. This result is consistent with previous research stating that well-designed HLT can help teachers predict and facilitate students' learning more systematically (Suwarto & Purnami, 2018). Furthermore, the integration of STEM through the Engineering Design Process (EDP) and the use of a real-life context, such as ice cream making, contributed to increased student engagement and motivation. Students were more actively involved in identifying problems, constructing mathematical models, and communicating their ideas.

This finding is in line with studies that highlight the effectiveness of STEM-based learning in improving students' critical thinking skills, conceptual understanding, and learning motivation (Saputri & Herman, 2022; Uzun & Şen, 2023). In addition, the use of contextual learning has been shown to help students connect abstract mathematical concepts with real-life situations, making learning more meaningful (Mutaqin et al., 2023). Compared to previous studies, this research provides a more specific contribution by integrating STEM components within a structured HLT design for algebraic multiplication learning. While earlier studies have examined STEM approaches or HLT separately, this study demonstrates that the combination of both can create a more effective and contextual learning trajectory. The findings suggest that the integration of STEM and HLT not only improves students' understanding but also supports the development of systematic and reflective thinking processes during learning.

CONCLUSION AND RECOMMENDATION

Based on the results of the research conducted, it can be concluded that a STEM-based hypothetical learning trajectory in algebraic multiplication materials can facilitate students' conceptual understanding in a contextual and gradual manner. This design consists of four main activities that integrate real-life contexts, namely, making simple ice cream, using the Engineering Design Process (EDP) approach. Students are guided to define problems, design mathematical relationships, compile algebraic models using variables, coefficients, and constants, and test and communicate the results. Students showed positive responses, active engagement, and interest in learning, which were designed to be exploratory and collaborative. The results of this study are expected to provide input in developing meaningful learning by utilizing learning trajectories and real-life contexts to increase student motivation and understanding. The results of this study can be used as a reference in developing STEM-based HLT designs for other mathematics materials by expanding the context to be more diverse and involving more interactive learning technologies to improve the overall quality of learning and student engagement.

REFERENCES

Ai'syah, A., Salma, U. Z., & Dewi, N. R. (2022). Pengembangan E-LKPD berpendekatan STEM menggunakan Google Form dan Linktree untuk melatih kemampuan berpikir kritis siswa SMP. *Proceeding Seminar Nasional IPA*, 301–314.

Andriani, W. (2020). Pentingnya perkembangan pembaharuan kurikulum dan permasalahannya. *Jurnal Pendidikan*, 5(2), 1–10.

Asmita, A., Yulianti, D., Kurniawan, D. A., Maison, M., Isnaini, N., Nurjanah, K., & Sari, I. D. P. (2022). Analisis permasalahan guru dalam menerapkan media pembelajaran pada mata pelajaran fisika di MAN 1 Tanjung Jabung Barat. *Jurnal Pendidikan MIPA*, 12(2), 170–177.

Gravemeijer, K., & Cobb, P. (2006). Design research from a learning design perspective. In J. van den Akker et al. (Eds.), *Educational design research* (pp. 29–63). London: Routledge.

Hendrik, A. I., Ekowati, C. K., & Samo, D. D. (2020a). Kajian hypothetical learning trajectories dalam pembelajaran matematika di tingkat SMP. *Fraktal: Jurnal Matematika dan Pendidikan Matematika*, 1(1), 1–11.

Hendrik, A. I., Lay, Y. O., & Amuntoda, Y. S. N. (2020b). Study of hypothetical learning trajectories in mathematics learning. *Pancaran Pendidikan*, 9(3), 1–10.

Ibáñez, M.-B., & Delgado-Kloos, C. (2018). Augmented reality for STEM learning: A systematic review. *Computers & Education*, 123, 109–123.

Lestari, D. E., & Suryadi, D. (2020). Analisis kesulitan operasi hitung bentuk aljabar. *JURING (Journal for Research in Mathematics Learning)*, 3(3), 247–258.

Milaturrahmah, N., Mardiyana, M., & Pramudya, I. (2017). Science, technology, engineering, mathematics (STEM) as a mathematics learning approach in the 21st century. *AIP Conference Proceedings*, 1868(1), 1–6.

Murnawianto, S., Sarwanto, S., & Rahardjo, S. B. (2017). STEM-based science learning in junior high school: Potency for training students' thinking skill. *Pancaran Pendidikan*, 6(4), 1–10.

Mutaqin, E. J., Herman, T., Wahyudin, W., & Muslihah, N. N. (2023). Hypothetical learning trajectory in place value concepts in elementary school. *Mosharafa: Jurnal Pendidikan Matematika*, 12(1), 125–134.

Saputri, M. D. (2023). Pengembangan media pembelajaran interaktif berbantuan GeoGebra berbasis STEM pada materi garis singgung lingkaran kelas VIII SMP. (Skripsi). Universitas Jambi, Jambi.

Saputri, V., & Herman, T. (2022). Integrasi STEM dalam pembelajaran matematika: Dampak terhadap kompetensi matematika abad 21. *JPMI (Jurnal Pembelajaran Matematika Inovatif)*, 5(1), 247–260.

Simon, M. A. (2020). Reconstructing mathematics pedagogy from a constructivist perspective. *Journal for Research in Mathematics Education*, 26(2), 114–145.

Suwarto, S., & Purnami, A. S. (2018). Upaya meningkatkan pemahaman konsep matematika melalui hypothetical learning trajectory pada materi vektor. *IndoMath: Indonesia Mathematics Education*, 1(2), 69–76.

Uzun, S., & Şen, N. (2023). The effects of a STEM-based intervention on middle school students' science achievement and learning motivation. *Journal of Pedagogical Research*, 7(1), 1–15.

Villaruz, E. J., Cardona, M. C. F., Buan, A. T., Barquilla, M. B., & Yuenyong, C. (2019). Ice cream STEM education learning activity: Inquiry from the context. *Journal of Physics: Conference Series*, 1340(1), 012092.