

Phenomenology of mathematics learning in high school students on relations and functions: An innovative approach based on conceptual innovation

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Abstract

This study aims to explore the learning experiences of high school students in studying the topic of relations and functions in mathematics. Employing a qualitative approach grounded in phenomenological methodology, the research focuses on students' subjective understanding of the classroom learning process. Data were collected through elicitation techniques, direct classroom observation, and documentation, involving four informants: three 11th-grade students and one mathematics teacher at SMA 1 Muhammadiyah Ponorogo. Data analysis was conducted thematically following the Miles and Huberman model, which includes the stages of data reduction, data display, and conclusion drawing. The findings reveal three main themes that shape students' learning experiences: (1) the meaning of learning mathematics for students, and (2) interaction and participation in the learning process. Students interpret mathematics learning differently depending on their level of understanding and their comfort with social interactions in the classroom. Students who understand the material tend to feel more confident during the learning process, whereas those who experience difficulties are more likely to be passive and hesitant to ask questions. In conclusion, meaningful mathematics learning should not only emphasize cognitive aspects but also consider the emotional and social dimensions of students' learning experiences.

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Learning experience, Relations and functions, Mathematics learning, Phenomenology, High school students

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Introduction

Mathematics plays a crucial role in various aspects of life, particularly in education. At every level of education, from elementary school to higher education, mathematics is a compulsory subject that students are required to study. Mathematics plays an essential role in formal education because it helps students develop reasoning abilities and fosters logical, analytical, critical, and systematic thinking. Thus, mathematics serves as a fundamental discipline that supports the development of higher-order thinking skills across all educational levels [1].

As a scientific discipline, mathematics is classified as an exact science that emphasizes conceptual understanding rather than rote memorization. The nature of mathematics requires learners to focus on understanding concepts instead of merely memorizing procedures or formulas. Therefore, students need to develop a solid understanding of mathematical concepts from an early age. With strong conceptual understanding, students can more easily master mathematical ideas and apply them in everyday contexts [2]. Furthermore, [3] [4] notes that students with strong mathematical understanding tend to demonstrate better problem-solving abilities than those with weaker comprehension. Hence, conceptual understanding is a key foundation for developing mathematical competence and effective problem-solving skills.

Despite its importance, many students continue to experience difficulties in learning mathematics, often because they do not fully understand the purpose of learning the subject [5] [1]. The primary objective of mathematics education is to enable students to comprehend the fundamental concepts underlying mathematical ideas. However, mathematics is frequently perceived as an unpopular subject by some students due to its abstract nature, the need to remember numerous formulas, and the complexity of the problems involved [6] [7]. This perception of mathematics as a difficult subject can negatively affect students' motivation and learning outcomes. Therefore, negative perceptions toward mathematics constitute a significant barrier to effective learning and student engagement [8].

Relations and functions are essential topics in mathematics instruction at the junior high school level and are revisited in greater depth at the senior high school level. Mathematics textbooks describe functions as fundamental concepts that underpin many areas of mathematics. A solid understanding of functions and the relationships between mathematical elements enables students to interpret problems more effectively and identify appropriate solutions [2]. However, many students still make errors in exercises and examinations due to an inadequate understanding of the concepts of relations and functions. They often struggle to describe these concepts accurately and fail to fully comprehend the meaning of the problems presented. This condition indicates that students' conceptual understanding of relations and functions remains limited and requires serious instructional attention [9] [10].

In addition, limited learning media such as the insufficient use of interactive software in mathematics instruction, particularly in teaching relations and functions also hinder students' conceptual understanding [8]. Based on the issues outlined above, this study aims to describe students' learning experiences in understanding the concepts of relations and functions using a qualitative phenomenological approach [11]. Through this approach, the study seeks to identify more meaningful and contextual learning methods that can help bridge the gap between instructional practices and students' conceptual understanding. Thus, this research is expected to contribute valuable insights into improving mathematics learning by emphasizing students' lived learning experiences.

Method

This study adopts a qualitative approach using a phenomenological method. Phenomenology aims to describe individuals' experiences, feelings, and understanding based on their direct awareness, in which everything that emerges in consciousness is regarded as a phenomenon. Through this approach, researchers are able to explore students' lived experiences in the mathematics learning process, particularly in relation to the topic of relations and functions. In summary, the phenomenological approach is appropriate for revealing the essence of students' subjective learning experiences [12] [13].

That qualitative research seeks to understand phenomena in depth by examining each case comprehensively, as the characteristics of the problems studied may vary across cases [14]. Through this approach, a holistic understanding of students' learning experiences can be constructed from their perspectives, producing contextual and in-depth insights. The primary data sources in this study were 11th-grade students at SMA 1 Muhammadiyah Ponorogo who had studied relations and functions, while additional data were obtained from mathematics teachers. Informants were selected purposively by considering the representativeness of experiences and the students' ability to convey their learning narratives reflectively. Thus, purposive sampling was employed to ensure the relevance and richness of the data.

Data collection techniques included classroom observation, in-depth interviews, and documentation. [15] explain that qualitative researchers commonly rely on direct involvement in the research setting, observation, in-depth interviews, and document analysis as primary data collection methods. In this study, observations were conducted initially to understand the classroom learning context, followed by semi-structured interviews to explore students' perceptions and experiences more deeply. Documentation was then used to complement and strengthen the data obtained from observations and interviews. Therefore, the combination of multiple data collection techniques enabled a comprehensive understanding of the learning phenomenon.

Data analysis was conducted using the interactive model proposed by [16], which consists of data reduction, data display, and conclusion drawing or verification. In the

data reduction stage, raw data from interviews, observations, elicitation and documentation were selected, simplified, and focused according to the research objectives. The data display stage involved organizing data into narrative descriptions, thematic matrices, or direct quotations that clearly represent students' learning experiences. Finally, the conclusion drawing and verification stage aimed to identify the meaning or essence of students' experiences and to re-examine emerging patterns to ensure the consistency and validity of interpretations, as emphasized by [17]. In conclusion, the interactive analysis model ensures that findings are systematically derived and analytically grounded.

The validity of the data was ensured through technique triangulation. Technique triangulation involves the use of multiple data collection methods to obtain information from the same data source. In this study, participant observation, in-depth interviews, and documentation were applied simultaneously to the same participants. This strategy enabled researchers to obtain a more comprehensive and credible depiction of students' learning experiences and the meanings embedded within them. Hence, triangulation was employed to enhance the trustworthiness and credibility of the research findings [14].

Results and discussion

Results

This study involved four informants consisting of three 11th-grade students and one mathematics teacher at SMA 1 Muhammadiyah Ponorogo show in Table 1. The student informants exhibited varying levels of conceptual understanding and cognitive abilities related to the topic of relations and functions, as well as diverse learning experiences. Informants were selected purposively to represent differences in academic abilities and learning styles. The mathematics teacher was included as an additional informant for triangulation purposes, providing an instructional perspective that enriched the interpretation of the findings. Specifically, Informant A was an active student who frequently asked questions when encountering difficulties and demonstrated confidence in problem-solving. Informant B tended to be more passive but showed interest in learning mathematics when the material was well understood. Informant C experienced difficulties in understanding the material and consistently displayed passive behavior during the learning process. Informant D, as a mathematics teacher, had teaching experience and had implemented various instructional strategies in the classroom. In summary, the selection of informants ensured diverse perspectives that supported a comprehensive exploration of students' learning experiences.

This study employed a phenomenological approach aimed at exploring the subjective experiences of students and teachers in the learning process of relations and functions. Data were collected through in-depth interviews and direct classroom observations conducted over several instructional sessions on the topic. These methods enabled the

researchers to capture participants lived experiences and meaningful interactions during the learning process. Thus, the phenomenological design allowed for an in-depth understanding of how relations and functions were experienced and interpreted by both students and the teacher.

Table 1. Students' learning experiences in mathematics

Theme	Category	Findings
Meaning of learning mathematics for students	Level of students' self-confidence	Students experience feelings of enjoyment and confidence when they successfully understand the material and answer questions correctly.
	Level of fear and doubt in understanding the material	Students feel hesitant to answer questions due to fear of making mistakes. Some students prefer to remain silent when they do not understand the teacher's explanation rather than asking questions.
Student participation in the classroom	Emotional closeness with the teacher	Students feel noticed and appreciated when they have a close and positive relationship with the teacher.
	Level of courage in asking and answering questions	Students tend to be more active when they understand the material. In addition, students are more willing to ask questions when the teacher is not perceived as strict or intimidating.
	Emotional-psychological barriers	Fear of the teacher's reaction makes students reluctant to ask questions. Feelings of embarrassment or fear of giving incorrect answers hinder student participation.
	Student participation	Teachers use direct prompts to encourage students to actively demonstrate their participation in class.

1. The meaning of learning for students

The results of interviews and observations indicate variations in students' learning experiences, as reflected in differences in their levels of understanding of the topic of relations and functions. Students who are able to understand the concepts and successfully solve problems tend to experience feelings of satisfaction, enjoyment, and increased self-confidence. They perceive success in understanding mathematics as a pleasant and meaningful experience. This is consistent with the statement of one student who stated, "...sometimes mathematics is fun when we understand it, so when I work on problems that I understand, I feel satisfied because I succeed..." (Informant B). These findings indicate that understanding the concepts of relations and functions provides psychological satisfaction and contributes to the formation of a positive meaning of learning for students.

In contrast, students who experience difficulties in understanding and solving problems related to relations and functions tend to exhibit feelings of fear and doubt and to behave passively during the learning process. They are often reluctant to ask questions and lack confidence in answering questions posed by the teacher. This condition is reflected in a student's statement, "sometimes I hesitate to answer questions, but once I understand, I think, oh, that's how it is" (Informant B), and is further supported by another statement, "I never ask

questions because I am afraid the teacher will get angry, so I feel hesitant and uncomfortable...” (Informant C). Such experiences reduce students’ self-confidence and lead them to perceive mathematics learning as a stressful activity. Therefore, it can be concluded that a low level of understanding of the material contributes to the formation of a negative meaning of learning, indicating that students’ meaning of learning is closely related to the emotional conditions they experience during the learning process.

2. Student interaction and participation in the classroom

The results of interviews and observations indicate that students’ psychological conditions and the communication patterns established by the teacher are important factors influencing students’ courage to ask and answer questions. Students who have a good understanding of the material generally demonstrate greater confidence in responding to and asking questions when necessary. In contrast, students who have not yet developed a sufficient understanding of the material tend to feel afraid, reluctant to respond, and prefer to remain silent. This is consistent with the statement of one student, who said, “I never ask questions because I am afraid the teacher will get angry, so I feel hesitant. When answering questions, I also feel afraid and embarrassed; I only respond when the teacher calls on me” (Informant C). These findings indicate that students’ participation in learning is not only related to cognitive aspects but is also strongly influenced by emotional security and their level of self-confidence in the classroom.

To address this issue, the teacher implemented various strategies to encourage the involvement of all students in the learning process. For example, during group activities, the teacher does not allow active and dominant students to always present the group’s work. Instead, opportunities are given to students who are usually passive so that they can take part in presenting the results of group discussions. As stated by Informant D, “... so I approach each group and ask them to divide the tasks; if a student has done the work, that student should not be the one presenting again—others must take the turn.” In addition, the teacher seeks to create a relaxed classroom atmosphere so that students feel comfortable, unafraid, and free to participate. This approach helps to create a more equitable learning environment while fostering students’ self-confidence and courage to ask questions and express their opinions.

Discussion

The findings of this study indicate that the mathematics learning process on the topic of relations and functions is shaped by an interplay of several factors, including students’ conceptual understanding, emotional comfort, social interaction, and the availability of adequate learning media and instructional support. Learning tends to become more meaningful when students feel psychologically safe, socially accepted, and pedagogically supported in ways that facilitate concrete and gradual understanding of

mathematical concepts. Thus, meaningful learning emerges from the integration of cognitive, emotional, social, and instructional dimensions.

1. The meaning of learning for students

The meaning that students attribute to learning mathematics is closely related to their experiences of success and failure in understanding the concepts of relations and functions [18]. Positive emotions such as enjoyment, self-confidence, and enthusiasm tend to develop when students demonstrate a good understanding of the material and are able to solve problems correctly [19]. Under these conditions, students perceive mathematics as an engaging and rewarding subject. In summary, successful learning experiences contribute to the formation of positive meanings of mathematics learning.

In contrast, students who experience difficulties in understanding the material often report feelings of fear, uncertainty, and embarrassment, particularly when they consider asking questions in class [20]. Limited conceptual understanding and confusion regarding relations and functions lead these students to perceive mathematics as a difficult and stressful subject. Consequently, the role of the teacher becomes crucial in shaping students' learning meanings. Teachers are expected to adopt a friendly, open, and non-punitive approach to students' mistakes in order to create a safe learning environment that fosters confidence and openness. Therefore, teachers play a key role in transforming negative learning experiences into positive and meaningful ones [3].

2. Student interaction and participation in the classroom

Student interaction and participation in classroom learning are strongly influenced by the emotional climate and communication patterns established by the teacher. Students who feel understood and experience minimal pressure are more likely to respond to questions, express opinions, and actively participate in classroom discussions. Thus, a supportive classroom atmosphere encourages active student engagement.

Conversely, students who fear making mistakes often choose to remain silent, even when they have questions or ideas to express [21]. Teachers also observe that only a small number of students tend to participate actively, while others remain passive throughout the learning process. To address this issue, teachers implement strategies such as rotating roles within group activities and providing individual guidance during discussions to encourage broader participation. Hence, instructional strategies that promote inclusivity are necessary to increase student participation.

These findings align with the study conducted by [22], who emphasizes that a positive and supportive classroom climate contributes to enjoyable learning experiences and enhances student engagement. This view is also consistent with

[23] theory of dialogical education, which posits that teachers should not function merely as transmitters of knowledge, but as facilitators who create spaces for equal, humane, and meaningful dialogue. In conclusion, a dialogical and supportive learning environment is fundamental to fostering active participation and meaningful mathematics learning.

Conclusion

Student participation in the learning process is strongly influenced by the emotional climate of the classroom. Teachers who adopt an open, supportive, and non-pressuring approach, and who are able to create a psychologically safe learning environment, can encourage students to develop the confidence to ask questions and actively engage in classroom discussions. Using a phenomenological approach, this study demonstrates that mathematics learning should not be limited to cognitive dimensions alone, but must also consider students' emotional and social experiences. Accordingly, teachers are expected to design and cultivate learning environments that are not only effective in enhancing academic achievement but also personally meaningful and humanistic for students.

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