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Investigation of the mathematical connection's ability of 9th grade students

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Abstract

This study aims to investigate students' mathematical connection ability in solving the problem of mathematical and correlation between indicators of mathematical connection ability. This research is correlation research. The sample of the study is 35 girls' students in the 9th grade in a middle school in Kerman province (south-east of Iran). Data collection is done by giving a test on mathematical connection skills. The variables in this study are indicators of mathematical connection ability, namely the connection between mathematical concepts, connections between mathematics and other sciences, and connections between mathematics and everyday life. Spearman's correlation coefficient was used to analyze the data after calculating the score and percentage of test answers. The findings showed that qualification of students in the indicator of the connection between mathematical concepts was good enough (69%), in the indicator of the connection between mathematics and other sciences was also good enough (66%), and the indicator of the connection between mathematics and everyday life was not enough (42%). Also, the results of Spearman's correlation coefficient showed that there is a significant relationship between both indicators of mathematical connection ability. Therefore, the connection between mathematics and everyday life of Students must be improved.

Keywords: Mathematic Connection, Middle school, Problem Solving, Real Life, Science

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Mathematics is one of the subjects taught in every level of school, both elementary school, middle school, high school to college (Vilianti et al., 2018), and mathematics has an important role in everyday life (Hasibuan, Sarigih, & Amry, 2019). In various countries mathematical connection capabilities are also a concern. In line with this, Nordheimer (2011) recommend that teachers allow students to recognize and make connections between mathematical ideas. Mathematical connection skills students are expected to be able to recognize and use relationships between mathematical ideas, understand how mathematical ideas are interconnected and underlie each other to produce a unified whole, and recognize and apply mathematics outside mathematical context (NCTM, 2000).

Mathematical connection is one of the must-have capabilities to solve problems. According to NCTM (2000), mathematical connections are important part that should be emphasized at every level of education. Hafiz, Kadir, and Fatra (2016) also said the ability of mathematical connections is one of the mathematical forces that must be developed in the learning of mathematics in schools. The ability of the

mathematical connections is required to relate to various ideas or mathematical ideas accepted by students (Fauzi, 2015). Siregar and Surya (2017) also asserted, with the ability of mathematical connections, the ability of students' thinking in mathematics is expected to become more widespread. In addition, he believed that the ability to Mathematical connection also can improve students' cognitive abilities such as recall; understand the application of environmental concepts and so on. Without applying the concept of student experience, it would be difficult to remember certain material and remember too many separate concepts whereas mathematics is rich in principles. Mathematical connections are interrelationships between mathematical topics, interrelationships between mathematics and other disciplines, and mathematical relation to the real world or in everyday life (Nordheimer, 2011). The ability of mathematical connections has three different directions, namely the connection between mathematical ideas and mathematical connections to the real world or other fields of learning mathematics outside (Saminanto & Kartono, 2015). In addition, mathematical connection ability is the ability to connect conceptual and procedural knowledge, using mathematics on other topics, using mathematics in life activities, using inter- topic connections in mathematics (Jäder, Lithner, & Sidenvall, 2019).

Students who master mathematical concepts are not themselves smart in connecting mathematics, in a study it was produced that students were able to use mathematical ideas related to real problems, but only a few students were able to explain why the idea was used in that problem (Suharto & Widada, 2018). However, if students can connect mathematical ideas the understanding of mathematics will take longer (Saminanto & Kartono, 2015). Through a mathematical connection, students can rebuild their understanding of prior knowledge and students are more familiar with new things if they are based on a concept they know (Suharto & Widada, 2018).

Connections are more important because they support students to increase understanding of the relationship between mathematical concepts and other science concepts (Pambudi, Budayasa, & Lukito, 2018). The mathematical connection skills make students and teachers try to find mathematics in real life, especially those related to students' lives and interests, relationships between mathematical concepts and knowing how mathematical concepts relate to other concepts and school lessons (Suharto & Widada, 2018). Important for teachers and students in the classroom is making connections because the purpose of teaching is to build a mathematical understanding (Saminanto & Kartono, 2015). Thus, mathematical connections can also help and support students in learning mathematics (Oktaviyanthi & Agus, 2019). According to the NCTM (2000), mathematics is not a collection of topics and ability of separate, even though math is often partitioned and taught in several branches. Some people say that mathematics is an integrated science. In fact, the students still have a difficult in connecting the material they have learned.

Second author of this paper as a teacher for many years, often see students who had strong performance in science, while they had weak performance in math. While I always thought that a weak student in math was weak in science. Additionally, students are more successful in solving problems of daily life than in math book problems. Since they have been exposed to the issues of the real world, they can understand them. Therefore, showing the correlation or non-correlation between students' performance in solving mathematical problems and their performance in solving problems in other sciences and daily life became the focal point of this paper. Sari, Mardiyana, and Pramudya (2020) identified three indicators of mathematical connection ability which are connection between mathematics concepts, connection between mathematics and other natural sciences such as physics and finally connection between mathematics and everyday life. So, the main research question which

guide current study formulated as how is the qualification of 9th grade students in indicators of the ability of mathematical connections? Based on this research question, below three hypotheses proposed and examined.

1. Is there a correlation between students' performance in the indicator of connection between mathematical concepts and their performance in the indicator of connection between mathematics and everyday life?
2. Is there a correlation between students' performance in the indicator of connection between mathematical concepts and their performance in the indicator of connection between mathematics and other sciences?
3. Is there a correlation between students' performance in the indicator of connection between mathematics and other sciences and their performance in the indicator of connection between mathematics and everyday life?

Mathematics is a subject that links concepts (Nurhasanah, Kusumah, & Sabandar, 2017). Mathematics is one of lessons that develop computational abilities (Cahdriyana & Richardo, 2020; as cited in Helsa & Juandi, 2023) Mathematics consists of various topics that are related to each other. These linkages are not only between topics in mathematics, but also the relationship between mathematics with other disciplines and the relevance of mathematics in everyday life (Agustini, Suryadi, & Jupri, 2017). Students' ability to understand the concept is the ability to not only know or remember some concepts learned but also able to express again in other forms that are easy to understand, provide interpretation of data, and able to apply the concept with its cognitive structure (Agustini, Suryadi, & Jupri, 2017). Concepts in learning mathematics are interconnected with each other. When the students learn a concept, then they need to learn the other ones. This state is called a mathematical connection, the ability of students in connecting a concept with the other concepts (Pambudi, Budayasa, & Lukito, 2018).

Student's ability to relate between topics in mathematics, associate mathematics with other sciences, and the daily life of so-called mathematical connection ability (Pambudi, Budayasa, & Lukito, 2018). This is in accordance with the opinion of Eli, Mohr-Schroeder, and Lee (2013) said that the mathematical connection ability is the ability to show the internal and external relations of mathematics, include: the connection between math topics, connections with other disciplines, and connections with everyday life. The mathematical connection is the ability to associate students' mathematical knowledge with other mathematical skills and real life (Rohendi & Dulpaja, 2013). Mathematical connections are part of a network of interconnected knowledge with other knowledge composed of critical concepts to understand and develop relationships between mathematical ideas, concepts, and procedures (Pambudi, Budayasa, & Lukito, 2018). The connections of this aspect are also reinforced by the opinions Mikovch and Monroe (1994 in Hermawan & Prabawanto, 2016), which states that "In mathematics, at least three kinds of connection are particularly subject to beneficial: connection within mathematics, across the curriculum, and with real world Contexts".

Siregar and Surya (2017) said mathematics consists of several branches and each branch is not closed which each stand alone, but a whole that united. They can see mathematical relationships affecting each other between mathematical topics, in contexts that link mathematics with other subjects, as well as in their own interests and experiences (Agustini, Suryadi, & Jupri, 2017). Mathematical connections have an important part that should be emphasized at every level of education (NCTM, 2000). According to NCTM (2000), modeling connections are the relationships between problem

situations that arise in the real world or in other disciplines with their mathematical representation, whereas Mathematical connections are relations between two equivalent representations, and between the completion processes of each representation.

For example, if a problem situation has modeling connections with algebraic and graphic equations, then the algebraic representation has a mathematical connection with a graphical representation. The ability of students to connect mathematically is one of the essential things that must be achieved by students in the learning process because if students know the relationship between the concepts, they will quickly understand the mathematics itself and open opportunities for students to develop their mathematical skills (Arthur, Owusu, Addo, & Arhin, 2018).

The mathematical connection ability emerges when the students can connect between one material to the others (Hendriana, Slamet, & Sumarmo, 2014). Students can connection the concepts that they learn because they have mastered the prerequisite materials related to daily life (Agustini, Suryadi, & Jupri, 2017). If the students can connect the material which they learn from the previous subject or with other subjects, then the learning of mathematics becomes more meaningful (Arthur, Owusu, Addo, & Arhin, 2018).

Sometimes students might give a written answer, but they cannot understand it (Saleh et al., 2018). The mathematical connection is vital to be developed in the students because it will help students in understanding a concept and can improve their understanding of other science by connecting the concept of mathematical concepts with other concepts (Hendriana, Slamet, & Sumarmo, 2014). Also, the ability of the mathematical connection needs to be widely developed as it can increase students' cognitive by remembering a concept, understanding, and applying the concept in daily life, without which students will find it challenging to learn mathematical concepts (Siregar & Surya, 2017). Gainsburg (2008) states that the purpose of the connection of mathematics given the students in secondary schools. The students will be able to recognize representation equivalent of a similar concept; recognize the relationship procedures on representing to procedure of equivalent representation; use and assess some mathematical connection topics; and use and assess the connections between mathematics and other disciplines.

METHODS

This research is correlation research. Correlation research is research that aims to discover relationships between variables using correlation statistics (Gall, Borg, and Gall, 2007). This study aims to investigate the mathematical connection ability of Middle School students in nine grade and correlation between indicators of mathematical connection ability.

The sample includes girls' students (15 and 16 years old) in 9th grade from Rehaneh middle school in Kerman. In January 2022, due to the pandemic on covid-19 virus, school classes were held online, and Reyhaneh School had 43 students in 9th grade. 8 of 43 girls' students were absent on the day of data collection, and a total of 35 students Participate in the test who were mixed achievers. Reyhaneh Middle School had three grades: 7th, 8th and 9th, the number of 7th grade students was small (11 people) and the 8th grade students were participating in another research. Another reason for choosing the 9th grade was that the students of this grade, considering their age, have probably touched more applications of mathematics in their daily life compared to other grades. In this study, researchers used a test to collect data (see Figure 1), which was designed according to the test used in Sari, Mardiyana, and Pramudya (2020). The test of Sari, Mardiyana, and Pramudya (2020) consisted of 6 questions about the ability of

mathematical connection in the field of algebra, in which two questions were designed for each indicator of mathematical connection (two questions from the math book, two questions from the science book and two the questions were written according to the experiences of the students in their daily life). In the present study, the test of Sari, Mardiyana, and Pramudya (2020) was not appropriate, because the students had not read some of the questions and the focus of this research was not on algebra. For this reason, according to the Sari, Mardiyana, and Pramudya (2020) test, the researchers designed a suitable test for their students. For the indicator of the relationship between mathematical concepts, questions were selected from students' math book. The book was not fully taught to the students, and we had to choose questions from the first half of the book. In addition, the questions should show the connection between several mathematical concepts. For the indicator of the relationship between mathematics and other sciences, questions were selected from the chemistry and physics section of the students' science book. The students' science book has three parts: physics, chemistry, and biology, but the biology part was not taught yet. Another reason for choosing these questions is that the examples of these two questions are given in the math books. Regarding the indicator of connection between mathematics and everyday life, the researchers designed two questions according to the students' experiences and their living conditions. All students in their lives should have experienced the data and conditions of two questions. Also, two questions should show the application of mathematics in everyday life. Unfortunately, there were no such questions in the math book.

Question 1. The maximum amount of salt dissolved in 100 grams of 20° C water is 38 grams. If we assume that the solubility of this salt, in 60 ° C water, is 40 grams and we cool 280 grams of this salt's saturated solution in 60 ° C water to 40 ° C, how many grams of salt will precipitate?

Question 2. A stone with a mass of 20 kg comes up to a height of 6 meters. Calculate the potential energy of the stone.

Problem 3. At Akbar Garden, there is a distance of 12 meters between two trees. One of these trees has a 4-meter rope tied to it. In his house, he has only two-meter-long ropes.

Based on the 4-meter rope that was tied to one of the trees, how many pieces of 2-meter rope he should use to be able to connect the two trees?

Question 4. The blue car moves in the opposite direction and twice of vector $\vec{A}=\begin{bmatrix}-1\\2\end{bmatrix}$. The red car moves in the same direction and twice of vector $\vec{A}=\begin{bmatrix}-1\\2\end{bmatrix}$. Find the relation between the motion vectors of the two cars.

Question 5. Ali wants to tile the surface with regular polygons. A regular octagon was used by him. To tile the surface, what regular polygons can be used next to this regular octagon?

Problem6. On the first Saturday of October, Hamid's father started working as a salesman in a public school. The school is only open in the morning and does not offer compensatory or extracurricular classes. At the end of each school day, he gets his salary. A total of 330,000 Tomans (Current Currency in Iran) was his salary in October. In October, assuming he will be paid a fixed amount on a daily basis, how much will he earn for 11 working days?

Figure 1. Tool for assessment of connection ability of students

The six mathematics teachers evaluated and confirmed the face and content validity of this test. They had a master's degree in mathematics education and had 15-26 years of experience in teaching 9th grade math book. The researcher was in contact with 4 of these teachers and the other two were introduced to him by others. Because this research was conducted during the coronavirus disease, there was not possible to communicate with more teachers. The test was sent to the teachers on WhatsApp, and they were asked to comment on the face validity and content validity of these questions and if they would like to change the questions. The content validity ratio (CVR) proposed by Lawshe in 1975 is a linear transformation of a proportional level of agreement on how many experts within a panel rate an item (Ayre & Scally, 2014). CVR test was used to check content validity, and its value was 0.99. The reliability of the test was also calculated using Cronbach's alpha, 0.76, which indicated its approval. The test time was 50 minutes. The questions were sent to the students on WhatsApp, and they were asked to send the picture of their answers after answering them.

The test results is analyzed to determine and obtain the level of mathematical connection ability of students according to assessment rubric (see Table 1) that designed by researchers with the help of the students' answers. First, the scores of the students in the test were calculated according to the rubric. The Qualification of the students in each of the indicators was determined according to the percentage, and then the performance of the students in the questions of each of the indicators was explained. Finally, Spearman's correlation coefficient was used to check the existence of correlation between indicators of mathematical connection ability. The percentage (P) to the total score for each indicator calculated and interpreted with the qualification (See Table 2).

Table 1. Description of assessment rubrics for tests of mathematical connection ability

Description	Score
The student does not respond.	0
Student cannot connect between concepts. The way and result are wrong.	1
Student cannot connect between concepts, but the way is correct, and the result is wrong.	2
Student can connect between concepts, but the way and result are incomplete.	3
Student can connect between concepts, but the way is correct, and the result is wrong.	4
Student can connect between concepts. The way and result are correct.	5

Table 2. The Qualification of Total Score Percentage (Kothari, 2004)

Percentage	Qualification
$85 \leq P \leq 100$	Very Good
$70 \leq P \leq 84{,}99$	Good
$55 \leq P \leq 69{,}99$	Good Enough
$40 \leq P \leq 54{,}99$	Not Enough
$0 \leq P \leq 39{,}99$	Very Less

RESULTS AND DISCUSSION

Students' Scores and Percentage for every Indicators of mathematical connection ability shown in the Table 3. It can be seen from Table 2 that the Qualification of the mathematical connection ability of students in indicator of connection between mathematical concepts is good enough (69%), in indicator of connection between mathematical and other sciences is good enough (66%) and, in indicator connection between mathematical and everyday life is not enough (42%).

Table 3. Students' Scores and Percentage of Mathematical Connection Ability Indicators

	Score of Indicators		
	Connection between mathematical concepts	Connection between mathematical and other sciences	Connection between mathematical and everyday life
		0	
Students Score in indicator	243	232	147
Total Score	350	350	350
Percentage	69%	66%	42%
Qualification	Good Enough	Good Enough	Not Enough

The description of the results of the analysis of mathematical connection ability test of students will be discussed in each question for each indication in more detail as follows. Table 4 shows the students' score and percentage on questions of each indicator.

Table 4. Students' Score and Percentage on questions of each indicator

Indicators of the ability of mathematical connections	Number of questions	Students Score	Total Score	Percentage	Qualification
Connection between mathematical concepts	4	132	175	75%	Good
	5	111	175	63%	Good Enough
Connection between mathematics and other sciences	1	66	175	38%	Very Less
	2	166	175	95%	Very Good
Connection between mathematics and other sciences	3	61	175	35%	Very Less
	6	86	175	49%	Not Enough

Connection between mathematical concepts: problems 4 and 5 (see Figure 1) are two problems of mathematical connection skills test on indicator of connection between mathematical concepts. In these problems, the connected concepts are the concept of vector, Symmetric vectors, regular polygons, Tile with regular polygons. The question 4 selected of mathematical book. Students in seventh and eighth grades become familiar with the vector and its coordinates and learn how to multiply a number in the coordinates of a vector. To solve this question, students must first obtain the motion vectors of the blue and red cars and then find the relationship between them according to their coordinates.

According to Table 5 qualifications of students in this question is good. The test answers indicated that some students correctly determined the motion vectors of the two cars, but were unable to explain the relationship between them, which might be due to a lack of understanding of the concept

of symmetry. As in Figure 2, the student drew the motion vectors of two cars by drawing, but she could not understand the relationship between the two vectors. Furthermore, some students did not pay attention to the direction of the motion vector of the car with vector $\vec{A}$ and simply assumed it was double. It may be due to carelessness or ignorance of how direction affects vector coordinates.

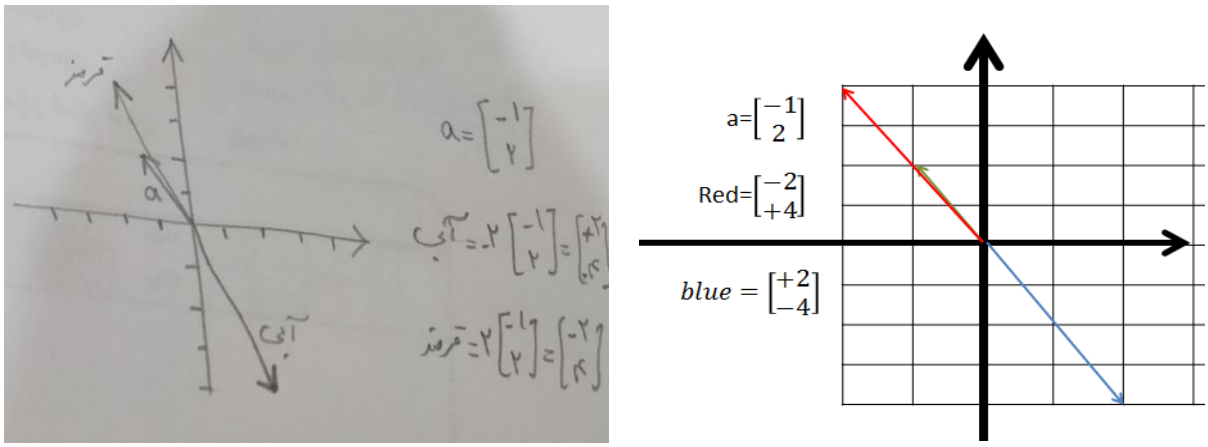


Figure 2. The incomplete answer of a student

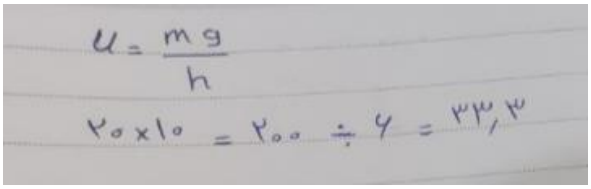
Question 5 is based on internal angles in the math book. During this lesson, students learn that it is possible to tile with polygons when their interior angles form a 360-degree angle. To solve this problem, the children must first determine each interior angle of a regular octagon using the formula $\frac{(n-2)\times 180}{n}$ (n is number of sides) and then figure out which regular polygon they should use to form a 360-degree angle. According to Table 5, qualification of students in question is good enough. Some students tried putting regular octagons together and other shapes so that there was no space between them to solve the problem, based on the test answers. Additionally, some students calculated each interior angle of an octagon, but were unable to connect the concepts of interior angle with tiling a surface (forming the same circle or 360-degree angle). In their responses, some students stated that they had forgotten the formula for calculating interior angles and thus could not answer the question.

Table 5. Kolmogorov- Smirnov test

Indicator	Statistic	d.f.	Sig.
Connection between mathematical concepts	0.258	35	0.042
Connection between mathematical and other sciences	0.235	35	0.019
Connection between mathematical and everyday life	0.352	35	0.0001

Connections between mathematics and other sciences: questions 1 and 2 (see Figure 1) are the problems of testing mathematical connection skills with indicators of connection between mathematics and other sciences and are drawn from the students' science textbooks. The concept of proportionality table or rational proportionality was considered in question 1, and the concept of obtaining the numeric value of an algebraic expression was addressed in question 2. The question 1 selected of the chemistry section of the students' science book. According to Table 5, qualification of students in this question is very lees; therefore, the student's performance was poor. According to answers they were not able to use proportionality tables to solve this question. Most students were unable to understand the question and make connections between its data. They performed incorrect operations on the numbers in the

question. This question had the most unanswered cases among the questions. The question 2 selected of the Physics section of the students' science book. The students must solve this question by writing a formula for potential energy and substituting the values for the variables. According to Table 5, the children's performance on question 2 was good. Number of students had given incorrect answers because they were unable to make mathematical connections between the data in the problems, i.e., they did not know or forgot the mathematical relationship between energy, weight, and height (U=mgh), as in Figure 3.



$$U=\frac{mg}{h}$$

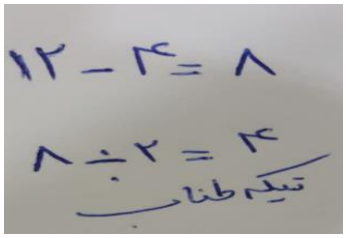
$$20\times10=200\div6=33/3$$

Figure 3. The wrong answer of a student

Connection between mathematics and everyday life: questions 3 and 6 (see Figure 1) testing mathematical connection skills with indicator of connection between mathematics and everyday life. In these two questions, we focused on the issues that students face in their everyday lives. To solve these questions, students must use four major operations (addition, subtraction, multiplication, and division). Of course, students must act on the problem data according to their daily lives. According to Table 4, qualification of students in this indicator is not enough. Details will follow.

In the third question, the students had to subtract 4 from 12, which became 8, and then divide 8 by 2, and finally the answer is more than 4 pieces of rope, because the ropes must be tied together. According to Table 5, qualification of students is very less. This question was answered by all students, but their answer did not match the real world. Unfortunately, the students got 4, as shown in Figure 4, but none of them considered how much rope was needed to tie them.

Qualification of students in question 6 is not enough, as show in Table 5. The schools of the students participating in the study are closed on Thursdays and Fridays, so in question 6, students had to subtract Thursdays and Fridays in a month. Saturday was the first day of the month, so there were 8 Thursdays and Fridays in the month. Few students took Thursdays into account, according to answers. In some cases, students have taken the number of school working days per week as 5 and then multiplied it by 4, which is the number of weeks in a month, and subtracted it from 30, which is incorrect. Because in the question, Saturday is the first day of October, but students did not count two working days. There were also students who ignored the school holidays and dividing the monthly salary by 30. Some students had only subtracted the number of Fridays, i.e., the number 4, from 30.



$$12-4=8$$

$$8\div2=4$$

Figure 4. Wrong answer of a student

Before using Spearman's correlation coefficient test, the Kolmogoroov-Smirnov test was used to check the normality of the data. The results of are Kolmogoroov-Smirnov test shown in Table 5. According to Table 5, since $p<0.05$ for all three indices of mathematical connection ability, the assumption of normality of the data is rejected. Therefore, Spearman's correlation coefficient was used to check the proposed hypotheses. The results of testing hypothesis are as follows.

1. There is a positive correlation between students' performance in the indicator of connection between mathematical concepts and their performance in the indicator of connection between mathematics and everyday life (r=0/363, p-value= 0/03).
2. There is a positive correlation between students' performance in the indicator of connection between mathematical concepts and their performance in the indicator of connection between mathematics and other sciences (r= 0/512, p-value= 0/002).
3. There is a positive correlation between students' performance in the indicator of connection between mathematics and other sciences and their performance in the indicator of connection between mathematics and everyday life (r= 0/357, p-value= 0/035).

According to the results of Spearman's correlation analysis, there is a positive correlation between the indicators of mathematical connection ability, and this correlation is stronger between the two indicators of the relationship between mathematical concepts and the indicator of the relationship between mathematics and other sciences.

The ability of mathematical connection is one of the useful abilities that seems to help the student to use mathematics more outside of school and in her daily life. Research about students in the field of mathematical connections is important to analyze the current situation and to achieve the desired situation, i.e., enabling students to use math skills in their daily lives and providing the best planning by the authorities and others. We therefore conducted the present study to investigate 35 ninth grade students' ability of mathematical connections and correlation between indicators of mathematical connection ability.

Study findings indicate that students' qualification in two indicators of connection between mathematical concepts and between mathematics and other sciences is good enough, but not enough in the indicator of connection between mathematics and everyday life. These findings are in line with the findings of Menanti, Sinaga and Hasratuddin (2018); Pambudi, Budayasa and Lukito (2020) and Sari, Mardiyana and pramudya (2020) conducted on the eighth grade of the study.

CONCLUSION

The students ignored the facts while solving the problems taken from daily life and tried to solve them by performing several mathematical operations without paying attention to the problem form. The students did well on the math textbook questions, indicating they can solve them. Children performed differently on the two questions relating to the relationship between mathematics and other sciences. In solving the question about the physics section of the science book where the formula had to be memorized, 95% of the students remembered the formula and were able to answer the question, but in the other question related to the chemistry section of the science lesson, some children were not able to make connections between the math material they already knew. Children did not perform well in the two questions related to the indicator of the relationship between math and daily life, and answers showed they did not pay attention to whether their answer corresponded to the real world. As a teacher,

I did not see examples of this example in the math book, and maybe this is one of the reasons for the poor performance of students in solving these kinds of questions. To improve student performance on the indicator of connection between mathematics and everyday life and get acquainted with the practical applications of mathematics in their daily lives, it is important to include examples from the real world in the text of the book. Additionally, it is good that teachers in the classroom ask students to design questions based on issues they face in life. Also, the findings showed that there is a positive correlation between the indicators of mathematical connection ability, and this correlation is stronger between the two indicators of the connection between mathematical concepts and the connection between mathematics and other sciences. The authors of the present study did not find any research on this matter, and this can be considered as an innovation of the present study.

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