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Designing teaching instructions catering students' needs: teaching solid geometry through problem-based learning (PBL)

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Abstract. In a mathematics classroom, students are diverse. They have different learning styles, interests, readiness, paces and abilities. It is challenging to know how each student learns and what learning methods appropriate for him or her. Thus, teachers need to be assisted in developing appropriate instructions based on students' needs. This issue prompted the researchers to find learning with a model that meets the needs of students on the volume of prism topic. The researchers have developed the learning materials on the volume of prism topic using problem-based learning (PBL). The appropriateness of the learning implementation to the students' needs then needs to be analyzed. The study involved 66 eighth graders in a junior high school in Banda Aceh, Indonesia. Data in this study were obtained from students' achievement after the PBL implementation and analyzed using Fisher's discriminant analysis. The finding showed that 50 students were in a successful group and 16 students were considered unsuccessful. This finding implies that the PBL accommodated the needs of the majority of students. Further, identifying characteristics of the two groups is necessary to modify the learning that has been previously developed to meet the needs of the unsuccessful group.

1. Introduction

As teachers, making sure all students learn mathematics well is necessary. To achieve the goal, teachers need to design an instruction that meets students' needs. However, in a mathematics classroom, students are diverse. Every student has different ways of learning, abilities, paces, readiness, and interests. Different students learn well by different learning models. Students will not learn well if teaching style conflicts students' learning style [1]. A shift from teacher-centered to student-centered approach is a recognition that learning should be focusing on students' needs. In a student-centered approach, teachers need to learn how to differentiate instruction [1]. This issue prompted the researchers to find teaching instructions that meet the needs of students on the volume of prism topic and to categorize students based on their achievement after implementing the instructions to examine the group of students who experience success through the learning model.

One of the student-centered learning models that can be used to teach geometry is problem-based learning (PBL). PBL appeared as recognition that students learn by doing and by thinking through problems. Originally, PBL was developed for adults, to train doctors in how to approach and solve medical problems in the real world wherein one case it might be difficult to identify symptoms of a patient, and in another case, a patient might have multiple symptoms [2]. Through PBL, the medical students researched a situation, developed appropriate questions, and produced their own plan to solve the problem. It was found that PBL developed the students' abilities to improve their knowledge and to learn how to deal with the new illnesses. They became "self-directed learners" and used available resources to help them to learn [2,3]. This successful learning then leads PBL adapted to other fields such as mathematics education.

Some researchers have used PBL in teaching mathematics [4-6]. Schettino used PBL to teach geometry. He defines “PBL as an instructional approach where students’ learning and content materials are constructed through the use, facilitation, and experience of contextual problems … in a discussion-based classroom setting where student voice, experience, and prior knowledge are valued” [4]. He believed that PBL allows students to use skills such as communication, collaboration, and technology literacy required by the current curriculum. Through the learning with PBL, he found that students made connections and saw the relationship among the math concepts, had the opportunity to create their own strategies and expressed their ideas. Thus, implementing PBL is one of the ways to meet not only the curriculum demand but also the students' needs.

Another study examined the effect of PBL on the students' performance in learning geometry [6]. The study revealed that students experienced independent learning and developed communication and research skills through PBL. However, some students still struggled in gathering the information in problem-solving so that they ended up with poor decision-making. This study suggests future research on PBL in a more extended period.

Those studies implemented PBL and described how students learned mathematics using PBL, their responses toward the implementation, and the challenges found during the implementation. However, none of the studies [4-6] groups students based on their achievements using Fisher's discriminant analysis after the PBL implementation. Therefore, this present study aims to examine students based on their performances after implementing PBL to investigate which group of students experience success. This will lead teachers in finding out teaching instructions that fit the need of the students. In addition to that, this study will describe the PBL implementation and students’ response toward the implementation.

2. Method

This present study is part of development research on mathematics learning with PBL model on the volume of prism topic. This study focuses on examining the appropriateness of the learning to the students’ needs. The participants were 66 students of grade 8 in a junior high school in Banda Aceh, Indonesia. This study was conducted in two phases. In the first phase, students were given a pre-test about the volume of a prism. Then, in the next session, both classes were taught the volume of a prism using PBL by the same teacher for one meeting. Two days after the class session, they were given a post-test. Students' grades on both tests were collected to see their progress on the topic. Also, data about students' math scores on the previous grade report were collected. Based on their achievement on the topic, the students from both classes were categorized into two groups, a group who was successful and had not, with minimum completeness criteria 65. To do this process, the researchers used discriminant analysis by Fisher method. Discriminant analysis is a statistical technique used for classifying observations, for example, predicting success in academic programs [7]. "Discriminant function analysis produces functions that help define the groups; it distinguishes the first group from others, then the second group from the rest, and so on" [8]. The researchers used SPSS (version 16.0) to get the formula of discriminant analysis. After that, students from each category were interviewed to find out their responses toward the implementation of PBL.

3. Results and discussion

During the first phase, the students were taught using PBL on the topic of prism volume. With PBL, the students were expected to be able to find the volume of a prism in real-life problems. Previously, the students had learned the volume of cubes and rectangular prisms. Using their prior knowledge, the students figured out the volume of triangular prisms. To motivate the students, the teacher showed them an application of the volume of prisms in real life. For example, the teacher showed a picture of a shower tub shape that looks like a prism and asked them how to find the volume of the water in the tub. In this way, the students realized that they needed to know the volume of the prism to be able to find the volume of the water.

In a similar way, the teacher gave students a real-life problem. However, at this time, the students worked in a group to solve the problem. Since PBL focuses students as a center of learning, students need to involve actively by working collaboratively in their groups [3, 5]. Then, to launch the problem, the teacher asked the students what they understood from the problem and what they had not. Also, the students were encouraged to pose questions about the problems to help them in solving the problem and write them all. Examples of student questioning are: What is the shape of the swimming pool? What are the length and the width of the pool? What is the volume of the water? What does it mean by sloping floor in between two parts of the pool? What is the width of each part of the pool? As solving the problem, the students also did some research from the textbook and recalled their previous knowledge. Working in a group allowed them to discuss and learn from others. Interaction among the students helps them to communicate their ideas and move them forward. This is aligned with what Schettino and Ahamad et al. revealed, that students would develop communication skills through PBL [4, 6].

A swimming pool has a dimension 30 m x 10 m with two different depths 3:4. On the surface of the pool, there is a sloping floor between two parts of the pool. If the length of each part is the same, that is, 14,4 m. Find the volume of water if the pool is full.

Figure 1. The problem assigned to students.

While students were working in a group, the teacher assisted them by asking purposeful questions to assess their thinking and to help them think forward. However, the teacher did not tell the students the answers. Instead, the teacher supported students' productive struggle. For example, when a group could not get started, the teacher asked them, "What do you understand from the problem? What information do you know about the problem? Could you please rewrite them?" Also, the teacher encouraged the students to look back at the questions they had posted before. This helped them to recall the information needed for solving the problem.

Students recorded their solutions on a poster then presented their strategies in front of the class. The teacher asked them to compare the solutions found by different groups and discuss it during the whole class discussion. This activity allowed students to clarify their thinking and revealed students' misunderstanding about the volume of prisms. A group of students found the volume of a prism by making a connection to the volume of a rectangular prism. To get the volume of a triangular prism, the students divided the volume of the rectangular prism by two (see Figure 3). Then, when a student showed a misconception, the teacher brought it to the class for further discussion so that other students will not perform the same misconception in the future. For instance, a student incorrectly modeled the problem. She misinterpreted the sentence: "On the surface of the pool, there is a sloping floor in between two parts of the pool" and drew a picture as in Figure 2.

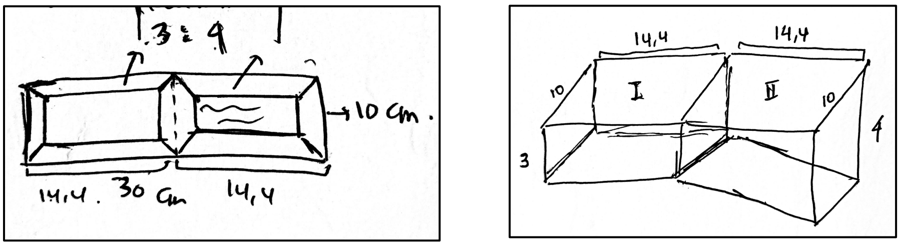

Figure 2. Student misinterpretation of the problem.

Then, the teacher asked a question to the class, "If we model the problem like this (as in Figure 2), how would you use information of the depth 3:4 in the picture? How would you put the numbers in the picture?" Some students reasoned that they could not determine the depth of another part of the pool if the surface is not flat. Some argued that there is a sloping floor between two parts of the pool; thus, the surface of both parts of the pool should be flat. Interestingly, a group of students believed that the volume of water could be varied because the depth of the parts of the pool is 3:4. That means that it could be either 3 m and 4 m, 9 m and 12 m, or 30 m and 40 m. Those will affect the volume of water in the pool. Such a discussion promoted students' reasoning and justification that helped them to understand the concept of the volume of a prism.

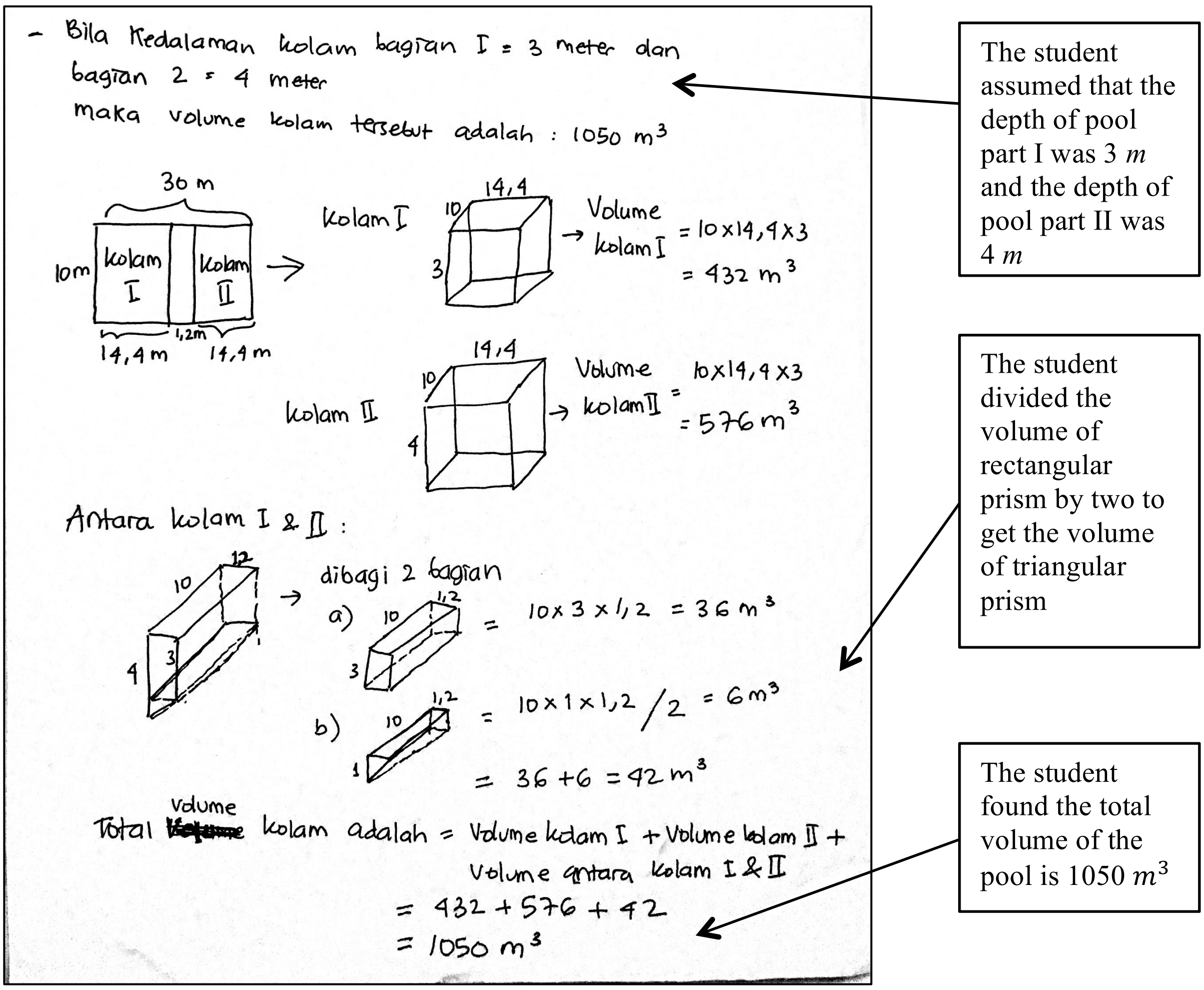

Figure 3. Example of a student's solution.

After learning the volume of a prism, the students were given a post-test in the following session. Then, students' achievements on both pre- and post-tests were examined. The data were normalized using the natural logarithm to minimize the error. By using SPSS software (version 16.0), the Fisher's linear discriminant functions were obtained in the following table.

Table 1. Fisher's linear discriminant functions.

Classification function coefficients		
	Group of students	
	Successful students	Unsuccessful students
Math score	3.463	3.470
Pre-test	.015	-.011
Post-test	.618	.255

Based on the table above, the discriminant functions for the two groups were obtained as follows.

Successful group = $3.463X_1 + 0.015X_2 + 0.618X_3 = 0$
Unsuccessful group = $3.470X_1 - 0.011X_2 + 0.255X_3 = 0$
Where:
X_1 = Math score on previous grade report
X_2 = Pre-test on the volume of prism topic before the class session (phase 1)
X_3 = Post-test on the volume of prism topic after the class session (phase 1)

In SPSS (refer to Table 1), every column to which variables correspond consists of coefficients that form a function for a group. These coefficients are called coefficients of Fisher's linear discriminant functions and could be used directly for group classification. Each coefficient in each formula is used to determine a subject to which group he/she belongs based on the highest score got from the formulas [9]. By referring to the procedure, scores of each student were substituted into the formula to find to which group the student belongs. A student will be in a group that has the highest score. It was found that 50 students belong to a successful group and 16 students were considered unsuccessful. This finding indicates that learning the volume of a prism using PBL met the needs of the 50 students.

When asked about the implementation of PBL, students from the successful group responded positively. They said the learning method used was different from they usually did, and they enjoyed the learning process. A student stated that he liked a whole class discussion because he could share his ideas, which was unusual in a mathematics classroom. As in a study by Ahamad et al., some students felt that they learned better using PBL than the traditional method and they could be independent learners [6]. However, some students from the unsuccessful group did not like discussion implemented in PBL. They found it hard to express what they thought and needed more time to process their thinking. They also were not confident in sharing their thoughts. A student mentioned that she preferred solving problems by herself because she needed to contemplate the problem. When asked "what would you do if you struggle?", she answered that she will ask the teacher and go back to think and solve the problems by herself. Other students still struggled to understand the concept of the volume of a prism and could not identify a prism in the complex solid geometry. Ahamad et al. also found that some students struggled with seeking information and discovery as required in PBL [6]. Students in the unsuccessful group were also asked their preference about the instructions implemented in the classroom. Some of them prefer working in a small group without having a whole class discussion. Some of them like working individually first then discussing with partners to ensure their answers.

These findings suggest that different students have different preferences for learning, paces, and interests. In general, the implementation of PBL accommodated the needs of the majority of the students. That implies the learning materials and instructions met the characteristics of the students. However, 16 students were still considered unsuccessful after the PBL implementation. This finding recommends that the learning with the PBL model on the volume of prism need a modification appropriate to the characteristics of the unsuccessful students. Further identification on the two groups of students is also necessary to design proper instructions for them.

4. Conclusion

Teaching geometry using PBL is one of the promising ways to enhance students' learning. This suggestion was based on the finding that majority of the students were successful through the learning with PBL model. PBL enables students to explore the problem by working in a group and students will be the center of learning. This activity could actively engage students in problem-solving and promote a meaningful discussion between students and teacher. However, some students might be inconvenient to learn geometry through such instructions. Some students learn well by contemplating the problem by themselves and cannot get distracted by others. Another prefers learning by discussion. Those differences lead teachers to find the best teaching instructions for their students and decide what kind of instructions and activities teachers should use in their classroom. Therefore, identifying the needs of the students who do not experience success through PBL is needed to design modified instructions to the learning process.

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