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IMPLEMENTATION OF K-MEANS CLUSTERING FOR STUDENT GROUPING IN THE RELATIONSHIP BETWEEN CONCEPTUAL UNDERSTANDING AND PROBLEM-SOLVING ABILITY

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ABSTRACT

The purpose of this study is to determine how conceptual understanding ability and problem-solving ability are related to each other without any prior treatment. The research method used is the correlational method. The population in this study consists of 376 ninth-grade students from SMPN 2 Karawang Barat. The sample was selected using a simple random sampling technique and calculated using the Slovin formula, resulting in a sample size of 79 students. The data collection technique involved administering an essay-based test consisting of six questions measuring mathematical conceptual understanding and four questions measuring mathematical problem-solving ability. The data analysis technique was conducted as follows: Students' answers were scored based on a predetermined scoring rubric. Student scores were grouped based on specific characteristics using the K-Means clustering method. Spearman's rank correlation test was conducted to determine the relationship between conceptual understanding ability and problem-solving ability. The research findings indicate that, across the entire sample and in Cluster 3, there is a significant relationship between conceptual understanding ability and problem-solving ability. However, in Cluster 1 and Cluster 2, a relationship exists but is not statistically significant.
Keywords: conceptual understanding; k-means clustering; problem-solving.

ABSTRAK

Tujuan penelitian ini adalah untuk mengetahui bagaimana kemampuan pemahaman konsep dan kemampuan pemecahan masalah terkait satu sama lain dengan tanpa memberikan perlakuan sebelumnya. Metode penelitian ini adalah metode korelasional. Populasi dalam penelitian ini adalah siswa kelas IX SMPN 2 Karawang Barat 376 orang. Pengambilan sampel menggunakan teknik simple random sampling dan dihitung dengan rumus Slovin sehingga jumlah sampel dalam penelitian ini adalah 79 orang. Teknik pengumpulan data dengan pemberian soal tes berbentuk uraian berjumlah 6 soal dengan indikator kemampuan pemahaman konsep matematis dan 4 soal dengan indikator kemampuan pemecahan masalah matematis. Teknik analisis sebagai berikut: Pertama, jawaban siswa akan diberikan skor dan dinilai sesuai dengan pedoman penskoran yang telah dibuat. Kedua, nilai siswa akan dikelompokkan berdasarkan karakteristik tertentu menggunakan metode K-means clustering. Ketiga, akan dilakukan uji korelasi rank Spearman untuk mengetahui hubungan antara kemampuan pemahaman konsep dengan kemampuan pemecahan masalah. Hasil penelitian menunjukkan pada keseluruhan sampel dan cluster 3 bahwa terdapat hubungan yang signifikan antara kemampuan pemahaman konsep dengan kemampuan pemecahan masalah. Pada cluster 1 dan cluster 2 menunjukkan bahwa terdapat hubungan tetapi tidak signifikan antara kemampuan pemahaman konsep dengan kemampuan pemecahan masalah.
***Kata kunci**: k-means clustering; pemahaman konsep; pemecahan masalah.*

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Introduction

Mathematics is one of the critical areas of education, as it is the basis for many other disciplines and is one of the main subjects of the curriculum. Mathematics also plays an important role in shaping students' mindset (Utami et al., 2018). According to the Minister of Education and Culture Regulation of the Republic of Indonesia Number 58 of 2014, which states that the purpose of mathematics learning is so that students can explain the relationship between mathematical concepts, understand these concepts, and can apply these concepts in solving problems accurately and accurately. Based on the objectives of mathematical learning, the ability to understand mathematical concepts is one of the cognitive abilities required in mathematical learning.

Conceptual understanding is a fundamental skill that students must possess to master other mathematical skills (Hulu & Siswanti, 2024). This is because concept understanding is at the most basic level in the cognitive aspect and is one of the main goals in learning. In addition, concept understanding is the ability to understand and explain an idea, as well as the ability to think logically, critically, creatively, and innovatively (Giawa et al., 2022). According to Hendriana (2018), understanding of mathematical concepts becomes an important cornerstone in thinking about solving various mathematical challenges as well as problems in everyday life. This suggests that the ability to understand mathematical concepts has a very significant role.

Students will find it easier to do math problems if they have a good understanding of the concept. A strong understanding of concepts allows students to identify patterns, choose the right strategy, and apply rules correctly when solving problems. If the student does not have sufficient concept understanding ability, then the student will have difficulty in the math learning process (Safi'i & Bharata, 2021). The indicator of the ability to understand mathematical concepts consists of: 1) re-exposing the concepts that have been studied, 2) classifying objects according to mathematical concepts, 3) applying concepts through algorithms, 4) giving examples or not examples to the concepts that have been studied, 5) presents concepts in various forms of representation, and 6) relate various mathematical concepts both internally and externally (Lestari & Yudhanegara, 2018).

Students are considered to have the ability to understand mathematical concepts if they meet indicators that demonstrate the ability to understand mathematical concepts. For example, in the study of the Two-Variable Linear Equation System (SPLDV), students are expected to be able to understand and re-explain the concept of SPLDV. Students can also group different equations based on the characteristics of SPLDV, giving examples both mathematically and in the context of everyday life. In addition, students are able to represent the concept of SPLDV in graph form, relate it to other mathematical materials, and apply this concept to solve various real problems in everyday life.

In fact, the understanding of mathematical concepts on the material of the Two-Variable Linear Equation System (SPLDV) has not reached the optimal level. This is evident during the learning process, where students are asked to group different forms of equations based on the concept of SPLDV, but many still make mistakes. In addition, the majority of students also have difficulty resolving problems related to SPLDV. This is in line with research conducted by Kartika (2018) at MTs of Kampar Regency, which reveals that students still often make mistakes in solving algebra problems during the learning process. These findings suggest that the student's level of understanding of mathematical concepts is still relatively low. Research conducted by Umam & Zulkarnaen (2022) at MTs Karawang Regency shows that students still have low mathematical concept understanding ability. This can be seen from the answers of students who have not fully met the concept understanding ability indicator with an average percentage of only 35.90%. In addition, students have difficulty applying the concept of solving through algorithms and in finding solutions to solving mathematical problems.

The difficulties experienced by students in understanding the concept of SPLDV certainly impacted their ability to solve math problems as a whole. Therefore, in addition to understanding the concept, students also need to have skills in applying the concept to solve various mathematical problems. Problem-solving skills play an important role in helping students relate learned concepts to more complex situations. Students with good mathematical concept understanding abilities can improve problem solving and perform systematic and complex mathematical calculations (Diana et al., 2021).

Problem-solving skills are important basic skills for students to develop ideas, build new knowledge, and improve math skills. According to Laia & Harefa (2021) that students who have mathematical problem-solving skills will be able to improve decision-making in their lives. Therefore, every student needs to have this ability. The problem-solving skills focus not only on the final results, but also on the student's thinking process in finding solutions to achieve the desired goals (Hidayatulloh & Wati, 2021). According to NCTM (Ruqoiyah, Muammar, & Wilujeng, 2023), the problem-solving ability is divided into four: 1) building new mathematical knowledge through problem-solving, 2) problem-solving that arises in mathematics and other contexts, 3) implementation and adaptation of various appropriate strategies for problem-solving, such as: 4) reevaluate and reflect on the process of solving mathematical problems. In addition, according to Polya (1985), there are four indicators in problem-solving ability, namely: 1) problem-solving, 2) solution-planning, 3) problem-solving and 4) re-examining the solution that has been obtained.

Problem-solving skills in mathematical learning can be identified if the student meets the predefined indicators. For example, in the Two-Variable Linear Equation System (SPLDV) material, students are said to have this ability if they are able to understand the problem by writing down known and questionable information from the problem. Furthermore, students should be able to plan completion by arranging appropriate mathematical models. After that, students are expected to be able to solve the problem using appropriate methods, such as substitution, elimination, or graphics, until they find a solution. After obtaining an answer, the student needs to reexamine the results obtained to confirm the truth. Finally, students must be able to conclude the results of the settlement as the correct answer to the problem provided.

The current condition of the field, students' problem-solving skills are still not optimal. This can be seen when students are given the task of story problems, where many students still have difficulty understanding the problems, making the right mathematical models, and using appropriate solving methods. In addition, students also often do not reexamine their results, causing the answers to be incorrect. This is in line with the findings made by Yuwono et al. (2018) at Turen Integrated Junior High School, which shows that students often have difficulty understanding the meaning of the story and making mistakes in describing and solving the problem. This difficulty arose because they were unable to convert the story's problems into appropriate mathematical forms. In addition, research by Indahsari & Fitrianna (2019) at SMK Cimahi also revealed that most students still often make mistakes in solving the problems given.

Students' difficulty in solving story problems suggests a close relationship between understanding concepts and problem-solving abilities in mathematics. The low understanding of concepts causes students to have difficulty translating problem information into correct mathematical models, thus inhibiting the problem solving process. On the other hand, weak problem-solving skills also have an impact on understanding concepts, because students are not accustomed to applying concepts that have been studied in various situations. This is in line with the opinion of (Sudane & Saadjad, 2021; Agustina & Vahlia, 2017), who stated that if students could understand the concept correctly, they would be easier to study mathematical materials and solve problems well. On the other hand, if the material is not well understood, the student will continue to make mistakes and experience difficulties in studying the next material.

Conceptual understanding and problem-solving skills are two important aspects of learning, especially in analytical subjects such as mathematics and science. These two abilities are interrelated and play a major role in students' success in understanding the material and applying it in real situations. Each student has a different level of ability to understand the same learning. Differences in level of ability among students are often challenging for educators in designing appropriate learning strategies. To determine the level of ability of students, their abilities can be grouped into several categories. This grouping of categories can be analyzed using cluster techniques.

Cluster analysis groups objects into multiple groups so that objects that are similar to other objects are grouped into one cluster (Zubedi, 2020). This method can group students according to specific capability patterns, thus providing a clearer picture for educators to design a learning approach that fits the needs of each group of students. In addition, this data-based grouping supports more effective and targeted educational decision making. With the use of cluster analysis technology, this research is expected to contribute significantly to improving the quality of data-based learning and supporting the development of more adaptive and innovative education strategies. Therefore, this study is important to identify the relationship between concept understanding ability and problem-solving ability.

The previous research conducted by Wulandari & Darminto (2016) at SMP Negeri 3 Purworejo with the title of research "relationship of creative thinking ability and concept understanding of mathematical problem solving". Research results show a significant relationship between the ability to understand mathematical concepts and the ability to solve problems with correlations of 0.65. This study only shows the relationship or absence between the ability to understand mathematical concepts and problem-solving abilities without considering the possibility of patterns or groups in the data.

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Another study conducted by Dwitasari & Noor (2024) at SMP Negeri 1 Rengasdengklok with the title of a study "cluster analysis for the relationship between mathematical communication ability and student's problem-solving ability". Research results showed that in cluster 1, the relationship was insignificant with a contribution of 7.4%. Cluster 2 was also insignificant with very weak links and a contribution of 2.2%. Cluster 3 also shows insignificant relationships with very weak and unidirectional relationships. In addition to showing or not the relationship between mathematical communication capabilities and problem-solving capabilities, there is a grouping of mathematical communication capabilities and problem-solving capabilities using K-means cluster analysis techniques.

The difference between this study and previous studies is whether or not there is a relationship between concept understanding ability and problem-solving ability and there is a grouping of mathematical concept understanding ability and problem-solving ability using K-means cluster analysis techniques. This technique processes large amounts of data in the database according to predetermined standards (Apriyani et al., 2023). Clustering algorithms are divided into two types, hierarchical algorithms, which discover clusters gradually in a predefined location, and partitional algorithms, which define the entire group at the same time (Merliana et al., 2015). One particular algorithm used was K-means, which determined the initial number of groups by setting centroid values.

K-means clustering is a method used to limit and divide data into one or more groups. In this study, students' concept understanding and problem-solving skills data were grouped into three groups to determine the high, medium, and low categories. K-means clustering has advantages in processing speed, making it easier to use. In line with the opinion of Sulistyawati & Supriyanto (2021), the K-means clustering method saves more time in the clustering process and provides effective data clustering results. Using this method, analysis results can be obtained more accurately and systematically, allowing researchers to draw clearer conclusions about the relationship between concept understanding ability and problem-solving ability.

Based on the description presented, it is seen that the ability to understand mathematical concepts with the ability to solve mathematical problems students have objections to each other. Thus, in this study, researchers were interested in conducting a study titled "Implementation of K-Means Clustering for the Relationship Between Conceptual Understanding Ability and Problem-Solving Ability".

Research Methods

This study is a quantitative study using correlation methods. The purpose of the correlation research is to determine whether there is a relationship between the variables studied, how strong the relationship is, and whether the relationship is significant or not (Laia, 2021). This study aims to find out how the relationship between concept understanding ability and problem-solving ability is, without any prior special treatment. The population in this study was all grade IX students of SMP Negeri 2 West Karawang, which was 376 people. Sampling using simple random sampling techniques is calculated using Slovin's formula:

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$$n = \frac{N}{1 + Ne^2}, \quad (1)$$

with a description:
n = number of research samples,
N = population size,
e^2 = margin error with 10% tolerance
Thus, the number of samples obtained in this study was $n = \frac{N}{1+Ne^2} = \frac{376}{1+(376\times(10\%)^2)} = 78{,}99 \approx 79$ persons. The data collection technique in this study was carried out by providing a test problem in the form of a description. The given problems were 6 problems that measured indicators of mathematical concept understanding ability, and 4 problems that measured indicators of mathematical problem solving ability. Data analysis techniques are performed in several stages. First, the student's answers will be scored and assessed in accordance with the scoring guidelines that have been created with the formula:

$$score = \frac{total\ score\ of\ all\ indicators\ obtained}{maximum\ score} \times 100. \quad (2)$$

Second, students' grades will be grouped according to certain characteristics using the K-means clustering method. K-means algorithmic measures according to Yudhanegara et al. (2020) as follows:
Let $X = \{X_1, X_2, \dots, X_n\}$ be the set of n objects. $X_i = \{x_{i,1}, x_{i,2}, \dots, x_{i,m}\}$ are characterized by the m feature set. The K-means algorithm looks for partition X into K clusters minimizing the objective function J with unknown variables U and C as follows:

$$J(U,C) = \sum_{l=1}^{k}\sum_{i=1}^{n}\sum_{j=1}^{m} u_{i,l}\, d(x_{i,j}, c_{l,j}). \quad (3)$$

Apply to:

$$\sum_{l=1}^{k} u_{i,l} = 1, for\ 1 \le i \le n, \quad (4)$$

where:
U is an $n \times k$ partition matrix,
$u_{i,l}$ is 0 and 1, $u_{i,l}$ = 1 ndicates that the object i is allocated to the cluster l,
$C = \{C_1, C_2, \dots, C_k\}$ is a set of K vectors representing the centroid K of the cluster,
$d(x_{i,j}, c_{l,j})$ is the distance between the i object and the cluster l centroid in the j feature. The distance is euclidean.
If the feature is numeric, then:

$$d^2(x_{i,j}, c_{l,j}) = \sum_{j=1}^{m} (x_{i,j} - c_{l,j})^2. \quad (5)$$

The above optimization problems can be solved by solving the following two minimization problems iteratively:

1. Fix $C = \hat{C}$ and solve the reduced problem $J(U,C)$. Problem J_1 resolved with:

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$$\begin{cases} u_{i,l} = 1 \text{ if } \sum_{j=1}^{m} d(x_{i,j}, c_{l,j}) \leq d(x_{i,j}, c_{t,j}), \text{for } 1 \leq t \leq k \\ u_{i,t} = 0, t \neq l. \end{cases} \tag{6}$$

2. Fix $U = \widehat{U}$ and solve the reduced problem $J(U, C)$. Problem J_2 resolved with:

$$c_{l,j} = \frac{\sum_{i=1}^{n} u_{i,l} x_{i,l}}{\sum_{i=1}^{n} u_{i,l}}, \text{for } 1 \leq l \leq k, \text{and } 1 \leq j \leq m. \tag{7}$$

Third, Spearman rank correlation test will be conducted to find out the relationship between concept understanding ability and problem solving ability. The hypothesis formulation is as follows:

Research hypothesis	=	There is a significant relationship between concept understanding ability and problem-solving ability.
Statistical hypothesis	=	$H_0: \rho = 0.$ $H_1: \rho \neq 0.$

In determining the correlation coefficient Spearman researchers used the following formula:

$$r_s = \frac{\sum {x_1}^2 + \sum {x_2}^2 - \sum {d_1}^2}{2\sqrt{\sum {x_1}^2 \sum {x_2}^2}}, \tag{8}$$

where:

$$\sum {x_1}^2 = \frac{n^3 - n}{12} - \sum Tx_1, \tag{9}$$

$$\sum {x_2}^2 = \frac{n^3 - n}{12} - \sum Tx_2, \tag{10}$$

$$\sum Tx_1 = \sum Tx_2 = \frac{t^3 - t}{12}, \tag{11}$$

description:
t = same data.
n = amount of data

Next, to find out how strong the relationship between concept understanding ability and problem-solving ability can be analyzed through the obtained correlation coefficient values. The interpretation of the strength of the relationship is based on the guidelines presented in Table 1. The following Guilford Emerical Rules:

Table 1. Guilford Empirical Rules

Interval	**Relationship Strength**
0,00 – 0,19	Very weak
0,20 – 0,39	Weak
0,40 – 0,69	Moderate
0,70 – 0,89	Strong
0,90 – 1,00	Very strong

Reference: (Lestari & Yudhanegara, 2018)

Correlation coefficient values range from +1 to -1. Positive values indicate a direct relationship between the two variables, meaning that if the understanding value of the concept is high, then the problem solving value will also be high, and vice versa. Negative values indicate a non-straightforward relationship, meaning that if the concept understanding value is high, then the problem solving value tends

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to be low, and vice versa. If the correlation coefficient is zero, then there is no clear relationship between the two variables. Furthermore, the coefficient of determination can be used to determine the extent of the influence between these variables

$$D = r_s^2 \times 100\%. \tag{12}$$

For test statistics using the following formula:

$$t_{count} = \frac{r_s\sqrt{n-2}}{\sqrt{1-r_s^2}}, \tag{13}$$

with n = amount of data. The significance of this study was 5% or 0.05 and the degree of freedom with the formula:

$$df = n - 2. \tag{14}$$

The test criteria are as follows:
If $t_{count} \le t_{\alpha/2}$ and $P - value > \alpha/2$ then H_0 is not rejected andH_1 is rejected.
If $t_{count} > t_{\alpha/2}$ and $P - value \le \alpha/2$ then H_0 is rejected dan H_1 is not rejected.

Results and Discussion

Results

Table 2 gives the following results of the test scores:

Table 2. Test results

Capability	Maximum Value	Minimum Value	Average
Conceptual Understanding	97,5	12,5	46,62
Problem-Solving	100	33	81,77

Table 2 shows that the student's test scores on the ability to understand mathematical concepts and mathematical problem-solving abilities for the two-variable linear equation system are still low. This can be seen from the minimum and average scores that indicate that students have not met the indicators of concept understanding and mathematical problem-solving skills. Next, students will be grouped into high, medium, and low ability categories using the K-means clustering method. Based on the steps of the K-means clustering algorithm, the researcher's initial steps form 3 clusters. Then, choose random student scores to be used as cluster 1 centroid, cluster 2 centroid, and cluster 3 centroid. Furthermore, each student's score will be calculated as the distance to each centroid, if the closest distance to the centroid cluster 1 then the student will enter cluster 1. Similarly, if the closest distance is to the cluster 2 centroid or cluster 3 centroid, the student will enter cluster 2 or cluster 3. Furthermore, each cluster will calculate its average value, which will be the centroid in the next iteration. Thus, in the first iteration the following results are obtained in Table 3 the results of the first iteration:

Table 3. Iteration result 1

	Cluster 1		Cluster 2		Cluster 3	
	CUA	PSA	CUA	PSA	CUA	PSA
Total Students	14 students		47 students		18 students	
Average	82,14	93,33	45,96	83,35	23,33	68,15

Table 3 shows that 14 students are grouped into clusters 1, 47 students in clusters 2 and 18 students in clusters 3. Furthermore, iteration 2 will be carried out by making the obtained average value as a new centroid. If the average value in iteration 2 is different from the average value in iteration 1, then iteration proceeds to iteration 3. Whereas if the average value in iteration 2 is equal to the average value in iteration 1, then iteration is dismissed. The following is the results of iteration 2 which is presented in table 4 as follows:

Table 4. Iteration result 2

	Cluster 1		**Cluster 2**		**Cluster 3**	
	CUA	**PSA**	**CUA**	**PSA**	**CUA**	**PSA**
Total Students	21 students		32 students		26 students	
Average	80,00	86,95	43,44	86,92	25,38	70,90

Table 4 shows that in cluster 1 there are 21 students, in cluster 2 there are 32 students and in cluster 3 there are 26 students. In the results of iteration 2 it appears that the average value of iteration 2 is different from the average value of iteration 1, so the iteration proceeds to iteration 3 by making the average value of iteration 2 the centroid of iteration 3. The results of iteration 3 are presented in table 5 as follows:

Table 5. Iteration result 3

	Cluster 1		**Cluster 2**		**Cluster 3**	
	CUA	**PSA**	**CUA**	**PSA**	**CUA**	**PSA**
Total Students	23 students		29 students		27 students	
Average	78,80	85,04	41,03	90,16	26,94	69,63

Table 5 shows that there is a change in the number of students in each cluster. Cluster 1 has 23 students, cluster 2 has 29 students and 27 students in cluster 3. In addition, the iteration 3 average value differs from the iteration 2 average value. So iteration needs to proceed to iteration 4. The results of iteration 4 are presented in table 6 as follows:

Table 6. Iteration result 4

	Cluster 1		**Cluster 2**		**Cluster 3**	
	CUA	**PSA**	**CUA**	**PSA**	**CUA**	**PSA**
Total Students	25 students		28 students		26 students	
Average	77,30	84,83	39,20	90,60	26,92	68,97

Table 6 shows that there is still a change in the number of students in each cluster and the iteration average score of 4 is different from the iteration average score of 3. In iteration 4 there were 25 students in cluster 1, in cluster 2 there were 28 students and the remaining 26 students in cluster 3. Next, the grouping process will proceed to iteration 5. The results of iteration 5 are in table 7 as follows:

Table 7. Iteration result 5

	Cluster 1		**Cluster 2**		**Cluster 3**	
	CUA	**PSA**	**CUA**	**PSA**	**CUA**	**PSA**
Total Students	25 students		28 students		26 students	
Average	77,30	84,83	39,20	90,60	26,92	68,97

Table 7 shows that there is no change in the number of students in each cluster and the iteration 5 average score is equal to the iteration 4 average score.

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Thus, the grouping process was discontinued. The results of iteration 5 also stated that the average score of cluster 1 was higher than the average score of cluster 2 and cluster 3 so that cluster 1 could be said to be a group of students with high-category abilities, cluster 2 average scores are between cluster 1 and cluster 3 average scores so that cluster 2 can be considered a group of students with moderate category capabilities, and cluster 3's average score is lower than the average score of cluster 1 and cluster 2 so that cluster 3 can be said to be a group of students with low category capabilities.

It can be concluded that based on the K-means clustering process, the following results were obtained: there were 25 students in cluster 1 with high category capabilities, cluster 2 with 28 students with medium category capabilities and the remaining 26 students in cluster 3 with low category capabilities. To determine the relationship between the mathematical concept understanding ability and the mathematical problem solving ability of students, Spearman rank correlation tests will be conducted on each cluster and all samples. The following are the results of the Spearman rank correlation test for all samples presented in table 8 as follows:

Table 8. Results of All Samples Rank Spearman Correlation Test

No	Statistics Symbols	Statistics Values
1	n	79
2	$\sum d_1{}^2$	60860, 5
3	$\sum Tx_1$	120
4	$\sum Tx_2$	396
5	$\sum x_1{}^2$	40960
6	$\sum x_2{}^2$	40684
7	r_s	0,255
8	$\alpha/2$	0,025
9	df	77
10	$t_{\alpha/2}$	1,99
11	t_{count}	2,31
12	$P - value$	0,024
13	D	6,48 %

Table 8 shows that $t_{count} > t_{\alpha/2}$ and $P - value \leq \alpha/2$ such that H_0 is rejected. It can be concluded that at the 95% confidence level across the sample there is a significant relationship between concept understanding ability and problem-solving ability. The degree of strength of the relationship between the two variables across the sample is in the weak category, with Spearman's correlation coefficient value of 0.255, which is between 0.20-0.39. The value of the correlation coefficient indicates a direct relationship, which means that if the concept understanding value is high, then the problem solving value is also high, and vice versa. The effect of the two variables was 6.48%, meaning that mathematical concept comprehension had an effect on problem solving ability by 6.48%, and vice versa, problem solving ability had an effect on mathematical concept

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comprehension by the same percentage. Furthermore, the results of the Spearman rank correlation test in cluster 1 presented in table 9 were obtained as follows:

Table 9. Rank spearman cluster 1 correlation test results

No	Statistics Symbols	Statistics Values
1	n	25
2	$\sum d_1{}^2$	1802
3	$\sum Tx_1$	13,5
4	$\sum Tx_2$	20
5	$\sum x_1{}^2$	1286,5
6	$\sum x_2{}^2$	1280
7	r_s	0,298
8	$\alpha/2$	0,025
9	df	23
10	$t_{\alpha/2}$	2,069
11	t_{count}	1,50
12	$P - value$	0,148
13	D	8,87 %

Table 9 shows that $t_{count} \leq t_{\alpha/2}$ and $P - value > \alpha/2$ such that H_0 is not rejected. It can be concluded that at the 95% confidence level in cluster 1 there is a relationship but is not significant between the ability to understand concepts and the ability to solve problems. Furthermore, the results of the Spearman rank correlation test in cluster 2 presented in table 10 were obtained as follows:

Table 10. Rank spearman cluster 2 correlation test results

No	Statistics Symbols	Statistics Values
1	n	28
2	$\sum d_1{}^2$	4284,5
3	$\sum Tx_1$	14
4	$\sum Tx_2$	76,5
5	$\sum x_1{}^2$	1813
6	$\sum x_2{}^2$	1750,5
7	r_s	$-0,202$
8	$\alpha/2$	0,025
9	df	26
10	$t_{\alpha/2}$	2,056
11	t_{count}	1,05
12	$P - value$	0,302
13	D	4,09 %

Table 10 shows that $t_{count} \leq t_{\alpha/2}$ and $P - value > \alpha/2$ such that H_0 is not rejected. It can be concluded that at the 95% confidence level in cluster 2 there is a relationship but is not significant between the ability to understand concepts and

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the ability to solve problems. Furthermore, the results of the Spearman rank correlation test in cluster 3 presented in table 11 were obtained as follows:

Table 11. Rank spearman cluster 3 correlation test results

No	**Statistics Symbols**	**Statistics Values**
1	n	26
2	$\sum {d_1}^2$	4666,5
3	$\sum Tx_1$	38
4	$\sum Tx_2$	22
5	$\sum {x_1}^2$	1424,5
6	$\sum {x_2}^2$	1440,5
7	r_s	$-0,629$
8	$\alpha/2$	0,025
9	df	24
10	$t_{\alpha/2}$	2,064
11	t_{count}	3,96
12	$P-value$	0,001
13	D	39,54 %

Table 11 shows that $t_{count} > t_{\alpha/2}$ and $P - value \leq \alpha/2$ such that H_0 is rejected. It can be concluded that at the 95% confidence level in cluster 3 there is a significant relationship between concept understanding ability and problem-solving ability. The degree of strength of the relationship between the two variables in cluster 3 is in moderate category, with Spearman's correlation coefficient value being -0.629, which is between 0.40-0.69. The value of the correlation coefficient indicates a non-straightforward relationship, which means that if the concept understanding value is high, then the problem solving value tends to be low, and vice versa. The effect of both variables was 39.54%, meaning that mathematical concept comprehension had an effect on problem solving ability by 39.54%, and vice versa, problem solving ability had an effect on mathematical concept comprehension ability by the same percentage.

Disccusion

Overall, statistical test results showed a significant relationship between concept understanding ability and problem-solving ability at 95% confidence, with a Spearman correlation coefficient of 0.255 indicating a weak but direct relationship. This means, the higher the understanding of the student concept, the higher their problem solving ability, although the effect is relatively small, which is 6.48%. However, when these relationships are further analyzed based on each cluster, the results obtained show variation. In cluster 1 with high capabilities and cluster 2 with medium capabilities, no significant relationship was found between concept understanding and problem solving. In contrast, in low-availability cluster 3, there is a significant relationship with the moderate degree of strength of the relationship, indicated by a Spearman correlation coefficient value of -0.629. This relationship is non-straightforward, meaning that students with high concept understanding tend to have lower problem-solving abilities, and vice versa. The effect between the two variables in this cluster is quite large, at 39.54%.

These findings suggest that while there is a relationship between concept understanding and overall problem solving, the relationship does not necessarily apply to all student categories. In low-skilled students, understanding of higher concepts does not necessarily improve their problem-solving skills, which indicates other factors that play a role in the problem-solving process. The factors that led to the results of this study suggest a different relationship between concept understanding ability and problem-solving ability in each cluster can be explained through several aspects. Differences in ability levels between students in each cluster can affect how they relate understanding concepts to problem solving.

In high-skill students (cluster 1), they may already have a strong understanding and no longer rely too much on understanding basic concepts in solving more complex problems, so the relationship between these two variables is not seen as significant. Whereas in low-skilled students (cluster 3), there is a greater dependence between the two, although the direction of the relationship is not direct, indicating that understanding of the low concept can lead to problem solving difficulties, and vice versa. Difficult problem solving can affect better understanding of concepts. Students with moderate abilities (cluster 2) are in between these two groups, where they may have sufficient conceptual understanding, but have not been fully able to effectively implement them in problem solving. This can happen because they are still in the transitional stage of developing critical thinking skills, so even though there is a relationship between the two variables, the results are insignificant. In other words, this significant or insignificant relationship is greatly affected by the complexity of internal and external factors affecting each group of students.

The results of this study have differences and similarities with previous studies conducted by Wulandari & Darminto (2016) found a strong and significant relationship between understanding mathematical concepts and problem-solving abilities with correlation coefficients of 0.65. while this study showed varying relationships in each student group and was not always significant. Meanwhile, the research of Dwitasari & Noor (2024) is more consistent in the method because they both use K-means clustering, but the research examines the relationship between mathematical communication capabilities and problem solving. with results showing insignificant relationships across all clusters and showing very weak relationships across the group, while this study still found significant but unidirectional relationships among students with low abilities. Thus, this study confirmed that the relationship between concept understanding and problem solving is not necessarily linear, so clustering approaches such as K-means clustering are more effective in understanding variations in relationships between variables.

The results of this study have several advantages that can provide new insights into the field of education, particularly related to the relationship between concept understanding and problem-solving ability. One of the advantages is the K-means clustering-based approach, which allows more in-depth analysis by dividing students into groups based on their abilities. This provides a more specific understanding of how the relationship between the two variables varies between groups of students, so it can be used to design a more targeted learning strategy. In addition, the use of statistical analysis with 95% confidence improves the validity of the findings, as it ensures that the conclusions drawn have a sound basis and can be empirically tested. Nevertheless, this study also has several limitations, such as relatively weak correlations in the analysis of the entire sample as well as the complexity of interpretation in low-power groups, which require further research.

The results of this study also make an important contribution in understanding the relationship between understanding concepts and problem-solving abilities among students with different levels of ability. These findings can serve as the basis for educators in designing more effective learning strategies that fit the needs of each student group. In addition, the results of this study can also be considered in the development of a more adaptive curriculum, in which the teaching approach is tailored to the level of students' abilities. Another impact is in education policy, where schools and policymakers can pay more attention to the balance between theory and practice in the learning process. Thus, this study not only provides theoretical insights but also has practical implications for improving learning effectiveness, especially in subjects requiring critical thinking and problem solving skills.

Conclusions and Suggestion

This study shows that there is a significant relationship between understanding the concept and overall problem-solving ability, although the relationship is weak and varied in each student group. In students with high and medium abilities, the relationship between the two variables is insignificant, while in students with low abilities, the relationship is significant but not direct. These findings indicate that other factors may play a role in supporting students' problem-solving abilities, especially for those with lower conceptual understanding.

Further research is suggested to use a qualitative approach to explore deeper factors that influence the relationship between concept understanding and problem solving. In addition, research with larger samples and different locations can help to understand these relationship variations more clearly. It is also necessary to examine other variables that may contribute to students' problem-solving abilities, such as learning strategies, motivations, or learning experiences. A more adaptive clustering-based learning approach can also be developed to increase the effectiveness of math education according to the level of ability of students. Conduct a comparative study of clustering algorithms such as K-means with other algorithms, to determine the most suitable and optimal clustering method in the context of this study.

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