

## **Students' Mathematical Connection Ability on Quadratic Function with Realistic Mathematics Education (RME) Approach**

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### **Abstract**

Students need to be able to make mathematical connections because it helps them learn math more thoroughly, retain it longer, and help solve problems. This study aimed to determine whether RME learning can improve students' mathematical connection skills. This type of research is experimental research with a nonequivalent control group design. This study used two groups as test subjects, each with 32 students, selected through a cluster random sampling technique. The data collection instrument used in this research is the mathematical connection ability test. The data analysis techniques used were an Independent Sample T-test, an effect size test, test results of each indicator of mathematical connection ability, and daily journal notes. The results showed that students who learned RME learning were more proficient in making mathematical connections than those who learned using conventional learning. In addition, the experimental group students experienced increased self-confidence and courage to express their ideas and see the surrounding events as part of the mathematical concepts they had learned.

**Keywords:** realistik mathematics education, mathematical connection, quadratic function

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### **Introduction**

A mathematical connection is one of the skills to be achieved in mathematics learning (Anggoro et al., 2022; NCTM, 2000; Wijaya & Dewayani, 2021). The capacity to connect mathematical concepts and topics, mathematics and other fields of science, as well as mathematics and real situations, is known as mathematical connection ability (García-García & Dolores-Flores, 2018; Hatisaru, 2022; Maisyarah & Surya, 2017). Making connections between mathematical ideas is essential for students to understand because it will result in a deeper and longer-lasting understanding (Hakim & Mulyono, 2020; NCTM, 2000). Mathematical connection skills also help students solve mathematical problems (Anggoro et al., 2022; Jawad, 2022; Pambudi et al., 2020; Romli, 2016; Yusuf et al., 2022). Therefore, practicing mathematical connection skills is very important so students can know the interrelationship of concepts inside and outside mathematics.

The importance of mathematical connection abilities is separate from students' mathematical connection abilities, which still need improvement. According to research by Hidayah et al. (2019), Oktafiana & Dewi (2020), Pebriyanti et al. (2018), and Setyaningsih et al. (2016), pupils' aptitude for mathematical connections is still low. Memorizing formulas is one factor that causes students' low mathematical connection abilities (Hafiz et al., 2017). Students cannot interpret interrelated mathematical concepts only by memorizing formulas.

So far, mathematics learning in schools has focused more on teaching mathematics as a rote science (Gazali, 2016) than training students' mathematical connection skills (Menanti et al., 2018). The teacher often becomes the center of learning, while students only passively receive

the information the teacher conveys (Fahrudin et al., 2021). Such learning does not involve students actively and hinders students' ability to see mathematics as interconnected sciences. Mathematics learning should actively involve students, make learning meaningful, and facilitate mathematical connection skills. Learning by presenting real situation problems will make learning mathematics more meaningful (Manik, 2020).

Realistic mathematics education (RME) is a learning approach that provides students with real-world scenarios they can see in their heads (*zich realiseren*) so that students can form models through these situations, which become mathematically formal (Heuvel-Panhuizen, 2003). RME has three principles: guided reinvention and progressive mathematizing, didactical phenomenology, and self-development models (Gravemeijer & Terwel, 2000). These principles imply that mathematics learning is an activity of rediscovering concepts with a starting point of realistic problems through a series of models built in stages until they reach a formal form. The process in RME makes math learning more meaningful (Purwadi, 2020).

In RME learning, students construct learned knowledge (Wubbels et al., 1997). Concepts are discovered through problem-solving activities, finding problems, and organizing knowledge (Gravemeijer & Terwel, 2000). Through a series of activities, students will thoroughly understand mathematics and how to use it to solve everyday problems (Yuliarni et al., 2022). RME can help students improve their understanding of mathematics because students learn mathematics by applying formulas to solve problems and by making them reason to rediscover mathematical concepts (Menanti et al., 2018). Thus, students know the benefits of studying mathematics.

According to research by Erita et al. (2022), teachers can enhance their students' mathematical skills by implementing the RME technique. Sukmaningthias et al. (2022) claimed that real-world problem-based learning can enhance mathematics connecting abilities. The RME technique is one method that may be applied to help students develop their mathematical connection abilities (Mufidah & Machromah, 2023). It is possible to train students' mathematical connection abilities through RME learning by presenting realistic problems and allowing students to create their models.

In the Merdeka Curriculum, quadratic function is part of phase E of algebraic elements and functions. The concepts in the quadratic function are interrelated (Hiltrimartin & Pratiwi, 2019). In addition to being related to other mathematical concepts, some concepts in the quadratic function are related to other fields of science, such as physics and sports (Supriyatun, 2019). Applying the quadratic function concept is also related to everyday problem-solving (Yanti et al., 2022). Thus, it is essential to master quadratic function because its concepts are interrelated between mathematical concepts and non-mathematical concepts.

However, students need help solving quadratic function problems. Students need help answering quadratic function problems because they cannot translate information from the problem into a mathematical model (Umairah, 2018). Lack of understanding of prerequisite knowledge and inability to connect concepts further contribute to students' difficulties (Azmi & Yunita, 2022). Students need help understanding quadratic function, another obstacle preventing them from solving problems (Mutmainah et al., 2022). In addition, students struggle to connect their understanding with factual problems in everyday life (Dewi et al., 2023).

Based on the explanation above, improving mathematical connection skills will help students understand different interrelated mathematical ideas. In order to train mathematical

connection skills, the RME approach was chosen as an alternative solution to familiarize students with developing mathematical connection skills, especially on quadratic function. The topic of quadratic functions was chosen because RME-based research for senior high school is still rare. The few experimental studies reveal the research's general results without detailing the acquisition of each indicator of mathematical ability. Therefore, this study details the elaboration of each mathematical connection indicator. The RME learning that took place was facilitated with RME-based student activity sheets (LAS) to trigger the increase in students' mathematical connection skills. Some existing experimental studies reveal the research results in general without detailing the results of the acquisition of each indicator of mathematical ability. Therefore, this study details the elaboration of each indicator of mathematical connection. The results of this research contribute as a reference for indicators that need further improvement using RME, and the advantages and disadvantages of this study can be considered by teachers in designing RME learning, especially on quadratic function with a local context.

### **Methods**

This research is experimental, with a nonequivalent control group design, and it was conducted on grade X students at SMA 1 Sewon, Yogyakarta. This study involved two groups of students, an experimental group and a control group, which were selected using a cluster random sampling technique, with each group totalling 32 students. The distribution of students into classes in this school was done randomly by considering the gender proportion so that they were considered to have almost the same ability. In addition, the selection of the two groups was based on the similarity of the results of the average semester exam for each class X. Based on the results of these calculations, class X4 was selected as the experimental group and class X6 as the control group. The selected test subjects are considered to represent other test subjects if RME-based learning with RME-based student activity sheets (LAS) developed is applied elsewhere. In the experimental group, learning was conducted using the RME approach and RME-based student activity sheets (LAS). In contrast, the control group learned conventionally by using books available at school.

The data collection instruments in this study were pre-test and post-test sheets of mathematical connection ability and daily journal notes during the learning process. The mathematical connection ability test consisted of 3 items in the form of descriptions concerning the indicators of mathematical connection ability from NCTM (2000): (1) using relationships between mathematical concepts, (2) using mathematical relationships with other disciplines, and (3) using mathematical relationships in everyday life. Three experts have validated the test instrument, and the results of the validation calculations show that the test instrument is valid. The reliability test results in the limited test show a Cronbach's alpha value of 0.702, so the instrument is reliable.

The data obtained in this study are quantitative data from the test results of mathematical connection skills and qualitative data from daily journal notes during learning. Quantitative data was processed using the Independent Sample T-test, the effect size test using Cohen's  $d$  formula (Cohen et al., 2018), and the test results for each indicator of mathematical connection ability.

## Results and Discussion

### Result

Table 1 below summarizes the experimental and control group students' mathematical connection skills test results.

Table 1

*Test Results of Mathematical Connection Ability*

Data	Total of Students	Score		Mean	
		Min	Max		
Pretest	32	Eksperiment	16.67	71.67	49.69
		Control	20.00	73.33	48.39
Posttest		Eksperiment	45.00	88.33	72.81
		Control	43.33	80.00	65.73

Table 1 presents data on how much the learning model impacts students' mathematical connection skills. The experimental group had a more significant average difference between the pre-test and post-test than the control group. Both groups' minimum and maximum scores also increased post-test and pre-test. However, the experimental group showed a more significant increase in maximum and minimum scores. In addition, the mean pre-test scores of the two groups had a slight difference, but the mean post-test scores of the two groups had a considerable difference. Furthermore, the average percentage of the acquisition of mathematical connection ability test results on each indicator is presented in Table 2 below.

Table 2

*Percentage of Completion of Mathematical Connection Ability Indicators*

Indicator	Experiment Group		Control Group	
	Pretest	Posttest	Pretest	Posttest
First Indicator	63%	90%	67%	88%
Second Indicator	51%	81%	57%	77%
Third Indicator	35%	48%	21%	32%

Table 2 shows that both groups' pre-test and post-test results on each indicator of mathematical connection ability increase. The experimental group outperformed the control group regarding the rise in the percentage of completeness of each indicator of mathematical connecting ability. However, the third indicator for both groups shows a smaller percentage gain in results compared to the other indicator. Furthermore, the Independent Sample T-test was conducted to determine the average difference in mathematical connection ability between the experimental and control groups. Before the T-test, a normality test was carried out, which stated that the data was normally distributed so that the T-test could be continued. A summary of the Independent Sample T-test results is presented in Table 3 below.

Table 3

*Independent Sample T-test Results*

Group	Experiment	Control
N	32	32
$\alpha$		0.005
Sig. (2-tailed)		0.001
Sig. (2 – tailed)		0.0005
2		

Table 3 provides information that, based on the pre-test and post-test mean difference test, there is a significant mean difference between the two groups. This means that RME learning is better and positively affects mathematical connection skills compared to conventional learning. In addition, an effect size test was performed to ascertain how RME learning influenced the facilitation of mathematical connection skills. The effect size results obtained a value of 0.66. Based on Cohen's effect size criteria, the effect caused by the application of RME learning provides a moderate effect in facilitating mathematical connection skills.

## **Discussion**

The results of the statistical calculations and the Independent Sample T-test showed that the improvement in mathematical connection skills of the experimental group students was more significant than that of the control group. Conventional learning in the control group begins with the teacher delivering the material, and students receive ready-made material from the teacher in the form of a summary of the formulas of the quadratic function. Such learning makes students memorize formulas and solve problems according to what the teacher exemplifies. Research conducted by Lesmana and Elniati (2023) also found that learning the lecture method and providing ready-made formulas made students memorize formulas without trying to interpret the formulas to solve problems.

The learning process in the experimental group differed from that of the control group, namely by using RME learning. In RME learning, the starting point begins with presenting realistic problems that students can imagine (Zulkardi & Putri, 2010). The LAS facilitated realistic problems and other RME principles in the experimental group. The activities in the LAS guide students in finding the concept of quadratic function so that students experience the process of rediscovering mathematical concepts themselves. Students' involvement in discovering their knowledge makes them assume that it is their mathematical knowledge and that they are responsible for their findings (Gravemeijer & Terwel, 2000).

Students in the experimental group were accustomed to creating their own learned knowledge, which helped them solidify their understanding of the quadratic function. The development of knowledge that students have will make it more substantial and lasting (Hakim & Mulyono, 2020; NCTM, 2000). Students in the experimental group could use quadratic functions to solve problems in daily life, other scientific fields, and mathematics topics. Table 3 shows that students in the experimental group outperformed those in the control group regarding the percentage improvement in test scores for each indicator of their mathematical connection skills. This statement is in line with the research results of Anggoro et al. (2022), Jawad (2022), Pambudi et al. (2020), Romli (2016), and Yusuf et al. (2022), which states that mathematical connection skills can help students in solving mathematical problems. Figure 1 shows a sample of students' post-test answers on the first indicator of mathematical connection ability.

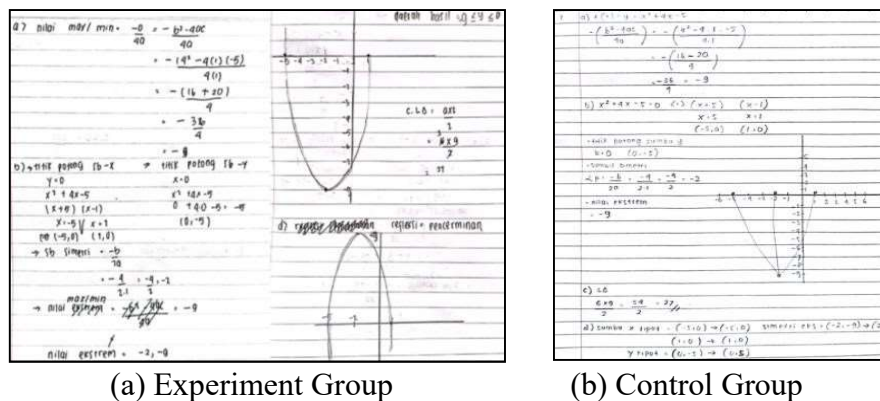


Figure 1. Sample of Post-test Answers for Indicators of Using Relationships between Concepts in Mathematics

Based on Figure 1, the experimental group of students on the indicator of using relationships between concepts in mathematics in general show that students can draw the graph of the quadratic function correctly and determine the result area. Students can determine the base size and height of the triangle formed to be correct when calculating the triangle area. In addition, students can also determine the graph of the result of reflection on the  $x$ -axis correctly. Meanwhile, the results of the control group students' post-test answers on the first indicator show that students tend not to be able to draw the function graph correctly because they experience errors in placing points on the cartesian plane or experience errors in applying the formula to determine the minimum value. Students can determine the triangle's area and the point of reflection but cannot draw the graph after being reflected.

The difference in answer results between experimental and control group students on the indicator of using relationships between mathematical concepts can be attributed to the learning experience of both groups. The experimental group experienced rediscovering the quadratic function concept through realistic problems in the LAS and reflecting on the findings. The realistic problems presented in the LAS refer to the characteristics of RME intertwining and the quadratic function having a relationship. This helps stimulate students to make connections between one concept and another by forming models during concept discovery. As a result, the experimental group students have a strong concept understanding that helps them connect existing concepts to solve problems.

In addition, before working on the LAS, students are given a test sheet containing problems related to prerequisite knowledge or concepts that have been previously learned. The goal is to revive students' memory of previously learned knowledge related to new knowledge to be learned and avoid students' misunderstanding of prerequisite material. In line with this, students' prior knowledge is developed to a higher level and serves as a bridge between students' understanding of the mathematics topics to be learned and their prior knowledge (Cahyani & Masruroh, 2020; Pratiwi et al., 2022). Students need help understanding the essential information and necessary materials, which contributes to the obstacles experienced by students in solving quadratic function problems (Azmi & Yunita, 2022; Siagian et al., 2021). Therefore, the provision of the sheet is carried out to evoke students' memory related to prior knowledge and minimize students' difficulties in solving quadratic function problems.

The control group students are used to receiving ready-made formulas, tend to memorize formulas and solve problems according to the solving steps explained by the teacher. This impacts students' mastery of concepts and the difficulties experienced by students when working on non-routine problems because students do not master the concepts. The obstacles experienced by control group students align with the research results of Mutmainah et al. (2022), that students have difficulty solving quadratic function problems because they do not master the concept. In addition, memorizing mathematical formulas makes students unaware of the relationship between existing concepts, thus limiting students in making mathematical connections. Figure 2 shows a sample of students' post-test answers on the second indicator of mathematical connection ability.

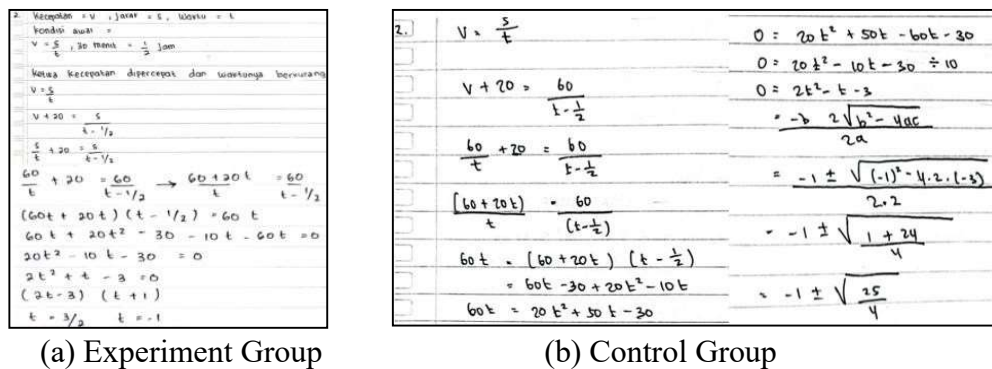


Figure 2. Sample of Post-test Answers on the Indicator of Using Mathematical Relationships with Other Disciplines

Based on Figure 2, students in the experimental group on indicators of using mathematical relationships with other disciplines generally show a tendency for students to be able to determine travel time but only solve the problem once finding the initial speed. However, 41% of students could solve the problem to determine the initial speed correctly. Meanwhile, the post-test answers of the control group students on the second indicator showed that the tendency of students could only make mathematical equations based on the information in the problem but could not find the value of the model that had been made and experienced problems in determining the roots of the quadratic equation.

Students in the experimental group could utilize the LAS to see how the mathematical principles they had learned related to other subjects or everyday concerns, which is why their answers on the second indication differed from those of the control group. Realistic problems contained in the LAS also involve problems related to solutions using concepts from other disciplines. In addition, the problem exercises in the LAS are designed to hone students' ability to apply mathematical relationships to other fields of science. Students are encouraged to practice making connections between mathematical ideas and other fields of science.

Meanwhile, control group students needed help determining the relationship between mathematics and other disciplines. The practice problems provided did not include questions to train students' connection skills, so the scores of control group students were lower than those of experimental group students. The obstacle encountered when the control group students could not determine the value of the roots of the arranged quadratic equation indicated that the control group students did not master the prerequisite. This is because the teacher only

checked the students' prior knowledge verbally, so he needed to learn the details of the student's initial abilities. In contrast, the experimental group was given a test sheet containing questions related to the prerequisite concepts so the teacher knew the students' initial abilities. Figure 3 shows a sample of students' post-test answers on the third indicator of mathematical connection ability.

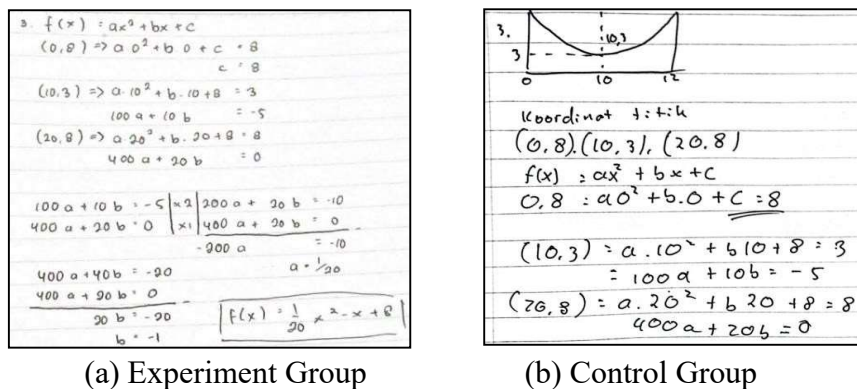


Figure 3. Sample Answers of Post-test Indicator Using Mathematical Relationships in Daily Life

Figure 3 shows the sample answers of experimental and control group students in solving the indicator of using mathematical relationships in everyday life. The third indicator is the indicator that has the lowest increase in pre-test to post-test scores. The third indicator question includes the type of story question that makes it difficult for students to solve problems because they need help understanding the question's meaning. This is in line with the findings of Sartono (2020), which shows that the reason that contributes to students' difficulties in solving story-based problems is the student's inability to understand the information presented. Students' answers in the third indicator showed a tendency for students to look for formed function formulas rather than solving problems that apply quadratic function formulas. This caused the low score of the third indicator. The student's success in finding the quadratic function formula that is formed indicates that the achievement of quadratic function is classified as successful even though this indicator needs to be maximized to find the final solution to the problem presented.

The experimental group's LAS was completed in a group discussion because it refers to the characteristics of RME interactivity. Students were actively involved in group discussions and more courageous in expressing their opinions in group discussions or presentations than before. The process of students asking, answering, discussing, cooperating, reflecting, and evaluating each other becomes essential in reaching the formal level (Zulkardi, 2002). In connection with this, group discussions create a process of exchanging ideas between students to get ideas or strategies for solving problems (Syafurudin, 2017). Learning mathematics with RME makes mathematics an individual activity and includes social activities.

Another finding from this study is that the experimental group students showed better self-confidence than the control group. This can be seen from students' activeness in conveying ideas in small and large forums when learning occurs. In connection with this, Streefland's (1991) research findings show that when students are encouraged to develop and create their ideas, they show a higher level of initiative (Risdiyanti, 2022). It is not surprising that the

mathematical connection ability of experimental group students is better than that of the control group because the confidence of experimental group students is also better. This aligns with research conducted by Ardiani et al. (2021) and García-García & Dolores-Flores (2021) that self-confidence affects mathematical connection ability.

With better confidence, students in the experimental group learned in both ways. This means that students are active in conveying ideas and asking questions, such as asking why one formula can be derived from another formula and conveying surrounding events that students have experienced related to quadratic functions. Such student attitudes are formed due to habituation through context, discovery of mathematical concepts, opportunities for mutual discussion, seeing the relationship between mathematics and other fields, and solving everyday problems. This is by the characteristics of RME and affects the improvement of students' mathematical connection skills. Meanwhile, the control group students were unfamiliar with using context and finding their concepts. They seemed to be accustomed to memorizing formulas without knowing the origin and use of formulas for various conditions. This is what causes the average results of the mathematical connection ability of the control group to be lower than the experimental group.

The teacher's role in learning will affect how students build their mathematical abilities. The teacher's job in RME learning is to help students understand the quadratic function being studied by guiding them and supervising their questions. By forming interrelated concepts to enhance mathematical connection skills, the RME learning process encourages students to participate more actively and generate meaningful learning experiences. The findings of this study are consistent with those of studies by Erita et al. (2022), Menanti et al. (2018), Mufidah & Machromah (2023), and Sukmaningthias et al. (2022), and others that show that RME learning improves students' mathematical proficiency. In this case, the teacher also has a role in stimulating students to improve their mathematical connection skills. In addition, different student activity sheets triggered different activity sheets in the experimental and control groups. The RME-based student activity sheet used by the experimental group stimulated the increase in students' mathematical connection skills, especially the quadratic function.

Based on the results of data analysis, it is known that different learning experiences influence the improvement of mathematical connection skills. Compared to conventional learning, learning with RME has a better impact on improving mathematical connection skills. The effect size test results reinforce this statement because the effect size value generated is 0.66. This means that RME learning moderately affects students' ability to make mathematical connections. With RME learning, in addition to improving students' mathematical connection skills, students also began to be actively involved in learning, such as increasing self-confidence, daring to convey ideas, and seeing mathematics as a science that is not separate from everyday life. These factors are supported by the student activity sheet, which is designed explicitly for quadratic function using RME principles.

### **Conclusion**

Based on the study's results, using RME learning to improve mathematical connection skills is superior to using conventional learning. This is based on the results of the Independent Sample T-test and the results of the effect size test. In addition, experimental group students

outperformed control group students in increasing the percentage of test results for each indicator of mathematical connection ability. Experimental group students showed a more confident attitude, dared to express ideas, and associated surrounding events experienced by students with mathematical concepts compared to control group students. This study used RME-based LAS to support the RME learning process. Future research can use RME-based LAS to support the RME learning process or use other RME-based learning media by deepening the indicators of mathematical relationships with other disciplines and conducting in-depth interviews with students to find out the changes experienced by students after receiving RME learning.

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