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Major Difficulty in Solid Geometry Learning for University Students:

Developing Visual Spatial Skills

Mega Eriska Rosaria Purnomo
Mathematics Education Department
Muhammadiyah University of Surakarta
Surakarta, Indonesia
mega.eriska@ums.ac.id

Isnaeni Umi Machromah
Mathematics Education Department
Muhammadiyah University of Surakarta
Surakarta, Indonesia
isnaeniumi@ums.ac.id

***Abstract*—This research aims were to describe major difficulty for university students in solid geometry learning process and to know the causes of the problem. This research used qualitative method. The data was collected by testing and interviewing respondents. Respondents were 39 mathematics education students in class D, Universitas Muhammadiyah Surakarta, academic year of 2016/2017. The interview was conducted to 6 students who did most errors in major error category based on the test results. The result of this research showed that most of students had main difficulty to develop visual spatial skills in solid geometry learning. They could not visualize shapes of solid geometry objects well. It was because they did not understand well about steps for drawing intersection plane of cube, drew cube carelessly, did not know the shape of cube if the frontal plane was not standard, and remembered the answer of the exercise.**

Keywords—difficulty; solid geometry; visual spatial skills

I. INTRODUCTION

Mathematics in university level is diffirent with school mathematics. It consists of geometry, arithmetics, algebra, and analysis. Based on [1] patterns of solving problems or questions in universities and schools are different too. Students usually answer multiple choice questions in school exam and that condition affects the way they answer essay questions in university exam. Most of them have difficulty to explain their ideas in written way.

Students in university level should have good understanding in geometry because ideas for geometry can be found easily in daily life, such as high buildings, patterns of batik clothes, etc. Reference [2] states that geometry could improve students' reasoning and proving ability. Therefore, abstraction and reasoning ability supported with logic and critical thinking are essential for university students so that they can learn geometry well.

However, learning geometry may not be easy and a large number of students have failed to develop understanding of geometry concepts, reasoning, and problem solving. The poor understanding in learning geometry often causes discouragement among the students that would lead to poor performance in geometry [3].

One branch in geometry for university students is solid geometry. This subject is one of the main subjects that must be learned well by students in Universitas Muhammadiyah Surakarta because it is a preliminary subject for more advanced geometry. Based on students assignments in solid geometry, some of them managed to determine the distance between two lines and calculate it correctly, but they concluded wrongly in the end. Moreover, some of them made some errors when drawing cube if the frontal plane is not ABFE. They also made mistakes when drawing the intersection plane of the cube. Some of them also incorrectly determined the segment when determining the distance between two points or two lines.

Some errors that they made in assignments show that they have difficulties in learning solid geometry materials. Based on [4] those difficulties affect students' problem solving ability and could make students fail to solve geometrical problems. Therefore, it must be solved by their lecturers, then students could reach good grades in solid geometry subject.

According to [5] and [6] one of the method to analyze errors in mathematics essay question is Newman Procedure that consist of five types. Those are reading, comprehension, transformation, process skill, and encoding. Reading errors will not happen if students can read the question. Comprehension errors will not happen if students can explain what the question was about. Then, transformation errors will not happen if students can select appropriate mathematical operators and procedures. Process skill errors will not happen if students can correctly perform mathematical processing and encoding error will not happen if students can represent answer appropriately.

On the other hand, there are five main foundation to identify student difficulties in mathematics learning. Those are number fact, arithmetics, information, language, and visual spatial skills Number fact skill relates to proficiency of number facts, tables, and mathematics principal. Arithmetics skill is about accuracy and logarithm in computational and mathematical working procedure. Information skill is expertise to connect information to a concept, operational, and experience as well the expertise to transfer information and transform problems into mathematical sentence. Language skill is proficiency of terms and relevance of mathematical information. At the end, visual spatial skills is skill to visualize mathematical concepts, manipulate geometrical shape and space meaningfully [7].

This research combined and adopted both ideas that consist of transformation, process skill, language, and visual spatial skills to identify the major difficulty for students in university level to learn solid geometry. Therefore, based on that background, the questions of this research were 1) what is the major difficulty for university students in learning solid geometry? 2) why university students have difficulty for learning solid geometry? This research purposes were 1) to describe major difficulty for university students in solid geometry learning process and 2) to know the causes why that problem happens.

II. Research Method

A. Design of The Research

This research applied a qualitative method to explore the major difficulty of university students in learning solid geometry by looking at some errors that they made in the test based on four categories. Those were language errors, transformation errors, process skill errors, and also visual spatial skills errors.

Respondents in this research were 39 mathematics education students in class D, Universitas Muhammadiyah Surakarta, academic year of 2016/2017. Then, an interview was conducted to 6 students who did most errors in major error category based on the test results.

B. Data Collection Technique

The data for this research was collected by testing and interviewing the respondents. The test was done by giving the students solid geometry essay questions which consisted of 4 questions on Tuesday, 11 April 2017. Meanwhile, interview was done to 6 students who made most errors in major error category on the test on Wednesday, 26 April 2017. Thus, data collection instruments consisted of questions of test and guiding line sheet for interview process.

C. Data Analysis Technique

According to [8] data analysis techniques that was used in this research consisted of: 1) data reduction: correcting the answers of the students, then determining who were the students that must be interviewed. Six students who made the most mistakes were then picked for interview process, 2) data presentation: the answers of the six students who made most errors in major error category were presented as interview materials. Furthermore, the results of the interview with six students was also presented in this step, 3) made conclusion or verification: comparing the students' answers in the test to the results of interview process to find out why they made those errors.

The next step was making data legality test by using triangulation method. It was done by comparing the results of the test with the results of the interview.

III. Results And Discussions

A. Results

This study produced both quantitative and qualitative data as a result. Quantitative data in this research was the percentage of student errors based on four categories from the test results. From that data, the major difficulty for university students in learning solid geometry could be known. Meanwhile, qualitative data was the analysis of the results from the test and interview.

In this research, language errors means having difficulties understanding mathematical terms and the information given in the questions. Moreover, it is also related to students ability to understand the meaning of questions or problems. Meanwhile, transformation errors happen when students could understand the questions, but they failed to change information into mathematics symbols, operations, and also mathematics sentences. Process skill errors happen if students could choose the right operations for solving problems, but they did procedure wrongly. Finally, visual spatial errors are related to having difficulties in visualising and manipulating shapes of geometric objects.

The test in this research consisted of 4 essay questions. Question 1a and 1b were about determining distance between two points and distance from line to plane respectively. Question 2 was about drawing intersection plane from cube then determine area of the intersection plane. Question 3 was about drawing a cube if given frontal plane, receding angle, projection comparison, and scale. Question 4 was about determining ratio from two solid objects if a cube was intersected by a plane.

According to the test results, the percentage of students' errors classified into four categories is presented in Table I.

TABLE I. The Percentage of Student Errors Divided into Four Categories from Test Result

Category	Question				
	1a	1b	2	3	4
Language Errors	5,13%	7,69%	10,26%	0,00%	0,00%
Transformation Errors	31,03%	48,72%	0,00%	0,00%	12,82%
Process Skill Errors	46,15%	30,77%	0,00%	0,00%	10,26%
Visual Spatial skills Errors	0,00%	0,00%	64,10%	61,54%	66,67%

It can be seen from Table I that the least percentage of students' errors in solving solid geometry problems came from language. The term of projection that was used in question 1 made it hard for the students to understand the meaning of the question. Then, the second and third rank were transformation and process skill errors. The greatest percentage of students' errors came from visual spatial skills. It was noted that students had great problems to develop their visual spatial skills in solid geometry learning.

Furthermore, based on the interview, it was noticeable that R1 (Respondent 1), R2 (Respondent 2), and R3 (Respondent 3) drew the intersection plane incorrectly in question 2 because they did not understand the steps of drawing an intersection plane comprehensively. The intersection plane was hexagon, but the intersection plane from R3 was triangle. Fig. 1 and Fig. 2 were the answers of the test from R3 and R5 respectively.

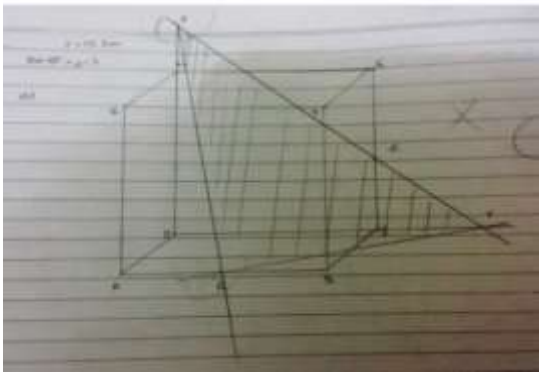

Fig.1. The test answer of R3 in Question 2

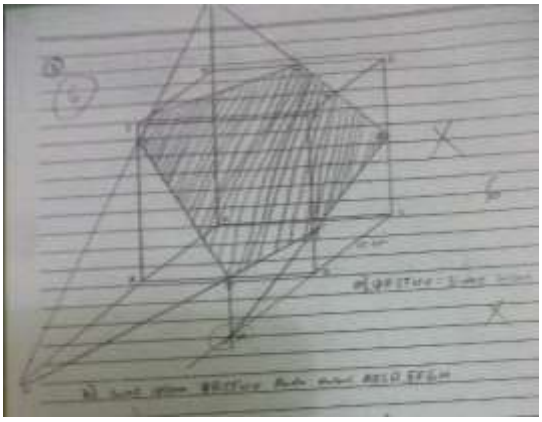

Fig.2. The test answer of R5 in Question 2

Moreover, R4 (Respondent 4), R5 (Respondent 5), and R6 (Respondent 6) answered question 3 wrongly. They drew a cube with wrong length of AE. It happened because they drew a cube carelessly. Meanwhile, R1 and R2 did it wrongly because they did not know how the shape of a cube is determined if ACGE was frontal plane. They admitted that they did not have good visualization. They also memorized the answers from the exercise in class. Fig. 3 and Fig. 4 showed the test answers of R1 and R2 in question 3.

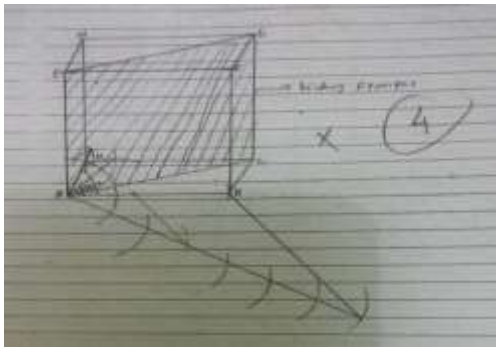

Fig 3. The test answer of R1 in Question 3

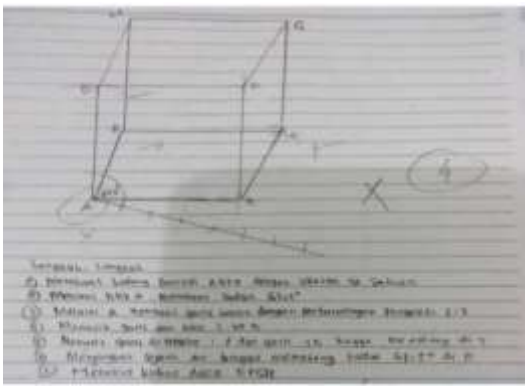

Fig 4. The test answer of R2 in Question 3

R6 answered question 4 wrongly because he did not understand the material well. He also tried to memorize the answers from the exercise. The intersection plane of the cube was AFH, then it divided the cube into 2 parts. Those were pyramid EAFH and solid object ABCDFGH, but the answer of R6 was shown in Fig. 5 below.

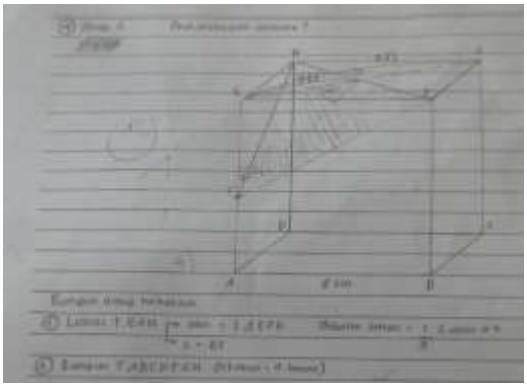

Fig 5. The test answer of R6 in Question 4

B. Discussions

Based on the results of this research, it could be seen that the biggest percentage of students' errors in solving solid geometry problems came from visual spatial skills. It implies that the major difficulty for university students in learning solid geometry was to develop visual spatial skills. The results of this research reinforced the previous research by [7] which stated that the students had difficulty to develop some skills, One of them being visual spatial skills. Furhermore, deficiency in visual spatial skills might cause difficulty in differentiating, relating, and organizing information meaningfully [9]. The lacked of ability to visualize mathematics problems and concepts could cause difficulties in solving the problem. Therefore, this problem has to be one of the priorities to be concerned by mathematics lecturers.

The mistakes happened because of various causes. Firstly, the students did not understand the steps of drawing an intersection plane comprehensively. Secondly, they also drew a cube carelessly. Then, some of them did not know how to determine the shape of a cube if the frontal plane is not standard.

Lastly, some of them memorized the answers from the exercise in class. Those facts indicated that students did not have good visualization ability in solid geometry learning. Actually, geometry requires visualizing abilities because it is a study of shapes and spaces. Reference [10] stated that the students who have good visualization tend to excel in mathematics than those who do not. Thus, this research supported the previous research by [11] which stated that teachers should guide their students to take advantages from their personal mistakes for improving their mathematics skills, such as visual spatial skills in learning solid geometry. It should be done by mathematics lecturers to prepare their students to have good spatial visualization skills because in the future they who will teach mathematics and geometry, and they should have at least basic spatial skillss [10]. According to [12] lecturers should give instructional activities that afford opportunities for fostering spatial abilities, and those should be included in pre-service programmes so that in the future they have a mathematical foundation to teach geometry. Then, based on [13] some researchers stated that educators need to develop instruction that emphasizes not the recall formal definitions and rules but construct dynamic activities of students for giving them visual spatial experiences and representations of geometrical shapes.

This research also reinforced the study that has been done by [14] which concluded that a lot of students had difficulties in understanding geometry, a crusial aspect in mathematics learning. Another research that was conducted by [1] in analytic geometry learning concluded that the most errors that have been made by students was process skill errors. Lecturers should create solid geometry learning meaningfully. According to [15] meaningful mathematics was formed by students, not by teachers. Moreover, a lot of studies have demonstrated that technology has an important role to develop spatial skillss. Based on [3], research that has been done by Hodanbosi concluded that students in Geometer's Sketchpad (GSP) group had significantly higher achievement scores on the Geometry Achievement Test rather than students in traditional group. Thus, lecturers could apply guided discovery or meaningful application learning by using media instruments, such as GeoGebra, Geometer's Sketchpad, Matlab, etc for improving students' understanding about solid geometry materials and giving them meaningful learning experiences.

IV. Conclusions And Suggestions

A. *Conclusions*

According to the explanation before, it can be concluded that the major difficulty for university students in learning solid geometry was develop visual spatial skills. It can be seen from the percentage of of students' errors in solving solid geometry problems, which was the greatest.

Those mistakes happened because the students did not understand the steps of drawing an intersection plane comprehensively. They also drew a cube carelessly. Then, some of them did not know how the shape of a cube is determined if the frontal plane is not standard andtried to memorize the answers of exercises that have been taught in class.

B. *Suggestions*

Some suggestions to the mathematics lecturers, they could create positive learning environment by applying cooperative learning, problem-based laerning, and other models that give opportunity for their students to discuss materials further in details. Then, they can also use interactive media to help students visualise by using GeoGebra. They can develop solid geometry instructional package that gives simplicity for students to improve their visual spatial skills.

Suggestion for students, they can learning by themselves by using GeoGebra software if they have difficulties to imagine about the shape of solid geometry objects. They can also learn and discuss difficult materials with their friends.

References

[1] I. Junaedi," Tipe kesalahan mahasiswa dalam menyelesaikan soal-soal geometri analitik berdasar *newman's error analysis,"* Jurnal Kreano, vol 3.2, pp. 125-133, 2012.
[2] NCTM, Principles and standards for school mathematics. Reston, VA: NCTM, 2000.
[3] R. A. Saha, A. F. M. Ayub, R. A. Tarmizi, "The Effects of GeoGebra on Mathematics Achievement: Enlightening Coordinate Geometry Learning," Procedia Social and Behavioral Sciences, vol 8, pp. 686-693, 2010.
[4]T. Tambychik, T. S. M Meerah, Z. Aziz, "Mathematics Skills Difficulties: A Mixture of Intricacies," Procedia Social and Behavioral Sciences, vol VII(C), pp. 171-180, 2010.
[5]E. Zakaria, Ibrahim, & S. M. Maat, "Analysis of students' error in learning of quadratic equations," International Education Studies, vol 3.3, pp. 105-110, 2010.
[6]N. Prakitipong & S. Nakamura, "Analysis of mathematics performance of grade five students in Thailand using newman procedure," Journal of International Cooperation in Education, vol 9.1, pp. 111-122, 2006.
[7] T. Tambychik & T. S. M Meerah, "Students' Difficulties in Mathematics Problem-Solving: What do They Say?," Procedia Social and Behavioral Sciences, vol VIII, pp. 142-151, 2010.
[8] Sugiyono, Metode penelitian pendidikan. Bandung: Alfabeta, 2008.
[9] D. V. Garderen, "Spatial Visualization, Visual Imaginary and Mathematical Problem Solving of Students with Varying Abilities,"Journal of Learning Disabilities, vol 39(6), pp. 496-506, 2006.
[10] K. Yenilmez & O. Kakmaci, "Investigation of the Relationship between the Spatial Visualization Success and Visual/Spatial Intelligence Capabilities of Sixth Grade Students," International Journal of Instruction, vol 8(1), pp. 189-204, 2015.
[11] A. Heinze & K. Reiss, "Mistake-handling Activities in the Mathematics Classroom: Effects of An In-service Teacher Training on Students' Performance in Geometry," Proceedings of the 31st Conference of the International Group for the Psychology of Mathematics Education, vol 3, pp. 9-16, 2007.
[12] H. Unai, E. Jakubowski, D. Corey, "Differences in learning geometry among high and low spatial ability pre-service mathematics teachers,"International Journal of Mathematics Education in Science and Technology, vol40(8), pp. 997-1012, 2009.
[13] G. Kospentaris, S. Vosniadou, S. Kazi, & E. Thanou, "Visual and Analytic Strategies in Geometry," Frontline Learning Research, vol 4(1), pp. 40-57, 2016.
[14] .C. Biber, A. Tuna, S. Korkmaz, "The mistakes and The Misconseptions of The Eight Grade Students on The Subject of Angles," European Journal of Science and Mathematics Education, vol I (2), pp. 50-59, 2013.
[15]M.L. Kennedy, S. Tipps, & A. Johnson, Guiding children's learning of mathematics. New York, NY: Thomson Higher Education, 2008.