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STUDENT ERRORS IN SOLVING THREE DIMENSIONAL PROBLEMS BASED ON NOLTING THEORY

Muhammad Ridha[1], Suhendra[2], Elah Nurlaelah[3]

[1,2, 3]Departemen Pendidikan Matematika, Universitas Pendidikan Indonesia
**Corresponding author.*
E-mail: *Muhammadridha@upi.edu[1)]*
Suhendra@upi.edu[2)]
Elah_nurlaelah@upi.edu[3)]

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Abstract

The third dimension is one of the materials that students need help understanding, so in solving three-dimensional questions, students make many mistakes. The purpose of this research is to find out the form of student errors and the factors that cause student errors in solving three-dimensional questions on the concept of distance to points, lines, and planes. This research is qualitative research with a case study approach. The subjects of this study were 65 students of class XII in one of the high schools in Bandung, West Java. The instruments used were three-dimensional test questions and interview guidelines. To analyze student errors in this study, the Nolting theory was used. The results of this study show that students' errors in solving three-dimensional questions are still relatively high, with a percentage of careless errors of 54%, concept errors of 65%, application errors of 3%, and test-taking errors of 37%. These errors cause these errors because students do not master the prerequisite material well, misunderstand the concept of distance, and the ability to see space is still relatively low and not thorough. Based on the results of this study, it can be concluded that the biggest error of students in the third dimension is the concept error in determining the distance of points, lines, and planes. Therefore, it is expected that educators can pay attention to errors and their causal factors so that similar errors do not occur.

Keywords: Student error; three dimensions; the Nolting theory

Abstrak

Dimensi tiga adalah salah satu materi yang sulit dipahami oleh siswa, sehingga dalam menyelesaikan soal dimensi tiga siswa melakukan banyak kesalahan. Adapun tujuan penelitian ini adalah untuk mengetahui bentuk kesalahan siswa dan faktor penyebab kesalahan siswa dalam menyelesaikan soal dimensi tiga pada konsep jarak titik, garis dan bidang. Penelitian ini adalah penelitian kualitatif dengan pendekatan studi kasus. Subjek penelitian ini adalah 65 siswa kelas XII di salah satu SMA di kota Bandung, Jawa Barat. Adapun intrumen yang digunakan adalah soal tes dimensi tiga dan pedoman wawancara. Untuk menganalisis kesalahan siswa dalam penelitian ini digunakan teori Nolting. Hasil penelitian ini adalah kesalahan siswa dalam menyelesaikan soal dimensi tiga masih tergolong tinggi dengan persentase careless errors 54%, concept errors 65%, application errors 3% dan test-taking errors 37%. Adapun faktor penyebab terjadinya kesalahan-kesalahan tersebut dikarenakan siswa tidak menguasai materi prasyarat dengan baik, kesalahpahaman konsep jarak, kemampuan pandang ruang yang masih tergolong rendah dan tidak teliti. Berdasarkan hasil penelitian ini dapat disimpulkan bahwa kesalahan terbesar siswa pada dimensi tiga adalah kesalahan konsep dalam menentukan jarak titik, garis dan bidang. Oleh karena itu, diharapkan kepada tenaga pendidik untuk dapat memperhatikan kesalahan dan faktor pernyebabnya agar tidak terjadi kesalahan serupa.

***Kata kunci**: Dimensi tiga; kesalahan siswa; teori Nolting*

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INTRODUCTION

Mathematics is a science that supports many other sciences in everyday life; almost every field of study requires mathematics. The importance of learning mathematics is not just mere calculations but honing the mind so that it becomes logical, critical, and systematic in solving problems (Abdurrahman, 2018). The subject matter of mathematics is abstract and has different levels of difficulty. These two things make mathematics challenging to understand for students who mostly think concretely. (NCTM, 2023), divides mathematics into five main discussion points: numbers, algebra, geometry, measurement and data analysis, and probability theory.

Geometry is a topic that needs attention, so it is consistently studied by kindergarten to high school students. Geometry is a branch of mathematics investigating points, lines, planes, and spaces and their properties, sizes, and relationships with one another (Fadhelina, 2021). The geometry needs to be studied because, first, geometry helps humans completely appreciate their world. Second, exploration in geometry can help develop problem-solving abilities. Third, geometry plays a significant role in other fields of mathematics. Fourth, geometry is used by many people in everyday life (Budiarto & Artiono, 2019).

In the learning process, there are minimum standards that need to be achieved by students. Geometry learning standards for students are to be able to analyze the characteristics and properties of two-dimensional and three-dimensional shapes, determine distances and locations, apply transformations, and spatial reasoning in solving problems (Kemendikbud, 2018). Students must master geometry concepts. Mastery of geometric concepts at one level will affect students at the next level (Novita et al., 2018). This is because mathematics has a hierarchical nature, so in studying mathematics at one level, one must master mathematics at the previous level. One of the geometry materials that students must master is three dimensions. This is in line with (Apriani, 2017); (Fauzi & Arisetyawan, 2020; Marfu'ah et al., 2019) stated that three-dimensional material is material that most students have difficulty understanding even though mastery of this three-dimensional material will affect students' mathematical problem-solving abilities and reasoning.

Given the importance of applying the three-dimensional material mentioned above, this material should be well mastered by students by predetermined learning standards. Nevertheless, the facts on the ground prove that this material is still a problem. Based on research conducted by (Sari, 2017), the misconceptions experienced by students about the concept of three-dimensional geometry are the concept of point-to-point distance, the concept of point-to-line distance, the concept of point-to-plane distance, and the concept of line-to-plane distance. Similar findings were also found in research conducted by (Suhady et al., 2019), who concluded that students had difficulty solving three-dimensional geometry problems on the concept of distance. The problems that have been happening for years cannot be ignored. If this is allowed to continue, the learning objectives will not be achieved; students will fail to master school mathematics.

The theory of error analysis is needed to find out student mistakes in

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solving problems. The theory of error analysis used in this study is the Nolting theory. This is because the Nolting theory is the newest among other error theories. The theory proposed by Nolting accommodates the points of error raised by other experts more simply and easily to understand. (Nolting, 2012), in his book Math Study Skills Workbook, he writes that to analyze errors in a mathematics test, a researcher must find the following types of errors: careless errors, concept errors, application errors, and test-taking errors.

Based on the description above, the researcher believes it is necessary to research student errors in solving three-dimensional questions to overcome student errors. Therefore, this research aims to find out the types of errors and factors that cause errors made by students in solving three-dimensional problems.

RESEARCH METHODS

This research is qualitative research using a case study design. Case studies are qualitative research that seeks to investigate something systematically. In exploring a phenomenon, the researcher and the perspective studied must be involved in its natural context (without any treatment given) (Gall, 2014). The subjects in this study were 65 students of class XII who had studied the third dimension material on the concept of distance between points, lines, and planes. The place of research is one of the high schools in Bandung, West Java, which is considered feasible based on the results of surveys and interviews with teachers.

The instruments in this study were divided into two, namely, the main and supporting instruments. The main instrument in this research is the researcher. Hardani et al. (2020) argued that qualitative researchers act as human instruments that focus research. At the same time, the supporting instruments in this study include three-dimensional test questions and interview guidelines that have met the valid criteria based on content and construct and readability tests. Based on the instrument, data collection techniques include test and non-test techniques. The following are the test questions given to students.

1. Given a cube $ABCD.EFGH$. Show it with a picture:
   a. Distance of point E to point C
   b. Distance of point E to line $\overline{AC}$
   c. Distance of point E to plane $BCGF$
2. Find the cube $PQRS.TUVW$ with ribs 6 cm. Determine the distance:
   a. Point T to line $\overline{PV}$.
   b. Point W to PRU plane

In determining the percentage of errors made by student researchers using the following formula:

$$P = \frac{n}{N} \times 100\% \qquad \ldots (1)$$

Description:

P = Percentage of types of student errors

n = The number of errors that occurred

N = The number of possible errors

The Table 1 shows the error classification categories based on the percentage of errors made by students. The Table 2 presents error indicators based on Nolting's theory.

Table 1. Student error percentage classification

Percentage	Category
$P \geq 55\%$	Very high
$40\% \leq P < 55\%$	High
$25\% \leq P < 40\%$	High enough
$10\% \leq P < 25\%$	Low
$P < 10\%$	Very low

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Table 2. Nolting error indicators

Type of Error	Indicator
Careless errors	Students carelessly rewrite the components of the given problem before solving the problem, the sign of the operation, and the result of the operation and answer.
Concept errors	Students do not master the concepts used in the third dimension material, including: Pythagoras, the operation of power numbers and roots, the concept of distance between points, lines and planes, and trigonometry.
Application errors	Students know the formula but cannot apply it to solve the problem.
Test-taking errors	Students did not complete the problem-solving steps until the end, changed the answer that was initially correct to be wrong, spent time on one problem so that other problems were not resolved, copied the wrong answer from another paper, left the answer blank, were in a hurry to collect so they did not check again, wrote conclusions.

The initial step in the data analysis process in this study was that the researcher examined students' answers. After conducting the examination, the researcher reviews the students' mistakes and categorizes these errors into the four categories proposed by Nolting based on the indicators in Table 2. From these errors, the researcher classifies the percentage of student errors based on Table 1 above. Researchers suspect the causes of errors made by students and other student errors will be studied more deeply regarding the causes and factors at the interview stage.

RESULTS AND DISCUSSION

The results of this study illustrate the findings that the researchers obtained from the research instruments that the researchers used, namely the three-dimensional test questions and interviews related to student errors in solving three-dimensional questions based on the Nolting theory. Table 3 below presents the percentage of student errors based on the type of Nolting error.

Table 3. Percentage of student errors

Error Type	Question Items		Error Percentage		Overall Percentage Error
	Soal 1	Soal 2	Soal 1	Soal 2	
Careless errors	26 students	44 students	40%	68%	54%
Concept errors	44 students	40 students	68%	62%	65%
Application errors	0 student	4 students	0%	6%	3%
Test-taking errors	22 students	26 students	34%	40%	37%

Table 3 shows that the mistakes made by students in solving three-dimensional questions are high. The type of careless errors is in the high category, the type of concept errors is in the very high category, the type of application errors is in the deficient category, and the type of test-taking errors is in the reasonably high category—the following types of errors made by students based on the type of Nolting error.

There are mistakes made by students, namely careless errors in the form of; (1) Students are wrong in using symbols, (2) Students are wrong in

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determining the results of operations, (3) Students are wrong in substituting values, and (4) Students are wrong in writing conclusions. Concept errors in the form of; (1) Students are wrong in determining the name of the cube, (2) Students are wrong in determining the distance of a point to a point, (3) Students are wrong in determining the distance of the point to the line, and (4) Students are wrong in determining the distance of the point to the plane. Application errors in the form of Students know the formula but cannot apply the formula they know. Test-taking errors in the form of; (1) Students not provide a picture of the distance from a point to a line or plane, (2) Students do not write down the length of the sides of the triangle, (3) Students do not write down units of length, and (4) Students do not write the final conclusion. The types of errors made by students will be discussed based on the type of Nolting error.

Careless Errors

Careless errors or errors caused by student carelessness, the percentage of occurrence of this error is 54% which belongs to the high category. This means that almost all students make mistakes with the careless error type, both students who have good abilities to students with low abilities. The following figure displays student errors with the type of careless error.

Figure 1 shows the work of a student with good math skills, but the student made a mistake in using the "=" symbol. The student's mistake was due to the student's habit of using the "=" symbol. Students feel this is not wrong, so they have often done it. This is also often found in student answer sheets, as in the research of (Nurussafa'at et al., 2016), which found that students were inconsistent with their writing, namely replacing the "=" sign with a random ":" sign, as well as the nature of students who were too hasty in writing.

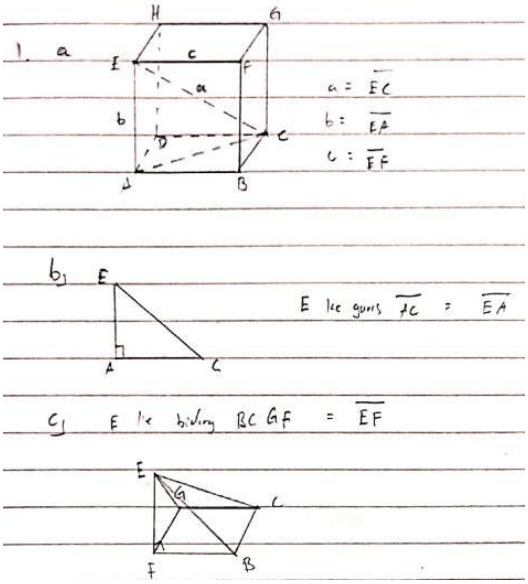

Figure 1. *Careless Errors* 1

Solving problems causes incomplete answers as expected and also experiences errors in the mathematical concepts it uses—other mistakes students make, as shown in the Figure 2.

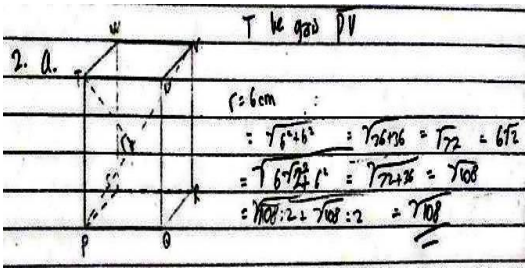

Figure 2. *Careless Errors* 2

In Figure 2, it can be seen that students made wrong calculations or mistakes in determining the results of operations. This is caused by writing mathematical sentences that need to be corrected. In addition, students did not master the prerequisite material well, in this case, rooted number operations

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material, resulting in miscalculations. In line with (Rosita & Novtiar, 2021); (Upu et al., 2022) that prerequisite material not conceptualized by students influenced the mistakes made by students in solving math problems. The student needs to write down what he is looking for so that the equation made by the student needs to be corrected.

Concept Errors

Students make concept errors due to a wrong understanding of the concept. The percentage of occurrence errors with the type of concept errors is 65% which is classified in the very high category. This means that most students do not master the material being studied. Students experience this conceptual error with low and moderate mathematical abilities. The Figure 3 shows the form of an error made by students.

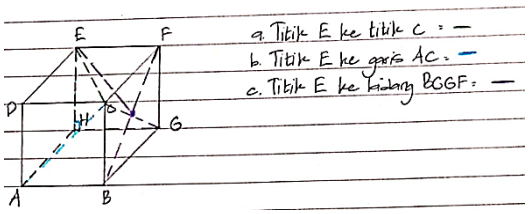

Figure 3. *Concept Errors* 1

Figure 3 shows a conceptual error made by students in the form of an error in naming the cube. As a result of this error, the student needs to be corrected in determining the distance being asked. This naming error occurs due to students' lack of attention regarding the naming of the cube, and students need to know there are rules for naming the cube. In addition, errors also occur in determining the distance from point to point, as shown in the Figure 4.

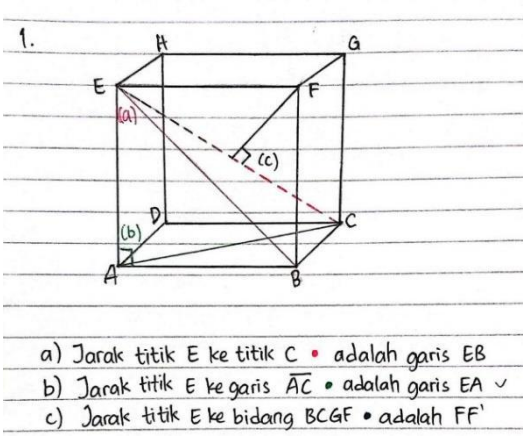

Figure 4. *Concept Errors* 2

Figure 4 shows the student's need to be corrected in determining the point-to-point and point-to-plane distance. This is caused by students' need for clarification regarding the location of the right angles in determining the shortest distance. In addition, similar errors also occur in other students, as shown in the Figure 5.

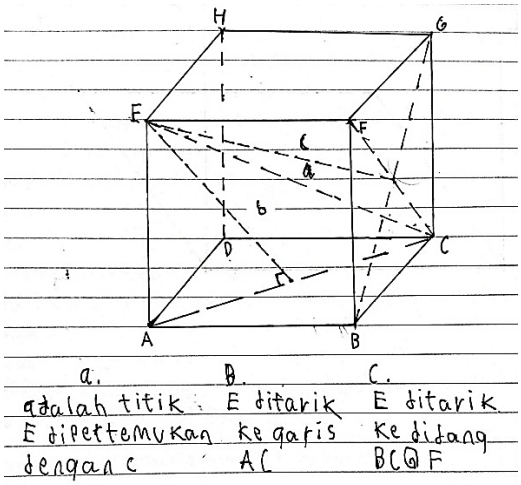

Figure 5. *Concept Errors* 3

Based on Figure 5, it can be seen that students needed to correct the distance of the point to the line and the distance of the point to the plane. This error is caused by students' mistakes in understanding the shortest distance, and students assume that the shortest distance from a point to the line or field is at the midpoint of the line or field.

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Errors in determining the distance of points to points, lines, and planes are also affected by the low spatial visibility of students. The ability to view space is needed to imagine an object form from a different perspective in solving three-dimensional geometric problems (Febriana, 2015). So because the students' ability to see is still low, it causes students to need clarification in determining the location of the elbows as a requirement for the shortest distance.

Application Errors

Application Errors are errors made by students in applying a concept or a formula. Based on the test results, this type of error is classified as very low, with a percentage of 3%. Students tend to know the formula used to solve problems but need to learn how to apply the formula. The student errors in applying the formula can be seen in Figure 6.

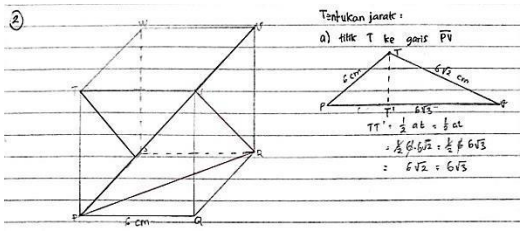

Figure 6. *Application Errors*

Figure 6 shows the student's mistake in applying the formula for the area of a triangle to find the distance from the point to the line. Students need clarification in reviewing a triangle from two sides of the base. The same thing was also found by (Nurfalah & Bernard, 2020); (Kurniasari, 2013); students made mistakes with procedural types, which included calculation errors and errors in applying formulas. The incorrect application of formulas and the way of writing equations results in inaccurate results, as shown in the picture.

Test-taking Errors

Test-taking Errors are specific errors that occur during the test. In this study, the percentage of occurrence of this error was as much as 37% which is in the reasonably high category. The following is a picture of the mistakes made by students.

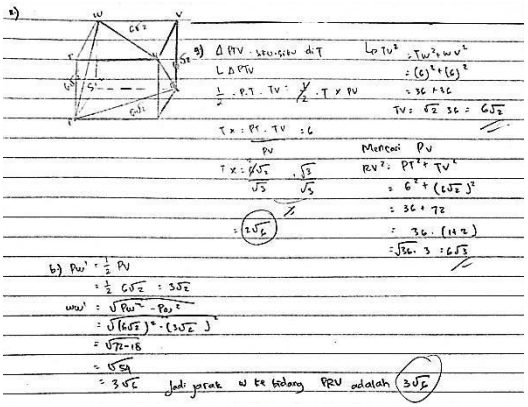

Figure 7. *Test-taking Errors*

Test-taking Errors are specific errors that occur during the test. In this study, the percentage of occurrence of this error was as much as 37% which is in the reasonably high category. The following is a picture of the mistakes made by students. Based on Figure 7, it is known that students should have described the distance of points to lines and planes to make it easier to find the distance being asked. As a result, in part b, the students made another mistake: the mistake of substituting the side length value into the formula used. In addition, students also made other mistakes, namely not writing the unit of length in the final result. In addition, students also still need to write down the conclusion of the distance being asked. The students' inaccuracy in working causes errors of this type. (Maulana & Pujiastuti, 2020); (Hidayat et al., 2013) also found similar errors, namely needing to be more thorough and students not completing answers

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perfectly in solving three-dimensional questions. This error should have been prevented if students checked again the answers that had been written.

CONCLUSIONS AND RECOMMENDATIONS

Based on the results of research and discussion, it can be concluded that students' errors in solving three-dimensional problems are still high in the types of careless errors and concept errors. The types of errors made are errors in abstracting the determination of distances and right angles between lines to lines and lines to planes. The main factors causing errors are not mastering the prerequisite material well, misunderstanding the concept of distance, and the ability to see space which is still relatively low.

Based on the results of this study, it is recommended for teachers who teach the third dimension to pay attention to concept errors and can train students' spatial visualization skills. The next researcher is expected to continue the study of students' geometry errors by reviewing how the teacher teaches, the accuracy of teaching materials, and student learning resources.

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