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STEAM+X Integrated Epistemic Learning Patterns in Ratio Learning for Secondary School Students

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Abstract

The concept of ratio is a fairly important mathematical concept, but it remains a persistent challenge for students. Therefore, this study aimed to optimize 3D representation skills and learning drive by developing epistemic learning patterns integrated with STEAM+X. X referred to aspects of history, culture, and architecture. The research design used was design-based research. Participants in this study consisted of 21 stakeholders in the field of education (teachers, school principals, and academics). The instruments used were a phenomenological questionnaire to explore the causes of students experiencing problems and an integrated STEAM+X ELP module to optimize student competence. The data were analyzed using a combination of thematic analysis and qualitative data analysis. The results revealed that there were five factors that caused low levels of both competencies, namely identity and orientation crisis, spatial experience deficit, motivation and engagement crisis, pedagogical mismatch, and ecosystem limitations. The solutions offered were a student-centered approach, technology and innovation, active and experiential learning, and ecosystem support. All of these components were represented in the form of an integrated STEAM+X ELP module, with the main activity referring to the *Subak Lingsar* miniature project. *Subak Lingsar* was chosen because it could support student learning of ratios, such as scale and the rate of change of water flow, as well as comparisons of value and inverse value. This study recommended that the module be implemented in the context of ratio learning by testing its impact on students' 3D representation abilities and learning drive in schools.

Keywords: 3D representation skills; epistemic learning patterns; learning drive; ratio learning; STEAM+X

INTRODUCTION

Ratio is one of the important concepts in mathematics because it has many practical benefits in life. Various studies show that students who master the concept of ratio are usually able to relate mathematical concepts to everyday life, other scientific contexts, and financial literacy (Certo et al., 2020; Kazunga & Bansilal, 2016; Phuong & Loc, 2020). Besides being beneficial for advanced mathematical concepts, the concept of ratio also plays an important role in other disciplines (Zavadskas et al., 2015). For example, the concept of ratio is used in decision-making to minimize risk and improve preference assessment (de Langhe & Puntoni, 2015). Ratios are a fundamental concept in mathematics learning, such as percentages, slopes, and trigonometric concepts (Fernandes & Leite, 2015). However, the existing facts reveal that learning the concept of ratio is poses persistent challenges for students in schools (Andini & Jupri, 2017; Çalışıcı, 2018; Wahyuningrum et al., 2017). Low 3D representation skills and suboptimal learning drive are serious problems experienced by students in this learning (Braithwaite & Siegler, 2018; Vágová et al., 2020; Wahyuningrum et al., 2017).

Learning drive essentially describes a student's inner motivation to actively engage in the learning process. Self-determination theory (Dunn & Zimmer, 2020) suggests that a strong learning drive emerges when a person's basic individual needs are met. Meanwhile, expectancy-value theory (Jiang et al., 2020) proposes that learning motivation is determined by the extent to which a person believes in the success of the learning process (expectancy) and perceives that what is learned has benefits or value for them (value). Therefore, learning drive in the context of ratio learning refers to the integration of students' beliefs in their abilities, leading to confidence in the success of learning, and the perception that the concept of ratio is beneficial to everyday life.

Several previous studies have identified various interrelated factors that have caused students to experience obstacles in learning the concept of ratio, including students' misunderstandings about proportional reasoning, their limitations in creating representations, and a lack of facilities and infrastructure that have supported learning (Andini & Jupri, 2017; Wahyuningrum et al., 2019, 2022; Winarni et al., 2021). One of the most dominant factors that has caused students to face these obstacles has been the use of teaching materials that have been less contextual and have not involved visual forms, resulting in less optimal conceptual understanding and student engagement (Sridana et al., 2025; Wahyuningrum et al., 2017). The teaching materials used by teachers have tended to be less interactive and have not adequately met students' needs (Sukarma et al., 2024). There have been quite a few studies that have developed interactive teaching materials for students in learning the concept of ratio to complement the scope of STEAM learning (Sari et al., 2024; Szilágyi et al., 2024; Wahyuningrum et al., 2017, 2022), but not many have used epistemic learning patterns (ELP) integrated with STEAM+X, with "X" referring to aspects of culture, history, and architecture (Bedewy & Lavicza, 2023; Isnawan et al., 2025). In the context of this study, ELP has been conceptualized as a learning framework that has emphasized the process of acquiring concepts through discovery activities, model construction, and reflection on thinking processes that have facilitated students to actively build and validate their mathematical knowledge, rather than simply receiving information from the teacher (Isnawan, Alsulami, & Sudirman, 2024; Sridana et al., 2025; Sukarma et al., 2024).

Current research presents an innovation in the form of integrating ELP with 3D representation, placing learning drive as the main motivational component. This differs from previous studies that focused on envelope techniques for ratio-proportion (Çalışıcı, 2018), the development of RME learning tools (Rahmawati et al., 2023), or project-based distance learning (Desmaiyanti & Sugiman, 2023). This provides a new approach to understanding how students construct knowledge through 3D representation with structured ELP. A comparison of current research with some previous studies can be seen in Table 1.

Table 1. Comparison of *Current Research* with Previous Studies

Aspects	Çalışıcı (2018)	Rahmawati et al. (2023)	Desmaiyanti & Sugiman (2023)	Current Research
Main Focus	Determining students' learning difficulties and investigating the effect of the envelope technique.	Development of RME learning tools on the topic of ratio.	Development of project-based distance learning materials.	Development of ELP for 3D representation and learning motivation.
Theoretical Approach	Misconception	RME	Project-based learning and dynamic software	ELP integrated with STEAM+X
Mathematical Competency	Conceptual understanding	HOTS	General spatial ability	3D Representation and Learning Drive
Research Design	Experimental design	Plomp model (3 Stages)	Quasi-experimental with dynamic software	Design-based research
Technological Innovation	Development of an envelope-shaped visual model conventional	Learning media and HOTS	Dynamic mathematics software	Google Gemini and Measure (App Store)
Culture	-	-	-	Subak Lingsar

Based on the previous description, the solution offered to optimize 3D representation and learning drive abilities is the STEAM+X integrated ELP. Therefore, this study aims to optimize students' 3D representation and learning drive abilities through the development of STEAM+X integrated ELP. Several research questions were developed to achieve this goal, including:

1. What factors cause students' 3D representation and learning drive abilities not to develop optimally?
2. How can the proposed solutions optimize 3D representation abilities and learning drives for students who are not developing optimally?
3. What is the design of learning that optimizes 3D representation abilities and learning drive?

METHOD

The design used in this study was design-based research (DBR). DBR was used for several reasons. First, DBR is specifically designed to develop and optimize educational interventions that align with research objectives (optimizing 3D representation skills and learning drive). In the context of this research, "learning drive" referred to students' intrinsic motivation and active academic engagement in learning. This concept had several key indicators: curiosity, persistence in problem-solving, active engagement in discussions when encountering concepts, and reflection during learning activities. Second, DBR allows for the simultaneous development of learning theory and practice (STEAM+X integrated ELP). Third, the iterative cycles in DBR enable testing the effectiveness of STEAM+X integrated ELP and making learning improvements based on empirical data (learning implementation results) (Hoadley & Campos, 2022; Scott et al., 2020).

The DBR procedure used included several stages, namely grounding, conjecturing, iterating, and reflecting (Hoadley & Campos, 2022; Isnawan et al., 2025). In the grounding stage, the researcher analyzed the initial conditions of students' 3D representation abilities and learning drive. After that, the researchers conducted FGDs with various education stakeholders regarding the factors causing the low levels of these two competencies and alternative solutions to optimize them. In the conjecturing stage, the researcher designed the learning based on the analysis results from the previous activity. At this stage, the researcher developed teaching modules using the ELP steps, designed the STEAM+X project

(*Subak Lingsar*), and integrated the project into the ELP steps. The final output of this activity was an ELP teaching module integrated with STEAM+X.

The next stage was iterating. At this stage, the researcher implemented the teaching module for several meetings, followed by regular reflection after the learning activities were completed. This reflection was intended to identify strengths and weaknesses in learning and to make improvements to address any shortcomings experienced. The final step was reflecting. In this activity, the researcher reflected on all the stages previously carried out to then make improvements to the shortcomings in each stage and the instruments used. To ensure the teaching module was of good quality with diverse perspectives, this research also adapted the lesson study activities (plan, do, and see). Due to several considerations, such as methodological and contextual factors, the DBR stage described in the context of this research was limited to the conjecturing stage. The subsequent stages, namely iterating and reflecting, were not implemented and were planned for subsequent research. Simply put, the research procedure was illustrated in Figure 1. The blue dotted lines indicated the DBR stages that were implemented in this study.

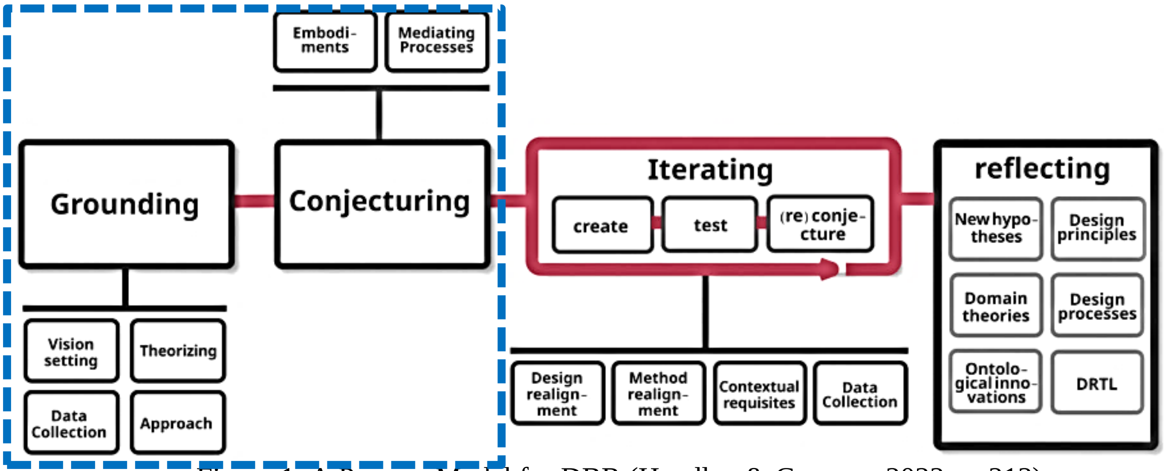


Figure 1. A Process Model for DBR (Hoadley & Campos, 2022, p. 212)

The participants in this study were 1 principal and 12 teachers from a private junior high school, as well as 6 academics and 2 mathematics education students from a private university in Mataram, Indonesia. The teacher participants had teaching experience ranging from 1 to 20 years, while the academics had teaching experience from 6 to 11 years. The participants consisted of 10 men and 11 women. The teacher participants were selected because the schools where they taught were identified as having students with low 3D representation skills and learning drive. The principal and teachers served as data sources to identify learning challenges and assess the feasibility of the module. Lecturers, acting as academics, acted as experts, providing advice during the design and validation stages. Several students participated in the simulation and usability testing of the module to obtain initial data on its practicality from a student perspective.

There were several instruments used in this study. First, a phenomenological questionnaire aimed at obtaining data related to the existence of practical problems, the factors causing students to experience practical problems, and alternative solutions to optimize students' 3D representation abilities and learning drive. The questionnaire was developed based on a review of relevant literature on spatial reasoning and student learning motivation (Kurt et al., 2023; Lee & Reeve, 2017; Salikhova et al., 2024). The questionnaire consisted of several open-ended questions designed to enable participants to express their experiences and perceptions in depth. Prior to use, the instrument was validated by three experts (two mathematics education experts and one contextual education expert) to ensure content validity and language clarity. It was also piloted with several teachers to refine the wording and question structure. Data collection related to this practical issue was conducted through focus group discussions (FGDs) involving all previously described participants. Second, an ELP module integrated with STEAM+X. This module aimed to obtain data related to student responses during learning.

There were two data analysis techniques used in this study. First, thematic analysis was used to analyze the results of the phenomenological questionnaire. The results of this analysis were used to answer research questions 1 and 2 because the themes that emerged from these results provided an overview of the conditions, causes, and solutions for optimizing the two targeted competencies. The thematic analysis conducted included several activities, such as familiarizing oneself with the data, determining initial codes, categorizing initial codes, identifying themes, reviewing themes, and defining or naming themes (Isnawan et al., 2022; Nowell et al., 2017; Sasidharan & Kareem, 2023). Second, qualitative data analysis was used to analyze the STEAM+X integrated ELP teaching module. This analysis included several activities: data reduction, presenting data in various forms of representation, and drawing conclusions (Sridana et al., 2025; Sukarma et al., 2024).

RESULTS

What factors cause students' 3D representation and learning drive abilities not to develop optimally?

Before identifying the factors that caused students' low 3D representation ability and learning drive, an initial overview of both competencies was provided. Based on the analysis results, it was found that 95,24% of teachers stated that students' 3D representation skills had not developed optimally, and 75% of students' learning drive had not developed optimally. This indicated that students were showing a crisis in 3D representation competence and learning drive in mathematics learning. This condition then required relevant corrective action. To identify potential solutions, it was necessary to analyze the factors that contributed to the low performance of these two competencies. The factors that contributed to low 3D representation ability were illustrated in Figure 2. Internal deficits were related to the lack of learning motivation and active student engagement. Pedagogical limitations referred to the gap between 3D learning needs and teaching practices. Infrastructure limitations referred to the lack of infrastructure and resources that supported 3D learning. Finally, environmental or experiential factors referred to the lack of exposure and practice in the 3D context.

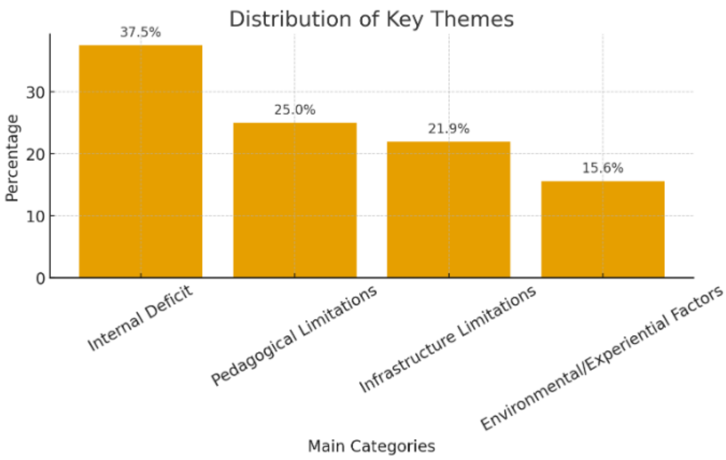


Figure 2. Factors Causing Low 3D Representation Ability

Regarding students' learning drive, it was found that there were 29 initial codes formed into 5 categories: motivational deficit and internal orientation, pedagogical limitations, infrastructure limitations, external and environmental factors, and stress and pressure factors. From those 5 categories, 4 themes emerged. TLD1-1 is related to the loss of meaning and purpose in the learning process. TLD1-2 referred to low emotional and cognitive engagement in learning. TLD1-3 is related to the gap between learning practices and students' motivational needs. Meanwhile, TLD1-4 referred to the limitations of systemic support from the learning environment. A description of this theme could be found in Table 2.

Table 2. Theme Description (Factors Causing Low Learning Drive)

Theme Code (TLD1)	Theme Description
TLD1-1	Identity crisis and learning orientation.
TLD1-2	Deficit in engagement and intrinsic interest.
TLD1-3	Ineffectiveness of the learning system.
TLD1-4	Deficiencies and the learning support ecosystem.

After further analysis, the factors that contributed to students' low 3D representation ability and learning drive were found to be similar. Based on the synthesis results, five factors were identified as contributing to students' suboptimal performance in these two competencies. A summary of these contributing factors was presented in Figure 3.

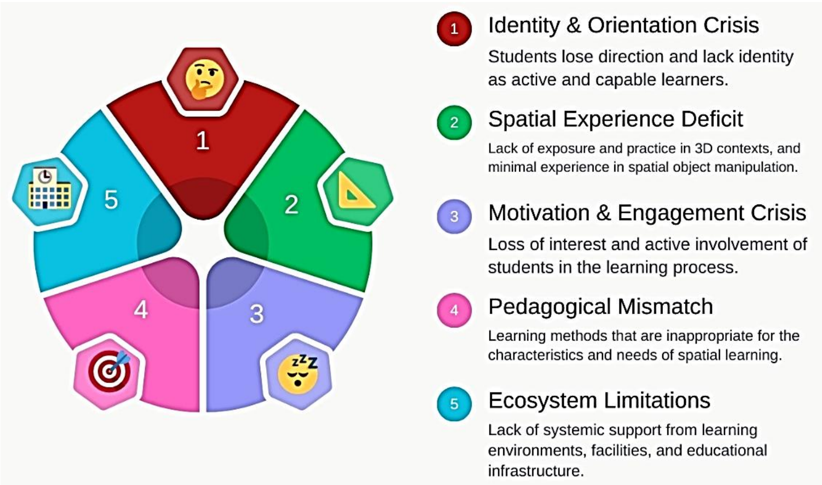


Figure 3. Model Synthesis of Causative Factors

How can the proposed solutions optimize 3D representation abilities and learning drives for students who are not developing optimally?

Based on the results of the thematic analysis of teachers' responses regarding the solutions offered to optimize 3D representation skills, it was found that there were 33 initial codes formed with 6 categories. These six categories were related to technology and media, pedagogical strategies, hands-on activities, pedagogical support, individualization, and infrastructure. From these six categories, four themes emerged as shown in Table 8. T3D2-1 is related to the integration of technology and interactive media to create rich and immersive 3D learning experiences. T3D2-2 referred to personalizing learning strategies based on students' individual characteristics, interests, and abilities. T3D2-3 concerned the development of 3D representation skills through hands-on experiences and manipulative activities. Meanwhile, T3D2-4 referred to the creation of a holistic learning environment that facilitated the optimal development of 3D skills. A description of the theme could be found in Table 3.

Table 3. Description of the Optimalization of 3D Representation Ability Solution Theme

Theme Code (T3D2)	Theme Description
T3D2-1	Technology-based multimodal learning.
T3D2-2	Experiential and hands-on learning.
T3D2-3	Student-centered learning approach.
T3D2-4	Supportive learning ecosystem.

Next, the thematic analysis of teachers' descriptions of solutions to optimize students' learning drive yielded 40 initial codes with 7 categories. From those 7 categories, 4 themes were formed. The first theme related to technology and innovation-based learning (TLD2-1). The second theme referred to a student-centered, holistic approach (TLD2-2). The third theme concerned active and engaging learning (TLD2-3). And the fourth theme referred to the development of sustainable learning drive (TLD2-4). Figure 4 showed a description of these themes.

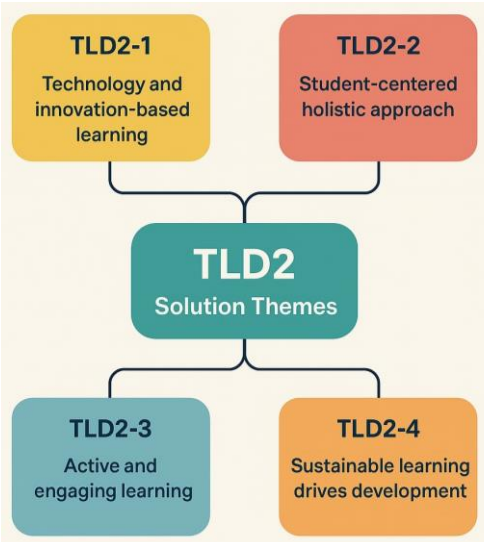


Figure 4. Description of the Optimal Learning Drive Optimization Solution Theme (TLD2)

Similar to the causal factors, alternative solutions for optimizing 3D representation ability and learning drive also shared several similarities. After analysis, a synthesis of the characteristics of solutions for optimizing both competencies was obtained. A summary of the characteristics of these alternative solutions was presented in Figure 5.

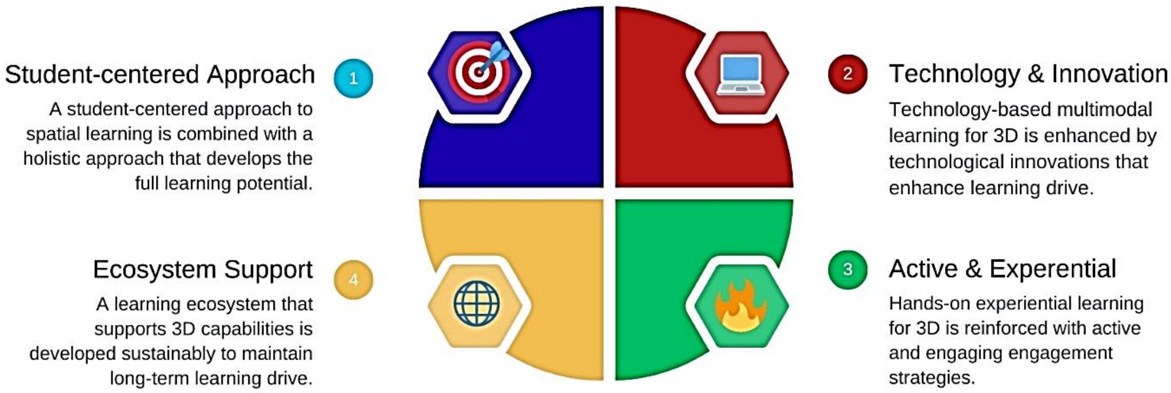


Figure 5. Alternative Solution Synthesis Model

What is the design of learning that optimizes 3D representation abilities and learning drive?

Based on the analysis of Table 3 and Figure 4, it was found that to optimize students' 3D representation abilities and learning drive in mathematics instruction, it was necessary to develop a learning design that integrated technology into instruction, actively engaged students in the learning process, adopted a student-centered approach, and fostered a comprehensive and sustainable learning ecosystem. One learning approach with these characteristics was epistemic learning patterns (ELP). More specifically, ELP that integrated STEAM+X. STEAM+X integrated ELP was a learning pattern that integrated STEAM+X projects into the steps or activities of learning that followed an epistemic learning pattern. STEAM+X integrated ELP consisted of several activities, namely initial activities, core activities, and final activities in learning (Figure 6).

Figure 6. Summary of STEAM+X Integrated ELP Activities

The initial activities consisted of *Let's Listen*, which referred to students listening to the learning objectives or targets they needed to achieve; *Let's Read*, which aimed to motivate students' learning through reading motivational stories related to the benefits of the material they would be studying in everyday life; and *Let's Guess*, which was related to confirming students' mastery of prerequisite material. A snippet of the *Let's Read* activity could be seen in Figure 7. Figure 7 presented several benefits of the concept of speed in everyday life. For example, speed enabled students to arrive at school on time, knowing the time and distance allowed them to manage their energy, helped car racers become champions, and illustrated the role of water speed in meeting life's needs.

The core activities consisted of several actions. *Let's Find a Solution* referred to students' activities in solving problems related to the STEAM+X project. The STEAM+X project presented in this study was the *Subak Lingsar* creation project. *Subak Lingsar* was one of the irrigation channels fairly created by the people of *Lingsar* to channel water to the rice fields of both Muslim and Hindu residents. In this activity, students used *Google Gemini* to find ideas related to the shape of the *Subak Lingsar* that would be created. A snippet of the problem presented could be seen in Figure 8. Figure 8 showed a problem for students to solve. This problem was related to *Subak Lingsar*. The image also explained the history of *Subak Lingsar* and asked students to sketch *Subak Lingsar* using their desired dimensions but adjusted these dimensions to actual or customary measurements. *Let's tell a Story* related to students presenting processes and solutions in front of the class as one of the introspective efforts in learning. *Let's Draw* conclusions regarding student validation of the mathematical concepts or procedures found. *Let's Practice* referring to the institutionalization aspect of students toward concepts they already possessed. This activity involved students solving new problems using the concepts they had learned.

***Let's Read* (5 Minutes)**

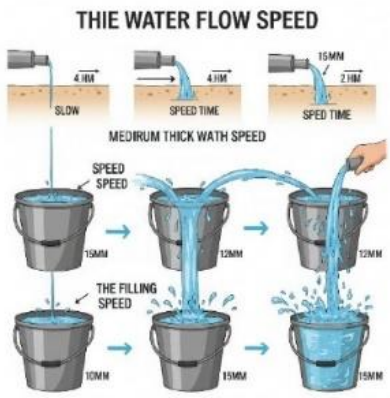
Read the story below carefully. Then, tell your friends what message the story conveys.

The Importance of Speed in Everyday Life

Why are we always on time for school? Speed is the answer! Understanding the rate of change helps us manage our schedules and arrive on time.

Cycling, want to know how fast you can pedal? Speed matters. Know your distance and time, and calculate your average speed. This will help you manage your energy or pace when you're pressed for time.

When racing cars, speed is key! The speed at which a car changes position is crucial, helping both the team and the driver achieve victory.



Filling a bucket? The speed of the flowing water determines how quickly it fills. Understanding flow rate is crucial in life.

Figure 7. Highlights from the *Let's Read* Activity

Let's Find a Solution (25 Minutes)

Work on this problem in groups. Divide the tasks, keep track of the time, and double-check your answers before submitting.

Daily Life Problems

Have you ever wondered how the rice fields in some areas of West Lombok are so fertile and evenly watered? The key is *Subak Lingsar*, a unique irrigation system where farmers work together to manage water from the *Lingsar Temple*. There's also the *Topat War* tradition, a way of expressing gratitude for abundant rice. Lingsar isn't the only place where subak is used; several other areas in Lombok also use it. Now, let's sketch a subak with precisely sized rice fields. Feel free to determine the actual size of the water channels *(Subak)* and rice fields, and don't forget to include scale in your sketch!

You can find subak ideas using Google Gemini.

Figure 8. Highlights from the *Let's Find a Solution* Activity

The final activity consisted of *My Reflection*, which referred to several activities. First, student reflection on mathematical concepts or procedures that had already been learned. In this activity, students were expected to reconfirm whether the learning objectives had been achieved or not. Second, student reflection on feelings related to students expressing how they felt after carrying out the learning activity. Third, student character commitment related to whether students would commit to performing various kinds of good deeds in life after learning. Finally, suggestions for improvement related to the suggestions students provided to enhance the quality of learning in the next meeting. A sample of student activities at the end of the session could be seen in Figure 9. Figure 9 showed that students were asked to reflect on the concept of comparison relevant to a particular mathematical model. The figure also reflected students' feelings and their commitment to helping each other. Students were also asked to provide reflections and suggest improvements for the next meeting.

My Reflection (5 Minutes) *Answer the following questions based on your current situation.*	
Consider the following model: $3\ subak \Rightarrow 4\ rice\ fields$ $6\ subak \Rightarrow A\ rice\ fields$ Is this model a comparison of equal value or inverse value?	**Equal/Inverse Value**
Put a tick (√) regarding your feelings after studying mathematics today.	
☐	☐
	
I am committed to helping each other with friends or others!	
☐	☐
Yes	No
What are your suggestions for improving learning at the next meeting?	
Don't forget to continue to be enthusiastic about learning and praying, children. May Allah SWT make you a successful person in this world and the hereafter in the future. Amen.	

Figure 9. Highlights of *My Reflection* Activities

DISCUSSION

The results of an in-depth analysis of the factors that hinder students in developing 3D representation skills and learning drive can be seen in Figure 3. Figure 3 shows that there are similarities in the causal factors between these two competencies, leading to the synthesis that there are five factors that cause these two competencies not to develop optimally. Regarding the solutions offered, information was obtained that there are four solutions offered to optimize students' 3D representation abilities and learning drive in mathematics learning. After a more in-depth analysis, it was found that the solutions offered tend to be the same (T3D2-1 is equivalent to TLD2-1, T3D2-3 is equivalent to TLD2-2, T3D2-2 is equivalent to TLD2-3, and T3D2-4 is equivalent to TLD2-4) (Figure 5).

The first alternative is the integration of technology and innovation into learning. The results of this study are in line with Sridana et al. (2025), who reveal that to optimize mathematical representation abilities, educators are expected to integrate various forms of innovation and technology into learning. This is because the use of technology provides opportunities for students to be more active and interactive during mathematics learning (Donovan & Loch, 2013). One example of technology that can be used is the utilization of AI (Popenici & Kerr, 2017), such as *Google Gemini*, as a tool to facilitate students when performing 3D representations.

The second alternative is student-centered learning, which refers to the use of a student-centered approach with the hope of optimizing all student potential. The results of this study are in line with Aliyu et al. (2023), who reveal that student-centered learning is one of the recommended approaches to mathematics instruction in the 21st century. This is because the learning facilitates students to use various competencies optimally through diverse learning activities (Friend et al., 2021). One example of student-centered learning that can be used is epistemic learning patterns (ELP) (Isnawan, Alsulami, & Sudirman, 2024; Sukarma et al., 2024). ELP is one of the learning patterns that include various student activities in constructing mathematical concepts or formulas (Isnawan, Sudirman, et al., 2023). Some previous research results also reveal that ELP is able to optimize students' mathematical representation abilities and learning motivation (Isnawan, Mastoor Alsulami, et al., 2024; Isnawan, Sudirman, et al., 2023).

Active and experiential learning then becomes the third alternative solution offered. This alternative relates to hands-on experiential learning to strengthen 3D representation skills with active and engaging strategies. The results of this study are in line with Guan et al. (2024), who reveal that direct experiential learning, such as hands-on activities, is one alternative solution for optimizing students' representation abilities and learning motivation. This is because such learning tends to be favored by students and has a long-term impact, as it involves the use of various student senses in the learning process (Urrutia et al., 2019). An example of a solution that can be used is the integration of STEAM+X in the form of a contextual 3D-based project, such as creating a miniature of an irrigation channel in one of the areas in Lombok, namely *Subak Lingsar*.

The final alternative solution relies on ecosystem support and sustainability. This solution relates to the availability of adequate facilities and infrastructure, continuous professional development for teachers, learning communities and peer support systems, as well as systematic and ongoing monitoring and evaluation. The results of this study are consistent with several previous studies (Fhloinn et al., 2014; Pinili et al., 2024; Trujillo-Torres et al., 2020), which reveal that the success of learning in optimizing mathematical competence is not a simple matter but requires a good support system from all parties with an interest in the world of education. In fact, continuous monitoring and evaluation is one of the keys to success in mathematics learning (Rincón et al., 2024). One operational example of this alternative is conducting FGDs with all relevant education stakeholders on practical issues and implementing lesson studies during the planning, implementation, and reflection on the developed mathematics learning.

Based on the research findings, it is found that the chosen solution to optimize students' 3D representation abilities and learning drive is the STEAM+X integrated ELP module. In the initial activities, the STEAM+X integrated ELP module contains three activities: learning objectives, a story to motivate students, and reinforcement of students' mastery of prerequisite material. This activity is based on the theory that students should clearly understand the learning objectives (Orr et al., 2022). This is because learning objectives are the target competencies and mathematical concepts that students should master by the end of the lesson (Herrera et al., 2020). Motivational stories are also based on the theory that students should know the benefits of the material they are going to learn (Maharaj-Sharma, 2024). Students who know the benefits of the material they are learning in everyday life tend to be more interested in learning activities (Johansen et al., 2023). The stories presented are also stories that are relevant to the students' context, their daily lives, and their cultural environment and use language that is easily understood by students so that they feel closer to the story (Wallace et al., 2022). Additionally, good mathematics instruction ensures that students understand all prerequisite material well so that they do not experience obstacles during the learning process (Kiser et al., 2022; Vandenbussche et al., 2018). This activity is expected to spark students' learning drive during the lesson.

Next, the STEAM+X integrated ELP module initiates learning by presenting a problem as an initial situation for students to construct concepts. This activity is based on the theory of didactical situations, which states that problems are situations that teachers can utilize as a means for students to construct mathematical concepts or procedures (Isnawan, Alsulami, Bonyah, et al., 2024; Isnawan, Alsulami, et al., 2023). In this study, the problem presented relates to the STEAM+X project, specifically *Subak Lingsar*. Students are asked to create a miniature of *Subak Lingsar* as one of the media to be used in solving the problem. The presence of this activity is expected to optimize students' 3D representation abilities and learning drive during instruction.

When creating the *Subak Lingsar* miniature, students are expected to learn and utilize various concepts from different disciplines (STEAM) without diminishing the essence of X (culture, history, and architecture) of the *Subak*. *Subak Lingsar* is expected to teach scientific concepts related to water flow velocity. *Subak Lingsar* uses the scientific concept of placing the dam higher than the rice fields so that water can flow faster (Alvaro-Berlanga et al., 2024). The size of the water channels is also expected to be different to maintain water pressure (Ramarao et al., 2023). Regarding the technological aspect, students are expected to use the latest technology, such as *Google Gemini,* to search for the *Subak Lingsar* model they create. Students also use the *Measure* app on their smartphones to help them calculate the length of irrigation channels and rice fields. This is intended to make learning more interactive and engaging for students (Belkacem & Hireche, 2025; Sunitha et al., 2023). Finally, it is expected that students' learning drive will grow with this activity.

The concept of engineering is also used by students because before making the miniature, students are first asked to sketch the miniature. Additionally, students are also expected to create various supporting elements for the *Subak,* such as water gates, irrigation channels, rice paddies, dams, and other objects typically found in rice fields. Students are also expected to create sketches with specific scales and from various perspectives. This activity is expected to facilitate the optimal development of students' 3D representation skills. This is based on the theory that miniature projects can optimize students' representational abilities (Masoud, 2017; Prabhu et al., 2025). This theory is supported by several previous studies (Remijan, 2016; Septian et al., 2020) that show that creating miniature projects leads to optimal development of students' representational abilities and learning drive.

Students are then expected to add an esthetic touch to the *Subak* they create. Students are given the freedom to add color, trees, huts, or other objects to beautify the *Subak* they create. Students are also given the freedom to use *Google Gemini* when searching for color combinations or supporting accessories for the miniature. The touch of art is expected to make learning more interesting, thus impacting students' learning drive. This integration of art is based on several studies that reveal the presence of artistic elements in mathematics learning makes learning more interesting for students, leading to optimal development of their learning drive (Ernest & Nemirovsky, 2016; Nutov, 2021).

Regarding the mathematical aspect, this project is used as a means to facilitate students in learning several concepts related to ratios. First, students are expected to learn principles about scale, rate of change (speed), and direct and inverse proportions (non-proportions). *Subak Lingsar* teaches students to construct the concept of scale well. The size of the miniature used should be realistic compared to the actual size of the *Subak*. The finished *Subak* is used by students to learn about speed. Students are asked to conduct several experiments on the *Subak* to determine the water flow rate, as well as the time or number of farmers needed to irrigate the water from the dam to the farmers' rice fields. This integration is based on a theory that reveals hands-on activities can optimize students' mathematical competencies, including representation skills (Meilon & Mariani, 2019). Students can rotate the *Subak* miniature to strengthen their 3D representation skills. Some previous studies also reveal that students' representation skills develop optimally through the use of hands-on activities in mathematics learning (Shi et al., 2023; Wong et al., 2024).

The presence of X in the form of *Subak Lingsar* is then expected to bring students closer to learning and help them better understand culture. Besides the cultural aspect, *Subak Lingsar* also has a long history related to interreligious harmony in Indonesia. *Subak Lingsar* teaches social values, such as sharing things fairly and working together to complete a task. These are the values that students are expected to uphold firmly when they grow up. This is because values guide a person when they are about to act and make a person a better and more civilized human being (Kamid et al., 2022; Nguyen &

Crossan, 2022; Vega-Tinoco et al., 2024). In the context of Islam, the value of justice is highly emphasized because it brings several social benefits, such as reducing conflict and disputes, creating a sense of security and comfort, and building trust among people (Karimullah, 2023; Shaukat et al., 2024).

The STEAM+X integrated ELP module also provides opportunities for students to reflect on solutions and processes while solving problems. This activity serves as a form of validation for students' work. This is based on the theory that students need validation from other students to ensure whether the solutions or strategies used to solve problems are correct or not (Biton, 2025; Calkins et al., 2020). This validation activity is then reinforced with the *Let's Summarize* activity. In this activity, students are expected to be able to summarize the mathematical concepts or procedures learned from previous problem-solving activities. This activity is the core activity in the process of constructing mathematical concepts or procedures. In this activity, students are expected to gain objective knowledge so that their understanding reaches the stage of ways of understanding (Bone & Doz, 2023; Harel, 2017, 2019).

The next learning activity in the STEAM+X integrated ELP module is *Let's Practice.* This activity aims to strengthen students' understanding of the mathematical concepts or procedures being studied (Sridana et al., 2025). This activity is an internal knowledge-building activity by the students (Sukarma et al., 2024). The last activity is *My Reflection.* This activity is an assessment for a learning activity because it involves self-assessment by students regarding learning objectives, feelings (social-emotional), commitment to upholding certain values, and suggestions for improving learning activities. This activity is based on several theories that state that students should be able to self-assess their understanding of the concepts or competencies that are the learning objectives at the end of the learning process, students' social-emotional well-being should improve after the learning activity, learning should instill positive values in students that underpin their actions, and students should be given the freedom to provide suggestions for improving learning (GUTU, 2023; Koç et al., 2024; Rose et al., 2021; Williams et al., 2019).

The findings of this study are expected to contribute to the SDGs, particularly SDG 4 (quality education), SDG 9 (industry, innovation, and infrastructure), and SDG 11 (sustainable cities and communities). The innovative STEAM+X-integrated ELP teaching module is expected to optimize higher-order thinking skills, learning motivation, and character values. Furthermore, the STEAM+X-integrated ELP encourages the integration of technology, including AI, into mathematics learning as a form of innovation in education. Finally, the integration of local wisdom, such as *Subak Lingsar*, serves as one of the project's inspirations, which is expected to foster public awareness of sustainability, collaboration, and social and cultural harmony within a community. Several recommendations for future research are proposed. First, piloting the STEAM+X-integrated ELP teaching module to optimize students' 3D representation skills and learning drive in schools. Second, conducting a comparative study between the STEAM+X-integrated ELP and other learning approaches to identify their advantages and limitations. Third, developing an AI-based adaptive digital learning model to expand the reach and sustainability of learning across various educational contexts.

CONCLUSION

Based on the previous description, several findings have been concluded. First, there are five factors that contribute to students' low 3D representation ability and learning drive: identity and orientation crisis, spatial experience deficit, motivation and engagement crisis, pedagogical mismatch, and ecosystem limitations. Second, the solutions that can be offered to optimize both competencies include a student-centered approach, technology and innovation, active and experiential learning, and ecosystem support. Third, the STEAM+X integrated ELP teaching module is one solution that represents the characteristics of the previously described solutions. The creation of the *Subak Lingsar* miniature is a STEAM+X project that was used. This is because the project is able to facilitate students in learning the concepts of scale, the rate of change in water flow (speed), and direct and inverse proportions. Additionally, the ELP learning module integrated with STEAM+X also utilizes AI assistance, such as *Google Gemini*, to train 3D representation skills and develop students' learning drive. This research has been able to develop an integrated STEAM+X ELP module that has been validated by experts but has not yet been tested in the classroom. Therefore, this study recommends that further research be conducted to examine the effectiveness of this module in optimizing the two previously mentioned competencies. The integrated STEAM+X ELP has the potential to impact classroom learning by encouraging teachers to integrate discovery-based learning, cultural integration, and technology in mathematics education. This provides an opportunity for a transformation of learning toward epistemic-oriented learning. This framework also has the potential to serve as a foundation for learning design and curriculum development in the future, especially in STEM education, in order to foster creativity, reflective thinking, and cultural sustainability. Future research is also expected to conduct broader classroom trials and comparative analyses with various innovative learning models to evaluate the pedagogical impact and scalability of ELP.

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DECLARATIONS

Author Contribution	:	Author 1: Conceptualization, Writing - Original Draft, Editing and Visualization; Author 2: Writing - Review & Editing, Formal analysis, and Methodology; Author 3: Formal analysis and Methodology; Author 4: Formal analysis; Author 5: Validation and Supervision. (https://www.elsevier.com/authors/policies-and-guidelines/credit-author-statement)
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