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Learning Trajectory of Numerical Problem-Solving Through STEM-Integrated Mathematics: A Didactical Design Research Approach

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This study aims to investigate students' learning trajectory while solving comparison problems using the KoPer learning media integrated with STEM, as well as to enhance students' numerical problem-solving skills. The research involved 27 fifth-grade students from Taman KalijagaPermai Elementary School in Cirebon City. The students are divided into four grup using utilized purposive sampling to form learning groups and conduct numerical problem-solving tests. Students' learning trajectories were observed through patterns of numerical problem-solving, and the Hypothetical Learning Trajectory (HLT) was employed to develop hypotheses and serve as a research guide. This qualitative study adopted a Didactical Design Research (DDR) approach. Data collection was conducted through interviews, tests, and documentation. The results indicate that creating a good and effective learning design for a STEM-integrated learning trajectory requires effectively combining STEM aspects. During the implementation of the learning trajectory, all groups conducted practical experiments using KoPer integrated with STEM, yielding varied group results, with three groups performing well and two groups not meeting expectations. The numerical problem-solving tests revealed diverse answer patterns among students. These differences represent new findings that are hoped to contribute to future research. Through STEM media, student learning improved, demonstrating that STEM education can stimulate innovation and critical thinking in problem-solving. In conclusion, STEM-

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integrated numerical problem-solving in mathematics education related to comparisons is significantly effective for practical application in learning.

Introduction

The ability to solve problems is one of the essential skills that must be developed in elementary school students (Yavuz et al., 2017). Problem-solving skills serve as a foundation for students to face various challenges and obstacles that may arise in both their learning processes and daily lives (Ahdhianto et al., 2020; Fitriani et al., 2020). At the elementary school age, students begin to be encounter to various simple problems that require problem-solving strategies (Chen, 2020). For example, they tackle math problems, comprehend instructions in academic assignments, and find solutions to issues in their surroundings. Through the experience of solving these problems, students can develop critical thinking, creativity, and sound decision-making skills (Guntur & Purnomo, 2024; Leavy & Hourigan, 2020).

Numerical problem-solving is a crucial skill that elementary school students must master, as it promotes cognitive and critical thinking abilities (Iswara et al., 2022; Kusumadewi & Retnawati, 2020). As it fosters various cognitive abilities and critical thinking skills (Kusumadewi & Retnawati, 2020). Mathematics education at this level typically starts with basic concepts such as arithmetic, simple geometry, and understanding patterns and numerical relationships (Turgut & Turgut, 2020). Advancing these skills is vital for developing students' cognitive capabilities, allowing them to process information, analyze situations, and devise solutions (Ocak & Eğmir, 2016; Wicaksono & Korom, 2022). Understanding students' cognitive development, as outlined in Piaget's theory, is essential for teachers to engage students effectively and enhance their learning teachers must communicate their ideas clearly through teaching activities before altering students' existing understandings (Fahma & Purwaningrum, 2021).

Based on research conducted by (Pertiwi, C. M., & Rohaendi, 2022; Salsabila & Pradipta, 2021) it can be concluded that there is still a low level of numerical problem-solving in elementary schools, attributed to a lack of opportunities for students to practice. Students face difficulties in problem-solving, both in mathematics and in real-world situations. According to (Verschaffel et al., 2020) learners have limitations in relating mathematics to concrete and relevant situations. Furthermore, students struggle to create problem-solving plans for problems they have not yet mastered (Iswara et al., 2022; Nurtanto et al., 2021). This contributes to the low level of numerical problem-solving in elementary schools. Therefore, to address this issue, the researcher aims to measure numerical problem-solving in elementary schools by utilizing STEM and KoPer (Comparison Koper) teaching media.

STEM, an interdisciplinary approach integrating Science, Technology, Engineering, and Mathematics, equips students with problem-solving skills for real-world challenges (AlAli, 2024). In mathematics, particularly in ratio and proportion, STEM's project-based approach connects theoretical concepts with practical applications, enhancing numerical problem-solving (Priemer et al., 2020; Wang et al., 2020). It has proven effective in improving elementary students' problem-solving skills, especially in ratio learning (Srikoon et al., 2024).

STEM helps students understand concepts like direct and inverse proportions, crucial for mathematical comprehension and real-life applications. By actively engaging students with technology, it fosters a deeper learning experience (Diana et al., 2021; Sarwi, 2021). Combining STEM with Learning Trajectory creates a structured learning framework that strengthens problem-solving skills and contextualizes learning through KoPer media, which enhances understanding of ratio and proportion in elementary education.

KoPer media, designed with STEM principles, visualizes concepts like comparison and numerical patterns (Vogel et al., 2022). By engaging students in activities like model construction, calculations, and verification, it promotes critical thinking and problem-solving (Cotič et al., 2024). The interactive nature of KoPer helps students visualize concepts in real-world contexts (Aliyah et al., 2020) and fosters active participation (Sakir & Kim, 2020). (Faoziyah, 2021) outlines steps for using STEM and KoPer in learning comparisons: Science (understanding electrical concepts), Technology (learning about electricity), Engineering (creating light graphs), and Mathematics (understanding comparisons).

Previous research shows STEM’s potential in enhancing students’ numerical problem-solving abilities, though there remains limited discussion on its impact on cognitive abilities (Dwianjani & Candiasa, 2018; Haafidah et al., 2022; Jatmiko, 2018). Studies by Abdullah et al. (2014) and Baharin et al. (2018) support STEM as an effective strategy for improving problem-solving skills in elementary education, offering students opportunities to integrate knowledge through STEM-based projects (Lou et al., 2011).

Observations at Taman Kalijaga Permai Elementary School identified issues with numerical problem-solving abilities, revealing that only 37% of 54 students in grades VA and VB demonstrated proficiency. Further evaluation is needed to improve these skills. Interviews with the VB class teacher indicated that numerical problem-solving is seldom used in mathematics instruction, as teachers typically rely on a one-way teaching approach, leading to a unidirectional learning process. The use of STEM teaching media is limited, focusing mainly on Science and Mathematics without sufficient integration of all components, forcing teachers to use available classroom resources as alternatives for instruction enhancement.

The use of numerical problem-solving to enhance elementary students' abilities is justified, as it establishes a strong foundation for developing mathematical skills (Putri & Santosa, 2015). This skill is essential for tackling mathematical challenges and applying knowledge in everyday situations. In the target elementary school, there are notable issues with students' limited numerical problem-solving skills and a lack of focus on improvement. To address these problems, it is crucial to integrate STEM and KoPer teaching media into mathematics instruction, aiming to enhance students' numerical problem-solving abilities and improve their answer patterns (Davidi et al., 2021). Research poses several questions regarding the integration of STEM in numerical problem-solving using DDR.

(1) How can the learning trajectory design that integrates STEM enhance numerical problem-solving abilities in mathematics education at the elementary level?
(2) How is the implementation of the learning trajectory for numerical problem-solving integrated with STEM in mathematics education at the elementary level?
(3) How can improvements be made in numerical problem-solving with STEM integration in mathematics education at the elementary level?

Method

Research Design

In this research, the design used is Didactical Design Research (DDR). DDR is a research approach that focuses on the design process and seeks to develop learning experiences aimed at solving complex issues in the field of education (Carlgren, 2012). According by (Fauzi & Suryadi, 2020) He implementation of DDR is divided into three main stages, which are as follows.

Figure 1. Stages DDR

The explanation of these stages includes: (1) Prospective Analysis: This involves constructing a didactic situation analysis that encompasses the learning trajectory to be mastered during instruction. The learning trajectory contains learning activities that cover the concepts of comparison within a STEM-based media; (2) Metapedidactic Analysis: In this stage, the researcher analyzes the obstacles faced by students who struggle with learning when working on comparison concept problems within the provided learning trajectory; (3) Retrospective Analysis: This connects the results of the didactic situation analysis with the findings from the metapedidactic analysis. At this stage, the researcher creates a didactic anticipation design related to the issues faced by students when applying the concept of comparison.

Participant

The researcher involved Taman KalijagaPermai Elementary School, with a total student population of 368. From this population, 54 students from grades VA and VB were selected as research informants. The researcher employed purposive sampling, choosing students based on their response patterns in numerical problem-solving abilities. A total of 27 students from class VB were involved as research informants, and the researcher selected 6 informants consisting of 3 categories: 2 students in the high category, 2 students in the medium category, and 2 students in the low category. These students were selected based on the results of the numerical problem-solving test.

Hypothetical Learning Trajectory with STEM

The researchers employed a Hypothetical Learning Trajectory in the study, incorporating the use of STEM-based media. This media application involved several stages, including collecting blocks, conducting experiments, recording results, creating proportion graphs, and light graphs, as well as implementing these into light graphs and evaluating the results with peers. This practice occurred in the classroom and was demonstrated by the teacher.

Table 1. Learning Trajectory with Numerical Problem-Solving

Sub Concept	**Task Description based on STEM**				**Learning Objectives**	**HLT Conjectures**	**Indicator Numerical Problem-Solving**
	Science	**Technology**	**Engineering**	**Mathematics**			
Understanding Direct and Inverse Proportion	-	-	-	Understanding and introducing the concept of proportion includes not only the basic material but also its properties.	Conceptual understanding provides a deeper learning experience for the next stage of studying proportion.	In the learning process, all students are expected to grasp both the concept and the properties of proportion.	• Demonstrating problem understanding • Ability to create or construct a mathematical model
Determining the ratios of direct proportion and inverse proportion	-	-	-	The next step is to calculate the ratio, which differentiates between types of proportion.	Calculating the proportion ratio helps students easily recognize the size of the proportion.	Assumptions about determining the ratio are linked to comprehension, and all students are expected to be able to calculate it.	• Choosing and Developing Problem-Solving Strategies
Applying them in creating proportion graphs	-	-	-	Creating graphs based on the type of proportion shows distinct differences.	Creating a proportion graph aims to evaluate students' understanding.	When constructing a proportion graph, there are assumptions about the types of graphs discussed in detail.	
Sketching a lamp graph	The lamp graph is related to the electrical circuit used in the lamp graph	Knowledge of electrical technology is necessary for implementing it into the lamp graph.	In sketching the picture, understanding the lamp circuit and its suitability in the calculation is needed.	When sketching the graph for the lamp, it is essential to understand the lamp's positioning.	Sketching can boost students' creativity in applying proportion.	Sketching proportion is hypothesized to have compatibility with the proportion graph depicted.	

Assembling Light Graphs and Proof	The lamp graph is related to the electrical circuit used in the lamp graph	Knowledge of electrical technology is necessary for implementing it into the lamp graph	The implementation of the graph sketch into the lamp graph	The suitability of the lamp graph will be evaluated by whether the lamp is turned on or off	Based on its design, implementing it in a light graph enhances students' cognitive abilities.	In the implementation, it is assumed that some students have creativity in installing or engineering the light graph.	• Ability to Explain and Choose the Correctness of Obtained Answers

Data Collection and Analysis

The data collection techniques used in this research included several methods: interviews, tests, and documentation from students, Interviews: This method was employed to gather direct information from students, allowing the researcher to gain insights into their experiences and understanding, Tests: The researcher utilized descriptive tests tailored to the indicators of numerical problem-solving. These tests were designed to effectively measure students' abilities while incorporating essential elements of mathematics education, Documentation: The researcher collected documentation in the form of images and notes to record the research process. This documentation aimed to capture students' results in completing the numerical problem-solving tests, providing a comprehensive view of their performance and progress.

The research instrument consists of an open-ended test designed to assess students' Numerical Problem Solving abilities. The test evaluates four key indicators (Mawaddah & Anisah, 2015): (1) Problem Understanding—identifying given and required information, (2) Mathematical Modeling—formulating real-world problems into mathematical representations, (3) Problem-Solving Strategy Selection—determining alternative solutions using relevant formulas, and (4) Solution Justification—detecting calculation errors and verifying the accuracy of responses.

A structured interview was conducted with fifth-grade students to elaborate on their responses and identify challenges encountered in the learning trajectory or ratio-related test. Students were selected based on their response patterns, categorized into high, moderate, and low proficiency levels. Students in the low category struggle to comprehend the material or fail to address certain aspects. The moderate category demonstrates correct mathematical modeling but lacks accuracy in calculations. The high category includes students who provide complete answers with precise mathematical models, accurate calculations, and detailed explanations, reflecting variations in students' comprehension and problem-solving skills in mathematics.

Validity and Reliability

Validity refers to how accurately a measurement instrument assesses its intended construct. This research conducted validity tests on the numerical problem-solving test instrument, emphasizing the importance of reliability for the instrument's consistency and dependability. Smart PLS was used for analysis, with the validity test requiring a cross-loading value above 0.70 to indicate a strong relationship between indicators and the construct. Composite Reliability was employed to measure reliability, with acceptable values above 0.7 (Vinzi et al., 2010). Additionally, Average Variance Extracted (AVE) assessed the variance explained by the construct, where an AVE value above 0.5 indicates good reliability (Fornell, C., & Larcker, 1981).

Table 2. Results of the AVE

	Average Variance Extracted (AVE)
Numerical Problem Solving	0,699

Based on the table above, all indicators have met the established criteria, as indicated by the AVE values greater than 0.50, which suggests they have adequate reliability for further testing.

Table 3. Results of the Composite Reliability dan Cronbach's Alpha

	Cronbach's Alpha	Composite Reliability
Numerical Problem Solving	0,951	0,958

Based on the results above, the testing of Composite Reliability and Cronbach's Alpha shows satisfactory values. All latent variables are reliable, with Composite Reliability and Cronbach's Alpha values ≥ 0.70. Therefore, it can be concluded that the tests used in this study are valid.

Result

Prospective Analysis of Learning Integrating STEM in Numerical Problem-Solving Ability

Through initial prospective analysis, this research aims to guide the learning process in a structured and systematic effort to enhance students' abilities. This approach is expected to encourage students' progress in mastering mathematical problem-solving.

Table 4. Initial Didactic Design Framework

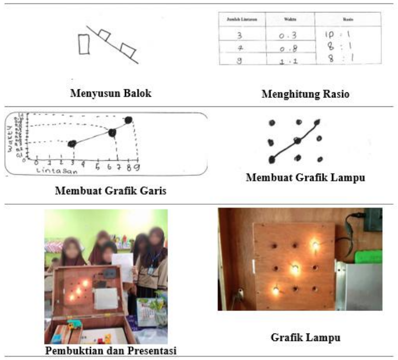
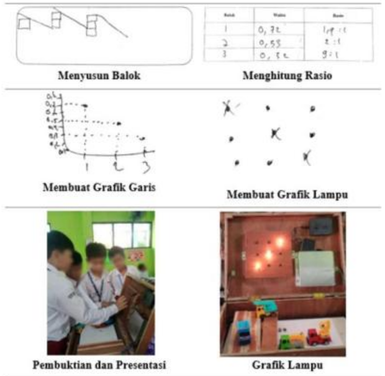
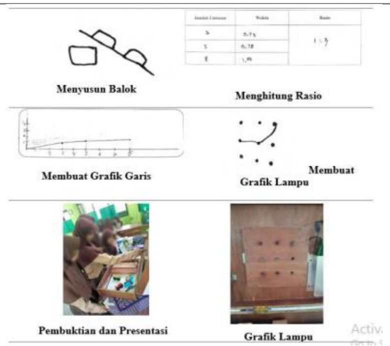
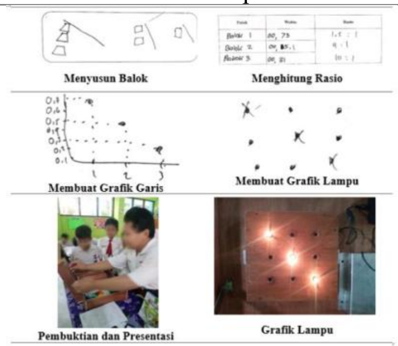
Activities	Learning Stages	Indicator Numerical Problem-Solving
Problem Orientation Towards Students	Problem Introduction	Demonstrating Understanding of the Problem
Concept Presentation	Concepts of Direct Proportion and Inverse Proportion	Ability to Create or Construct Mathematical Models
Discussion Investigation	• Model • Ratio • Line graph • Lamp graph	Choosing and Developing Problem-Solving Strategies
Proof and Presentation	• Investigation Proof • Results Presentation	Ability to Explain and Justify the Accuracy of the Obtained Answers
Test	Test numerical problem-solving	

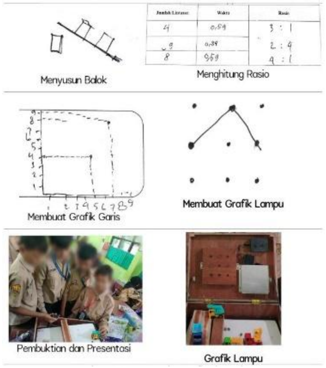
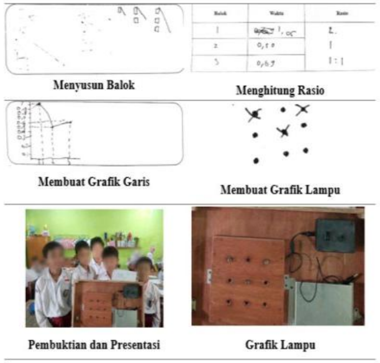
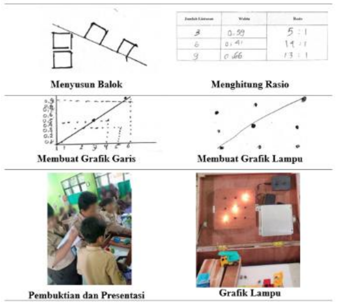
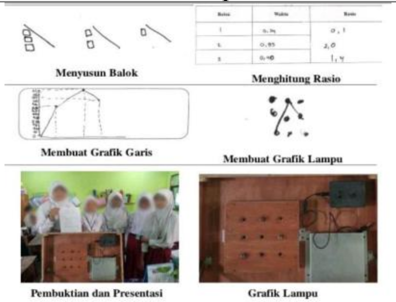
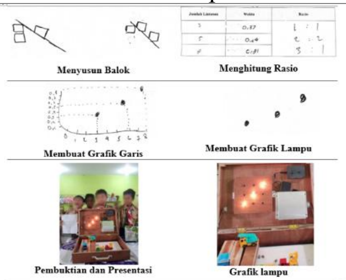
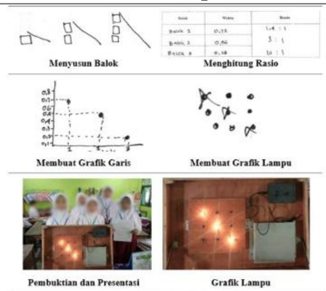
In the initial learning stage, the teacher engages students with questions about proportions in everyday life to enhance their prior knowledge. This interactive session helps build a foundational understanding before introducing more complex material. The teacher explains different types of proportions, encouraging active participation and collaboration among students. While two students correctly provide examples of direct and inverse proportions, one struggles, indicating varied understanding. To align perceptions and ensure comprehensive comprehension, the teacher must offer additional guidance and support.

Metapedidactic Analysis Learning Integrating STEM in Numerical Problem-Solving Abilities

In implementing the didactic design learning trajectory, a treatment was applied to class VB, consisting of 27 students. This learning design focused on teaching direct and inverse proportions, with metapedagogical analysis conducted in groups during the lessons. Students were divided into five groups of four to five members, where they had the opportunity to conduct experiments using STEM media three times. Each group was assigned specific tasks, such as recording results, performing experiments, timing with a stopwatch, and making observations. This learning approach encouraged active student involvement in understanding the concept of proportion, allowing them to interact and collaborate on related activities. STEM-based learning aims to help students explore, discover, and gain a deeper understanding of the concept of proportion.

Table 5. Results of Learning Direct and Inverse Proportion

<table>
<tr><th>Group</th><th colspan="3">Result</th><th>Indicator Numerical Problem-Solving</th></tr>
<tr><td>Group 1</td><td>
Results of Direct Proportion</td><td>
Results of Inverse Proportion</td><td>The first group successfully created accurate graphs for direct and inverse proportions, demonstrating a solid understanding. Their graphs correctly depicted the relationships, and their presentation was accurate.</td><td>The first group effectively created accurate graphs for direct and inverse proportions, demonstrating a strong grasp of the concepts. Their graphs featured increasing and decreasing diagonals, and their presentation of calculations and light graphs was precise.</td></tr>
<tr><td>Group 2</td><td>
Results of Direct Proportion</td><td>
Results of Inverse Proportion</td><td>The second group struggled with both direct and inverse proportions, resulting in an incorrect light graph. Through discussion, they identified mistakes in graph placement, indicating incomplete understanding.</td><td>The second group's responses on direct and inverse proportions were incorrect, leading to an unilluminated light graph that failed to represent the proportions. Discussions revealed errors in graph placement and representation, indicating their limited understanding of the concepts.</td></tr>
</table>

Group 3	 Results of Direct Proportion	 Results of Inverse Proportion	The third group made errors in both types of proportions, with their light not illuminating and their graph resembling a triangle. Discussions revealed that some members lacked full comprehension and were less engaged during lessons.	The third group made mistakes in both types of proportions, resulting in an unilluminated light and a triangular graph with no proportional relationship. Discussions uncovered a lack of understanding, with some members less engaged during lessons.
Group 4	 Results of Direct Proportion	 Results of Inverse Proportion	Group Four excelled in direct proportions, with their light graph showing a clear diagonal relationship. While their line graphs had some inaccuracies, they showed progress. However, their inverse proportion work was flawed, with imprecise calculations and incorrect graphs resembling triangles.	Group Four demonstrated a solid understanding of direct proportion, correctly calculating ratios and creating accurate line and light graphs. However, their understanding of inverse proportion was lacking, as their graphs failed to show the necessary diagonal, indicating a need for further guidance.
Group 5	 Results of Direct Proportion	 Results of Inverse Proportion	Group Five demonstrated a strong understanding of both direct and inverse proportions, with their light graph showing increasing and decreasing diagonals. Their ability to work collaboratively was also notable.	Group Five effectively illuminated their light graph with both increasing and decreasing diagonals for direct proportion, reflecting a good understanding. For inverse proportion, the light illuminated an inverse diagonal, showing a solid grasp of the concept. Their teamwork and problem-solving abilities were also commendable.

In this study, after students learned about proportions using STEM-integrated KoPer media, the researcher administered a test to assess students' understanding. This test aimed to evaluate the comprehension of key concepts that had been taught and was conducted in class VB as research informants. The categorization of students was divided into three categories: high, medium, and low. Two informants were selected from each category for further interviews.

Learning Experiment: Bridging Theory and Practice

The learning experiment was structured to operationalize the Hypothetical Learning Trajectory (HLT) through sequenced STEM activities that progressively scaffolded students from concrete manipulation to abstract reasoning. Each experimental phase (model construction, ratio calculation, and graph interpretation) was deliberately designed to test specific components of the HLT while allowing natural emergence of student reasoning patterns. This approach enabled researchers to validate the hypothetical trajectory against actual learning behaviors observed during hands-on tasks with KoPer media, particularly in how students transitioned between different representation modes (physical blocks → numerical ratios → graphical outputs).

During implementation, the experiment functioned as a diagnostic tool that revealed nuanced challenges in students' proportional reasoning. The tactile nature of KoPer media created visible "breakpoints" in understanding, for instance, when groups struggled to align physical block arrangements with corresponding mathematical ratios. These moments provided critical opportunities for just-in-time interventions, where teachers could address misconceptions before they became entrenched. Importantly, the experiment's design captured not only final outcomes but also the cognitive processes behind them, offering insights into why certain groups succeeded while others required remediation.

Analysis of Students' Answer Patterns in Numerical Problem-Solving Based on High Category

Based on the results of the numerical problem-solving test, four students were identified. Students in the high category with scores of 90. From these four students, the researcher selected two to serve as informants for this study and conducted in-depth interviews with them. Through these interviews, the researcher explored their understanding, strategies, and processes for solving numerical problem-solving tasks.

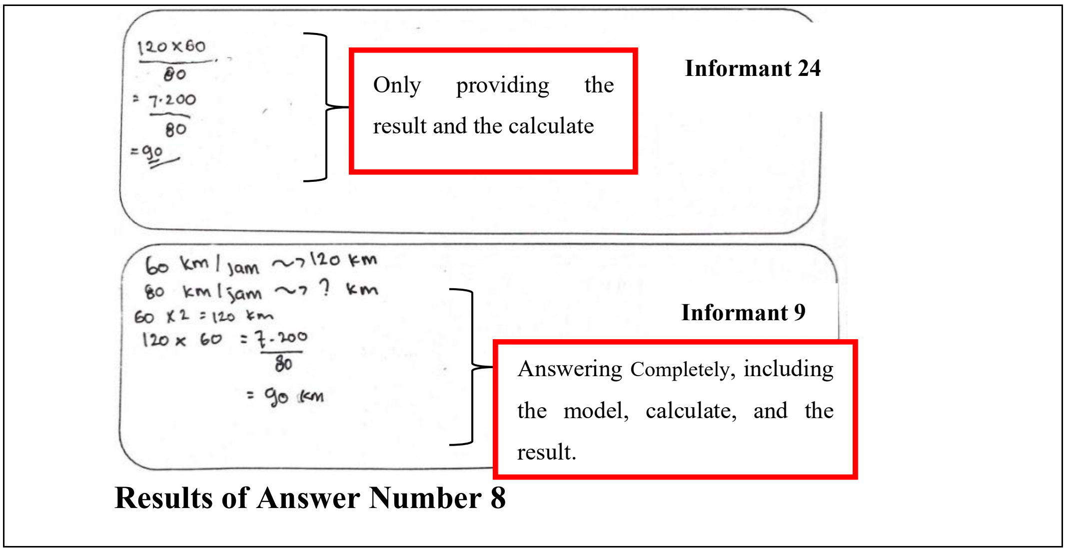


Figure 2. Student Response Patterns in the High Category

Based on the answer patterns in the high category for the numerical problem-solving test, the researcher selected a sample from question number eight. The responses from students in the high category showed significant differences compared to the overall student population. In this question, high-category students tended to use more systematic and structured problem-solving steps. They not only focused on obtaining the final answer but also demonstrated a deep understanding of the mathematical concepts involved, as well as the ability to identify patterns and develop effective strategies for solving the problems. After reviewing the students' answers, the researcher conducted interviews with the students. Below is the interview dialogue.

Researcher	:	How do you calculate and answer question number 8?
Informant 24	:	I use multiplication, teacher.
Informant 9	:	I add them first, teacher, then calculate the ratio. For question 8, I use cross-multiplication and apply the method downwards.
Researcher	:	How do you think you can get the result of 7.200?
Informant 24	:	I multiplied, teacher, from the result of 120 x 60 = so the result is 7.200. Don't you have a more complete and detailed answer?
Informant 9	:	I think it's the same, teacher, from 120 x 60.

Based on the interview results, it was revealed that there were students who could answer the questions correctly and perform accurate calculations. When providing answers, these students not only stated the final result but also explained the calculation process thoroughly. They demonstrated a good understanding of the concepts taught, were able to apply systematic problem-solving steps, and produced accurate answers.

Analysis of Students' Answer Patterns in Numerical Problem-Solving Based on Medium Category

From the results of the numerical problem-solving test, fifteen students were identified in the medium category. Interestingly, the average score for these students was mostly around 80. The researcher selected two students to serve as informants from this medium category. Through interviews with these two students, the researcher aimed to gather more in-depth information.

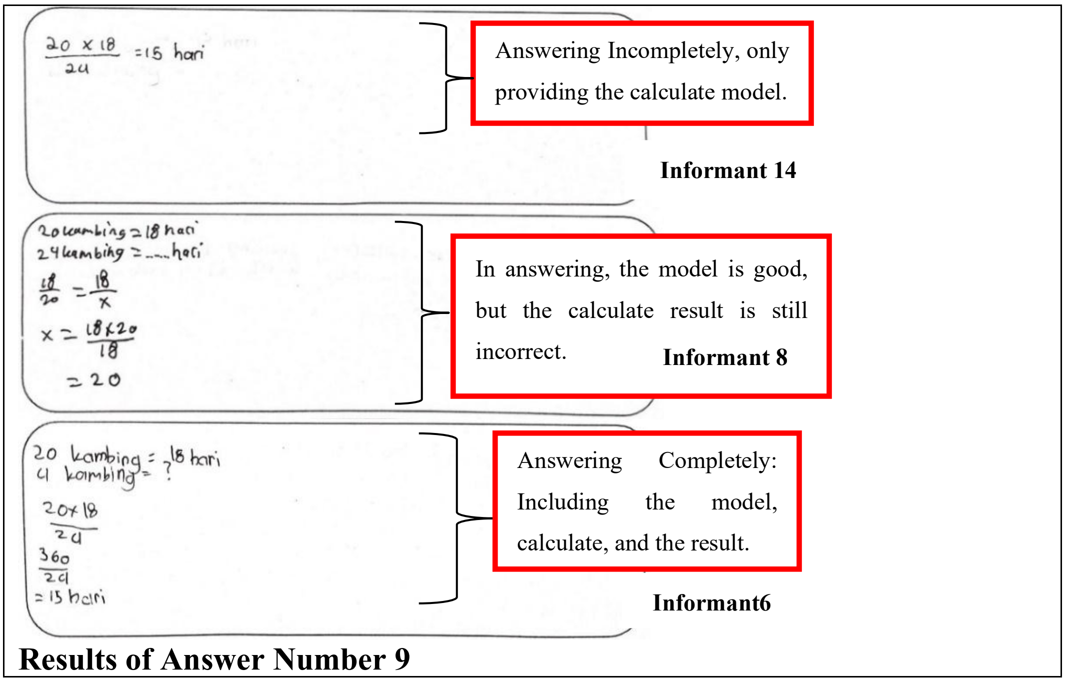


Figure 3. Student Response Patterns in the Medium Category

Based on the answer patterns in the medium category for the test, the researcher selected a sample from question number nine. The response patterns from students in this category demonstrated a fair level of ability, although they differed from the patterns observed in the high category. While the response patterns of medium-category students were not as complex as those of high-category students, they still demonstrated a reasonable understanding of the mathematical concepts involved. Students were able to provide correct answers, although their explanations and steps might not be as detailed or structured as those shown by students in the high category. Below is the interview dialogue.

Researcher	:	How do you answer question numbe 9?
Informant 14	:	I just add them directly.
Informant 8	:	I multiply first, teacher, then divide, and then use cross-multiplication.
Informant 6	:	For question 9, I look for what is given first, teacher, then calculate 20x18 to see what the result is, then divide that result by 24, and later the answer will be 15, teacher.

Based on the analysis of the students' answer patterns, it was revealed that in solving problems on the numerical problem-solving test, students exhibited a variety of response patterns. Some students provided only the final result, while others presented more comprehensive answers by including calculation models and detailed steps for their solutions. This suggests that many students still struggle with understanding the problems, selecting appropriate mathematical models, or applying systematic problem-solving procedures.

Analysis of Students' Answer Patterns in Numerical Problem-Solving Based on Low Category

Based on the results of the numerical problem-solving test, five students were identified in the low category, with an average score of 50. The researcher selected two of these students to serve as informants for this study and conducted in-depth interviews with them.

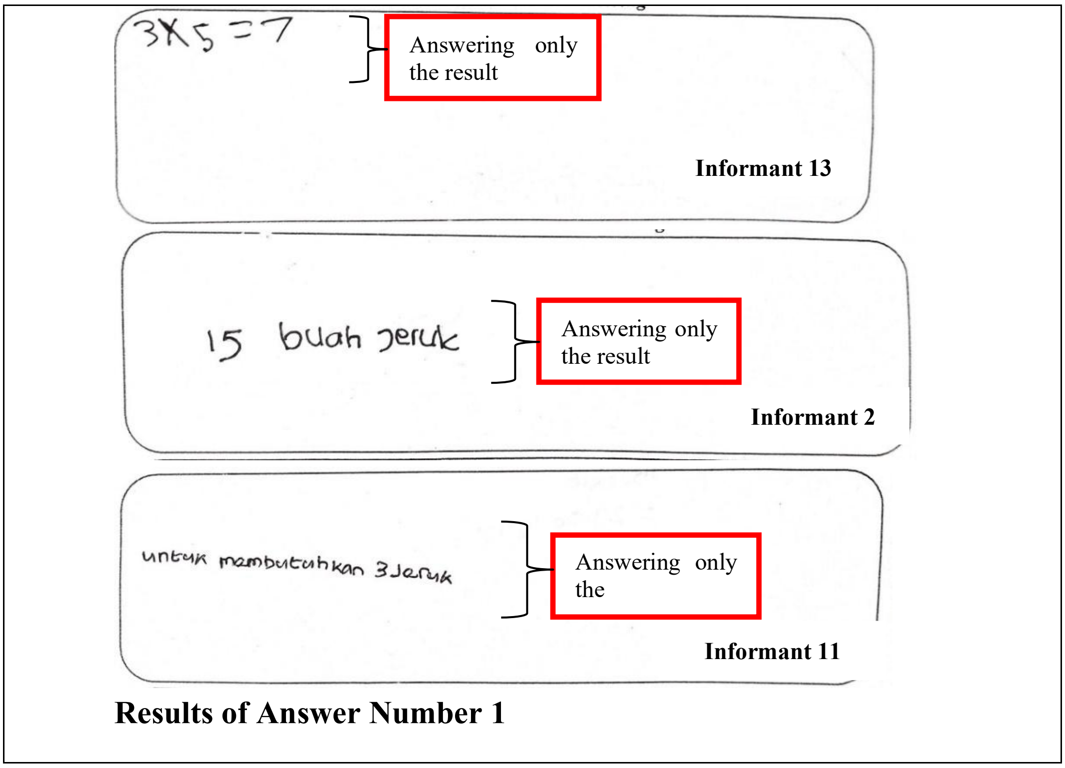


Figure 4. Student Response Patterns in the low Category

Based on the answer patterns in the low category for the test, the researcher selected a sample from question number one. The response patterns from students in this category indicated suboptimal ability, with most presenting only the final result without explaining their process. These students exhibited a limited understanding of the fundamental concepts necessary for problem-solving. They struggled to identify relevant information, select appropriate strategies, and apply systematic steps. Additionally, several students had difficulties comprehending the provided information, interpreting the questions correctly, and determining the necessary steps to reach the correct solution. After reviewing the students' answers, the researcher conducted interviews with them. Below is the dialogue from the interviews.

Researcher	:	How do you answer question number 1?
Informan 13	:	I'm still confused about calculating the multiplication.
Informan 2	:	From 3 x 5, teacher, the result is 15 oranges.
Informan 11	:	I still don’t understand, teacher, how to calculate it. So I just wrote

Based on the interview results, there was a variation in the students' answer patterns. Some students continued to struggle with solving numerical problem-solving tasks. It highlighted that there are still concepts that require further attention and support.

Retrospective Analysis Learning Integrating STEM in Numerical Problem-Solving Abilities

After implementing the developed didactic design, the researcher conducted a retrospective analysis by compiling the final didactic design plan.

Table 6. Final Didactic Design Plan

Activities	**Learning Stages**	**Indicator Numerical Problem-Solving**
Problem Orientation and Concepts	Problem Solving and Concepts of Proportion	Demonstrating Understanding of the Problem
Learning Implementation	• Model • Ratio • Line Graph • Lamp Graph • Proof	Ability to Create or Construct Mathematical Models Choosing and Developing Problem-Solving Strategies Ability to Explain and Justify the Accuracy of the Obtained Answers
Measurement of Student Abilities	Test numerical problem-solving	

Based on the outcomes of the learning process from the final didactic design, the researcher received feedback from the involved classroom teacher. During the STEM media practical sessions, it was suggested to enhance the KoPer media to allow students to implement it alongside other groups. In the implementation phase of the learning design, activities that improved students' numerical problem-solving indicators were incorporated, such as the creation of mathematical models. Students constructed blocks using the KoPer media, calculated ratio comparisons, and created line and light graphs. These activities helped students apply their understanding of the proportion concepts taught earlier and engage in problem-solving investigations within the LKPD, encouraging them to develop mathematical models and demonstrate a solid conceptual understanding.

Table 7. Description of STEM-Based Learning

No.	**Activity**	**Sub Concepts**	**Implementation STEM**				**Indicator Numerical Problem-Solving**				**Students' Thinking**
			S	**T**	**E**	**M**	**Demonstrating the Understanding of the Problem**	**Ability to Create and Structure Mathematical Models**	**Selecting and Developing Problem-Solving Strategies**	**Ability to Answer and Verify the Accuracy of the Obtained Answers**	
1	Problem Orientation and Concepts	Problem solving				√	In the problem-solving process, students are presented with guiding questions related to everyday life contexts in the topic of proportion	-	-	-	All students are anticipated to grasp the concepts of direct proportion and inverse proportion.
		Concept proportion				√	-	Understanding and identifying the concept of proportions involves not only the foundational material but also the properties and types of proportion.	-	-	
2	Implementation of Direct and Inverse Proportion	Model			√		-	To understand the concept of proportion, students are asked to create appropriate mathematical models using	Creating diagrams requires an understanding of the circuit of lights and its relevance in calculations.	-	Students' reasoning in determining proportions is closely tied to their understanding of the concepts taught. All students are expected to perform calculations effectively, such as

						KoPer learning media.			determining ratios in the student LKPD. They are also tasked with creating line graphs and light graphs, along with conducting proofs, and presenting their findings in response to LKPD questions. This activity allows teachers to assess students' understanding and problem-solving abilities related to proportions, and the presentation results can help identify ways to improve future learning.
Ratio				√	-	-	After grasping the concept, students are tasked with determining the ratio, which is used to differentiate between types of proportion. They are required to calculate the ratio in the Student LKPD.	-	
Line Graph				√	-	The creation of a line graph is conducted after determining and calculating the ratio in the Student LKPD based on the types of direct and inverse proportion.	In the process of solving proportion problems in the LKPD, students collaborate with their peers to strategize on creating the necessary line graphs.	-	
Light Graph	√	√	√		-	To create a lamp graph, it is essential to understand the circuit of lights and their relevance in both ratio calculations	To create the light graph with KoPer learning media, students need to accurately understand how to position the lights, as this will	-	

								and line graphs.	determine whether they will turn on.		
		Proof	√	√	√	√	-	-	-	After following the instructions in the KoPer learning media and completing the LKPD, students then conduct proofs and present their work from the LKPD.	
3	Measurement of Student Abilities	Test Numerical Problem-Solving	-	-	-	-	Students are asked to understand and solve the problems presented in the test questions given by the teacher.	Students are required to construct mathematical models accurately, calculate them correctly, and present their work in a logical sequence.	Students solve the problems in the test to determine their answers.	After students complete the test individually, their answers are reviewed. This process will categorize students as research informants to evaluate their understanding and ability to solve the test questions.	This test allows the teacher to assess students' understanding and ability to solve the given numerical problems. Each answer and the process behind the students' work will provide valuable insights for future actions.

The STEM-based learning phase aimed to enhance students' numerical problem-solving skills using KoPer media. Activities like constructing mathematical models, calculating ratios, and creating graphs helped students improve their understanding of proportions while promoting collaboration and critical thinking. These activities align with research by Könings et al. (2021) and Naujokaitiene et al. (2020), highlighting the importance of engaging learning experiences. A subsequent numerical problem-solving test revealed variations in students' abilities to apply the concepts, with some demonstrating a deep understanding. Astuti et al. (2021) emphasize that evaluating activities and test results helps identify areas needing further guidance, improving students' problem-solving skills for both academic and everyday challenges.

Table 8. Describing Numerical Problem-Solving Indicators

Categories	Informants	Describing Numerical Problem-Solving Indicators			
		Demonstrating the Understanding of the Problem	**Ability to Create and Structure Mathematical Models**	**Selecting and Developing Problem-Solving Strategies**	**Ability to Answer and Verify the Accuracy of the Obtained Answers**
High	Informants 9	Students demonstrate a clear understanding of the problem and can articulate it effectively.	Students are capable of constructing mathematical models effectively.	In solving problems from the test, students answered correctly and competently; however, there was one question where they provided an incorrect response.	Students explain their reasoning logically and in detail. This reflects their strong understanding of the concept of proportions, both in completing worksheets and in test questions.
	Informants 21	Students have a good understanding of the problems in both the test and the LKPD.	Students perform well in constructing mathematical models.	In solving problems from the test, students are doing well; however, for one question, their performance was satisfactory, but the answer was not correct.	Students explain their reasoning logically but recognize that they answered one question incorrectly. This indicates they understand the concepts well but need to improve their accuracy on test questions.
Medium	Informants 10	Students appear to understand the problems presented in the test.	Students are fairly good at implementing mathematical models.	In completing the test questions, students show some misunderstandings, as indicated by several incorrect answers and a lack of logical flow in their responses.	Students offer fairly detailed explanations for their answers but acknowledge confusion about questions they don't fully understand. This indicates a need for further

					evaluation and guidance.
	Informants 14	Students are good at understanding the problems in both the test and the LKPD	In constructing mathematical models for the test questions, students appear to be effective and organized.	In solving the test questions, students perform well overall, but there are still a few questions where their answers are incorrect and some questions they find confusing.	In explaining the correctness of their answers, students provide detailed and clear responses, but there are questions they do not fully understand.
Low	Informants 2	Students are fairly good at understanding the test questions	Students complete and construct their responses, showing a reasonable understanding.	In solving problems to complete the test questions, there are several questions that students did not address well or thoroughly.	In explaining those questions, students seem to lack confidence and exhibit confusion in their answers. This suggests that they still need guidance and additional practice.
	Informants 3	Students are fairly good but still require guidance in understanding the test questions.	Students appear confused when constructing mathematical models.	In solving problems from both the test and worksheets, students are able to complete them, but their answers are often incorrect, although they do answer some questions correctly.	Students provide insufficient detail in their explanations and continue to show confusion. The results indicate that they require further guidance to achieve optimal outcomes.

Discussion

Designing an effective STEM-integrated learning trajectory requires a meticulous combination of STEM aspects to ensure successful learning outcomes (De Meester et al., 2021). Nur et al. (2022) emphasize that instructional design should establish specific and measurable objectives to provide clear guidance for students. Furthermore, studies by Morze et al. (2021) and Plass & Pawar (2020) highlight the importance of tailoring materials to students' initial abilities, enabling instructional content to be adapted based on their comprehension levels. Learning activities should be structured to encourage exploration and active student engagement by connecting STEM concepts to real-world experiences (Mebert et al., 2020; Yang & Baldwin, 2020).

In designing a learning trajectory, several key aspects must be considered to achieve optimal learning outcomes (Wilson et al., 2015). Darmayanti et al. (2022) and Wilson et al. (2015) assert that instructional design should align with numerical problem-solving indicators to ensure that students develop relevant mathematical skills. Meanwhile, findings from Shishigu et al. (2018) and Thahir et al. (2020) underline the necessity of considering students' problem-solving abilities by providing adaptive materials suited to their comprehension levels and designing activities that are challenging yet accessible.

The effective use of STEM media and instructional tools is crucial in helping students understand and apply the concepts being taught (Hafni, 2020). (Ramadhan, 2023) highlights that well-designed STEM media can enhance students' comprehension of mathematical concepts while fostering active engagement in learning. Additionally, studies by An-nidhof et al. (2024), Kutlu et al. (2022) and Tuong et al. (2023) demonstrate that well-structured instructional media not only facilitate conceptual understanding but also establish connections with real-world applications. Consequently, a systematically designed approach can improve students' problem-solving skills in STEM domains.

The implementation of the learning trajectory allows students to engage in collaborative learning through the use of KoPer media, which has been integrated with STEM concepts (Rafanan et al., 2020). Collaborative learning plays a crucial role in encouraging discussions and the exchange of strategies to solve assigned tasks (Mora et al., 2020). By utilizing KoPer media, students not only gain a deeper understanding of mathematical and scientific concepts but also develop critical and creative problem-solving skills. Throughout the process, each group explores various scenarios and relevant experiments to enhance their comprehension of the subject matter. According to (Jatisunda et al., 2021), the implementation of a learning trajectory within the DDR model supports the structured development of students' mathematical skills, leading to more effective conceptual understanding. In line with this, Lo & Hew (2021) emphasize that well-designed learning trajectories engage students in activities that foster both conceptual comprehension and mathematical proficiency. Furthermore, research by Rotar (2022) and Sezgin (2020) indicates that instructional interventions involving systematic explanation, practice, and discussion help students navigate different stages of conceptual understanding within a learning trajectory.

In the context of learning proportional reasoning and STEM, studies indicate that using KoPer instructional tools integrated with STEM is highly effective (Guntur et al., 2023). Students are divided into groups and assigned specific tasks during learning activities with KoPer media, such as recording results, manipulating toy cars to determine travel distance, and observing speed and ratio relationships. Subsequently, each group constructs a light graph and calculates ratios based on the provided worksheets. In this process, the instructor acts as a facilitator, guiding students in graph construction and data analysis. These activities not only enhance student engagement in learning proportional reasoning and STEM but also foster teamwork, problem-solving abilities, and deeper conceptual understanding.

An analysis of learning outcomes shows variations in students' understanding across groups. Group 1 demonstrated correct comprehension of proportional reasoning, successfully illuminating the light graph. Group 2 struggled with miscalculations, causing their light to remain off. Group 3 also faced difficulties, with errors in calculations and graph representation. Group 4 illuminated their light but had inaccuracies in their graph. Group 5 presented an accurate light graph, indicating a strong grasp of the concepts. These differences highlight the range of student understanding and problem-solving skills in applying the concepts. Uliyandari et al. (2021) suggest that mastery of subject matter enhances students' ability to apply learned concepts.

Following the learning trajectory, the next step involves evaluating outcomes within the DDR framework, considering learning activities, student feedback, and teacher observations to identify areas for improvement, such as the need for additional KoPer media (Supena et al., 2021). Refining the instructional design aims to enhance learning effectiveness and encourage collaboration. Walkington & Bernacki (2020) emphasize the importance of continuous evaluation in optimizing learning outcomes. Research by Arianto et al. (2024) and Wei et al. (2021) supports the role of evaluation in adapting instructional designs. By identifying strengths and weaknesses, improvements can be made (Muñoz et al., 2022). A systematic evaluation ensures the effectiveness of KoPer media in developing students' skills and understanding of mathematical and STEM concepts.

The study's integration of STEM and the learning trajectory aims to adapt STEM approaches to mathematics education and develop a structured trajectory for understanding proportional reasoning. STEM is not merely an auxiliary tool but central to problem-solving-based instructional design. This approach is unique in its use of KoPer media, an interactive tool that helps students connect mathematical concepts to real-world applications. For example, in understanding proportions, light serves as a visual aid, enhancing comprehension through experiential learning. Unlike previous studies that treat STEM as supplementary, this study integrates STEM throughout the learning process, from identifying proportional patterns to analyzing results using light graphs. The success of this instructional approach depends on students' ability to explore concepts. Some groups improved significantly in graph construction and result analysis, while others faced challenges in interpreting complex data.

Conclusion

The integration of STEM and Learning Theory (LT) through KoPer has been proven effective in enhancing students' numerical problem-solving skills. Unlike previous studies, this approach aligns each stage of LT with STEM principles, creating a learning environment based on exploration and hands-on experience. Students actively engaged in exploration demonstrated a better understanding, although some still required additional guidance. Moving forward, adaptive learning strategies and the development of more interactive KoPer are expected to further optimize the effectiveness of STEM and LT integration in mathematics education. Furthermore, this research can serve as a foundation for future studies exploring other factors influencing students' mathematical problem-solving abilities, ultimately enhancing the quality of learning in elementary education.

Declarations
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Ethics Statements:*Ethical approval for this study was provided by the Social Sciences Ethics Committee within the researcher's university*
Conflict of Interest: The author declares no conflict of interest.
Informed Consent:*An informed consent form was obtained from each participant*
Data availability: *The data used in this study are not publicly available due to ethical restrictions but can be individually provided on a reasonable request.*

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