Volume 4, Number 2, June 2023
Journal of Research on Mathematics Instruction
DOI: https://doi.org/10.33578/jrmi.v4i2.89
Journal's Webpage: http://jrmi.ejournal.unri.ac.id

Analysis of Learners' Errors in Working on Formative Tests on the Topic of Quadratic Equations and Functions

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ARTICLE'S INFORMATION

Article history:

Received: Apr-01-2024

Reviewed: Jun-01-2024

Accepted: Jun-17-2024

Keywords: Error Analysis, Quadratic Equation, Quadratic Function

ABSTRACT

The purpose of this study was to determine and analyze the errors of students in working on formative tests on the topic of Equations and Quadratic Functions by completing the perfect square root method and the ABC formula. This type of research is descriptive research with a qualitative approach. In this study, the subjects were taken from 12 students of class XI IT SMKS Dar El Hikmah Pekanbaru, each of which consisted of 2 students from the upper, middle, and lower groups. In this study, data collection techniques based on observation, written formative test questions, and interviews were used to determine students' errors in solving the topic of Quadratic Equations and Functions. In this study, it can be concluded that students' errors in solving the topic of Quadratic Equations and Functions with the method of completing the perfect square root and the ABC formula are the lack of understanding of the concept of the method, the lack of assignment of the topic, and the lack of students' mathematics learning so that students make many mistakes in solving problems.

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INTRODUCTION

Education is a crucial aspect of life because education is one of the processes that develop oneself so that one can face all forms of changes and problems with an open attitude without losing one's identity [1], [2]. In Law No.20 of 2003, education is an effort to create a learning atmosphere and learning process so that students actively develop their potential to have religious and spiritual strength, self-control, personality, intelligence, noble character, and skills needed by themselves, society, nation, and state.

Education plays a crucial role in supporting the success of Industry 5.0 [3]. Education in the Industry 5.0 era emphasizes the importance of integrating technological sophistication and human touch, focusing on cooperation between humans and machines. In this context, education must adapt to prepare individuals with relevant skills to work in an automated and connected environment. This includes the development of interdisciplinary capabilities that combine science, technology, engineering, and maths (STEM) with social skills, creativity, and critical thinking. Education should also emphasize mastery of advanced technologies such as artificial intelligence, robotics, and the Internet of Things (IoT) and facilitate a deep understanding of how these technologies can improve efficiency and innovation. Thus, a human-centric approach is key, where technology enhances quality of life, enriches human work, and promotes sustainable development. Therefore, education in the Industry 5.0 era must lead students to become competent users of technology and innovators who can design solutions for a better future.

Mathematics is one of the branches of education taught in the Indonesian education system. According to Permendiknas No.22 of 2006, mathematics learning is needed to fulfill academic requirements and help students think logically, systematically, analytically, critically, innovatively, and creatively. In mathematics, students are required to be able to solve mathematical problems.

Sujono suggests the definition of mathematics as an exact and systematically organized science [4]. Mathematics is also a science of logical reasoning and problems related to numbers and numbers. Based on this opinion, it can be concluded that learning mathematics is not just about mastering formulas or being able to do calculations.

In learning mathematics, you must also be able to reason and logic. So, when finding problems related to mathematics, students are able to get a solution quickly and think critically to examine the problem, the cause of the problem, and the right solution to solve the problem. Learning mathematics means learning various mathematical concepts, understanding the links between concepts, and applying them [5].

Maths, often seen as relevant only in academic contexts, plays an important role in students' daily lives. Math skills help students develop logical and analytical thinking abilities to make rational and informed decisions. In everyday activities, such as shopping, cooking, or planning a trip, students use mathematical principles to calculate costs, measure materials, or estimate time. Mathematics also strengthens our understanding of the world, such as interpreting graphs and statistics in the news, understanding regularities and patterns in nature, or even optimizing strategies in games and sports. This ability to apply mathematical concepts in real contexts not only enhances practical skills but also prepares students for future challenges and decisions. Therefore, mathematics is an academic subject and a vital tool that shapes how students interact and understand the world around them.

Along with recognizing that mathematics has broad relevance beyond the classroom environment, teaching approaches must adapt to enhance students' understanding and practical skills. This demands mathematics education that emphasizes memorizing formulas and calculation techniques and develops conceptual understanding and the ability to apply mathematical knowledge in real-life situations. Learning should be designed to link mathematical concepts with relevant examples and applications so that students can see a direct connection between what they are learning and how this is used in their daily lives. Thus, students become better equipped to face real-world challenges, use mathematical skills to solve problems, make informed decisions, and make sense of information obtained from various sources, ultimately improving their readiness for the future.

Considering the relevance of mathematics in everyday life raises the need to emphasize awareness of potential errors in applying mathematical concepts. Mathematics does facilitate decision-making and problem-solving; however, an incomplete understanding or misunderstanding of mathematical principles can lead to mistakes in their application. Therefore, mathematics education should strive to prepare students with learning strategies that strengthen conceptual understanding and facilitate the practical application of mathematical knowledge. This approach involves identifying and addressing areas where students often experience difficulties, enabling educators to improve the quality of mathematics learning. The ultimate goal is to ensure that students understand mathematics not as a series of mechanical procedures but as essential and applicable concepts, allowing for accurate and efficient application in their real-life context.

According to [6], students' errors in solving mathematics problems or problems are caused by several factors, including (a) errors in understanding mathematical concepts, (b) errors in using mathematical formulas, (c) calculation errors, (d) errors in understanding symbols and signs; and (e)

errors in choosing and using the solution procedure. Therefore, to understand mathematical concepts, paying attention to previous concepts is necessary.

One of the most common errors is concept understanding errors. According to [6], students have difficulty identifying a given concept's properties and recognizing the conditions that determine a concept. Meanwhile, [7] states that conceptual error is a mistake students make in interpreting terms, ideas, and principles. Conceptual errors can also be said to be students' mistakes in understanding the basic concepts contained in mathematics problems.

One of the maths learning topics taught is Quadratic Equations and Functions. The solution of quadratic equations can be done in three ways, namely: (1) factorization, (2) completing the perfect square, and (3) the abc formula. However, students still lack an understanding of quadratic equations and functions. This is supported by research conducted by [8], where students made errors in the transformation and process skills steps. Other learner errors on quadratic equations are due to students' weak mastery of topics such as algebra, fractions, negative numbers, and algebraic expansion, in line with research conducted by [9], who said that many of the students did not understand the concept of quadratic equations and miscalculated in solving quadratic equation problems.

Based on observations made by researchers during activities in class XI IT SMKS Dar El Hikmah Pekanbaru, it was found that students still did not understand the concept of the three methods of solving quadratic equations. Many students still do not understand when the three methods are used. In addition, many students still do not understand the basic concepts of algebra, such as addition, subtraction, multiplication, and division, and many of the learners still do not understand algebraic operations. On the other hand, less conducive learning causes students to not focus on learning in class. This can result in low student learning outcomes.

As a teacher, you must increase students' interest in learning mathematics. One of these efforts is explaining topics that students do not understand and proposing formative tests to help students understand the concepts of these topics. Therefore, to increase students' interest in learning mathematics, the researcher conducted a study to analyze students' errors when doing formative tests on quadratic equations.

METHODS

The research was conducted using descriptive research with a qualitative approach. Bogdan and Taylor [10] define qualitative research as a research procedure that produces descriptive data in the form of written or spoken words from people and observed behavior. Creswell [11] defines qualitative research as investigating social phenomena and human problems. Qualitative research is a strategy for searching for meaning, understanding, concepts, characteristics, symptoms, symbols, and descriptions of a phenomenon, focus and multimethod, natural and holistic, prioritizing quality, using several methods, and presenting narratively in scientific research [12].

Thus, it can be concluded that qualitative research is a technique that uses narratives or words to explain and describe the meaning of each phenomenon, symptom, and certain social situation. In qualitative research, the researcher is the key instrument to interpret every phenomenon, symptom, and certain social situation. Therefore, researchers must master the theory to analyze the gap between theoretical concepts and the occurring facts.

The advantages of qualitative research can be seen from broad and open investigations, direct and representative participants, in-depth analysis, rich and detailed information, exploring different views, being more descriptive and discovering new knowledge, dynamic processes, allowing new

evidence, rich social phenomena and in-depth criticism, holistic interpretation, the ability to explore values, beliefs, and assumptions, encourage creativity and innovative explanatory frameworks, involvement in data collection as well as data analysis, and encourage participation [13].

This research aims to find out and analyze accurately and precisely students' mistakes in the formative test on quadratic equations using the method of solving perfect square roots and the ABC formula. The subjects in this research were class. The researchers took the subjects of this research based on recommendations from the mathematics teacher, so they took six subjects of students with heterogeneous abilities. Next, the researchers grouped students according to their abilities. So, to determine the category for each group, the range of scores for each student was looked at. The range of student scores to determine their groups is as follows.

Table 1. Formative Test Results

Range Score	Category
71-100	High
41-70	Moderate
0-40	Low

Data collection techniques in this study were observation, written tests, and interviews. Observations were made to find out whether the learning process took place by the teacher and whether it went well and in accordance with the Teaching Module used. Written tests were conducted to show students' errors in solving quadratic equation problems. Interviews were conducted to triangulate answers written by research subjects to study and trace the subject's errors in solving the problems given.

RESULTS AND DISCUSSION

The research conducted by the researcher was conducted in the odd semester to test the task of describing the topic of quadratic equations, the method of completing perfect square roots, and the ABC formula to students of class XI IT SMKS Dar El Hikmah Pekanbaru, which amounted to 6 students. This study aims to determine and analyze students' errors in working on formative test questions on the topic of quadratic equations, the method of completing perfect square roots, and the ABC formula.

Determination of the subject of this study based on the results of the formative test given to 12 students of class XI IT SMKS Dar El Hikmah Pekanbaru and based on observations made and the number of errors experienced by students in answering questions, variations in the location of errors experienced, able to express opinions related to the questions given, and willing to be interviewed. So, six research subjects were obtained from two upper, middle, and lower groups. The following are the results of the formative tests of the six subjects.

Table 2. Formative Test Results

Research Subject	Test Results	Category
S-1	100	High
S-2	100	High
S-3	70	Moderate
S-4	67	Moderate
S-5	37	Low
S-6	30	Low

Research conducted by researchers found three student errors in solving formative test questions, including (1) concept errors, (2) principle errors, and (3) calculation errors. The following

explains the three types of errors experienced by students in solving the formative test questions.

1. Concept Error

Concept errors experienced by students in solving quadratic equation problems are errors in determining the formula to answer the problem. These errors are identified as follows.

a. Learners still do not understand when to use the ABC formula and the factoring method formula. This can be seen from the students' formative test results.

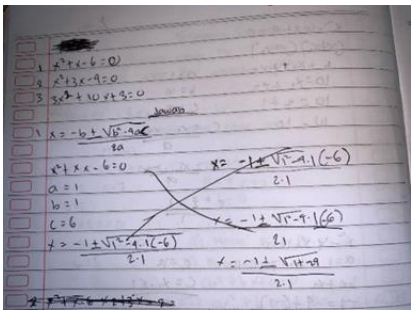

Figure 1. Results of Students' Work

After being confirmed through interviews, it turned out that the learners did not realize the error of the formative test.

(Transcript 1)

P : What method was used to solve the problem?
S-6 : Using the ABC formula ustadz.
P : Why do you use the ABC formula? Why didn't you use the factorization method?
S-6 : I think I can use the ABC formula, ustadz.
P : When did you use the ABC formula?
S-6 : When it cannot be factored ustadz.

Transcript 1 shows that students do not understand when the concept of the abc formula is used. This indicates that students cannot distinguish when the quadratic equation can be factored or cannot be factored. This causes students to use the ABC formula in the formative test question, and the results of the students' work are wrong because they do not understand the concept of the ABC formula.

b. Learners still do not understand the completion of the method of completing perfect square roots. In solving the formative test questions, students are still wrong.

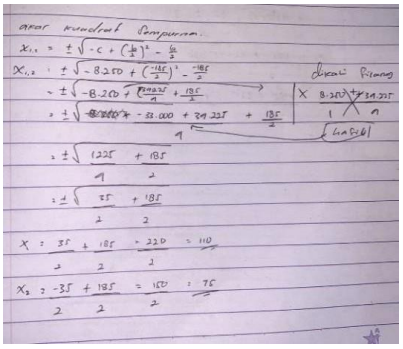

Figure 2. Results of Students' Work

The interview results found that students were still confused about the concept of the method of completing the perfect square root.

(Transcript 2)

P : Which step are you still confused about?

S-5 : In the third and fourth steps, ustadz.
P : What confused you at that step?
S-5 : I don't understand how to solve it, ustadz.

Transcript 2 shows that students still do not understand how to solve the quadratic equation by completing the perfect square root. This is because students do not understand the concept of the method so to solve the problem, students cannot.

2. Principle Error

Principle errors experienced by students in solving formative test questions are skipping or ignoring steps in the solution process and mistakes in solving problems not in accordance with the question's instructions. These errors can be identified as follows.

c. Learners tend not to identify the quadratic equation, the values of a, b, and c, which can sometimes make learners mistaken and wrong in working.

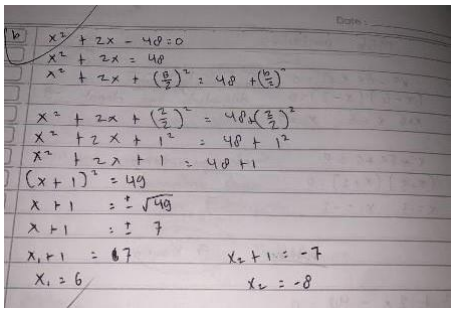

Figure 3. Results of Students' Work

From the interview results, the participant realised the error in working on the formative test question, where there was an initial step left behind.

(Transcript 3)
P : According to S-3, steps from what has been done are left behind.
S-4 : I don't think so, ustadz.
P : Are you sure that there are no steps left behind?
S-4 : Sure, ustadz.
P : So which ones are a, b, and c? Why don't you write them down?
S-4 : Owhh yes, ustadz.

Transcript 3 shows that students do not identify the quadratic equation. Learners tend to directly substitute the values of a, b, and c into the formula without writing it down first.

d. Learners use other formulas or methods that the teacher does not teach. This can be seen from the formative test questions that were used.

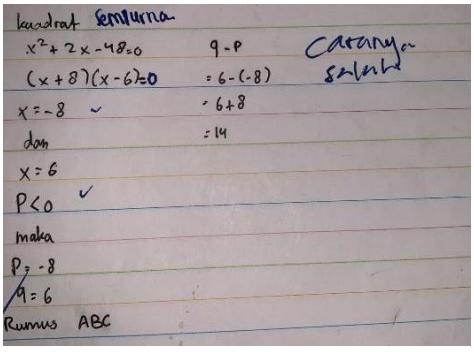

Figure 4. Results of Students' Work

Journal of Research on Mathematical Instruction, Vol. 4, No. 2, June 2023, 29-37
DOI: https://doi.org/10.33578/jrmi.v4i2.89
jrmi.ejournal.unri.ac.id, Online ISSN: 2715-6869

The interview results found that students did not use the method that had been taught but used other methods obtained from the Internet.

(Transcript 4)

P : Where did you get the formula from?

S-5 : From the internet ustadz.

P : Why do you use the formula from the Internet?

S-5 : Because I did not listen to the ustadz's explanation when he explained.

Transcript 3 shows that students prefer to use formulas on the Internet rather than asking back to the teacher or friends what they do not understand. Although the learners' work results are correct, the principles taught differ from the formula from the Internet.

3. Calculation Error

Errors that are often encountered are calculation errors by students. Calculation errors occur in performing addition and subtraction operations, operation signs in mathematics that are still wrong, errors in fractional number operations, and finding the root value of a number.

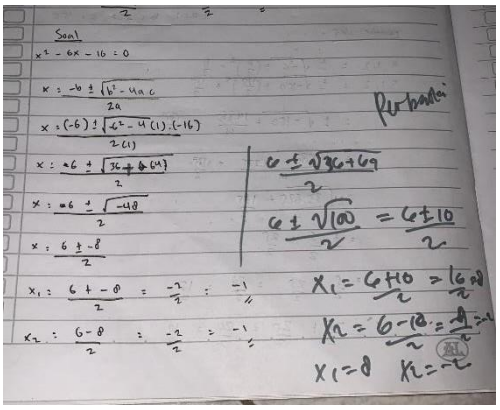

Figure 5. Students' Work

After being confirmed through an interview, it turned out that the learner knew the location of his mistake in working on the formative test question.

(Transcript 5)

P : Do you know where the mistake is?

S-6 : The wrong sign, right, ustadz?

P : Yes, the mark is wrong. What else is wrong besides that?

S-6 : I don't know, ustadz.

P : Let's see if it's true that $\sqrt{(-48)}$ results in -8 ABC.

S-6 : Owhh, yes, wrong ustadz.

Transcript 5 shows students still make mistakes in basic mathematical operations. This can be seen from the answers obtained. And students still don't understand how to get the root value if it is negative. This is because the learning process is still centered on the teacher. This can be seen when researchers conduct observations in the classroom. Students are not active during the learning process because the methods are less interesting, contextual problems are not presented, and learning is still teacher-centered.

CONCLUSIONS AND SUGGESTIONS

The types of errors experienced by students in solving formative test questions on the topic of quadratic equations, the method of completing perfect square roots, and the ABC formula are (1) concept errors identified: students still do not understand when using the concept of the ABC formula and factoring formula, and students still do not understand the concept of completing the perfect square root; (2) principle errors identified: students do not identify the values of a, b, and c from the quadratic equation and use other formulas or methods; (3) calculation errors identified: students are still wrong in basic mathematical operations such as addition and subtraction.

The factors that cause the errors experienced by learners in solving quadratic equations are as follows: low students' prerequisite knowledge about number operations students not understanding determining the roots of quadratic equations by completing the perfect square form. Students do not understand the ABC formula to determine the roots of quadratic equations when used, and students are less careful in using arithmetic operations.

Based on the research results, the author recommends improving students' understanding of quadratic equations. Firstly, curriculum and learning approaches should focus on building deep conceptual understanding. Learning materials need to be designed to be more contextualized, connecting the concept of quadratic equations with real applications in everyday life. This can help students see the practical value of what they learn and encourage them to apply their knowledge in various situations.

Secondly, teaching methods should be more interactive and student-centered. Teachers should encourage inquiry-based learning, where students are actively involved in the learning process through exploration, discussion, and reflection.

Thirdly, continuous formative assessment is important to implement. This allows teachers to routinely monitor students' learning progress and identify areas that require additional attention or intervention. The feedback should be constructive, help students understand their mistakes, and encourage them to think critically about ways to correct and improve their understanding.

Fourth, teacher professional development is a key aspect in improving the quality of mathematics teaching. Mathematics teachers must have solid pedagogical knowledge, a deep understanding of concepts, and the skills to integrate technology into their teaching. Workshops, seminars, and professional training can help teachers update and improve their teaching methods, making them more effective in teaching complex mathematical concepts.

Finally, collaboration between schools and parents should be improved to support mathematics learning. Parents need to be provided with resources and strategies to help their children learn at home, including an understanding of mathematical concepts and how to support independent learning. Schools can organize information sessions and workshops for parents, strengthening home-school relationships and encouraging a cohesive learning environment. For example, parents ask their children about their assignments and obstacles after coming home from school to encourage a cohesive learning environment. Parents must also be needed in the child's learning process because parents also have an important role in the child's growth and development.

Apart from that, teachers must also use interesting learning methods to apply in the learning process. This was obtained based on the results of observations from researchers. For example, they are using interesting learning models, using interesting learning media, and using learning tools in accordance with the demands of the current independent curriculum. In quadratic equation material, teachers can use teaching materials or resources such as Student Worksheets so that students can

discover concepts and formulas for quadratic equations. Teachers can also use interactive learning media for students to make learning more enjoyable.

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