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The challenge-based learning to students' spatial mathematical ability

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Abstract. The low ability of students thinking in geometry requires a new perspective in creating a more challenging and better mathematics learning process. This study aims to improve mathematical spatial ability through challenge-based learning using the Quasi-Experiment Method and Non-equivalent Pretest-Posttest Control Group Design. The instruments used PAM test and spatial thinking ability test. Analysis of quantitative data used t-test, Mann–Whitney U test, and Adjusted Rank Transform, two-way ANOVA. The study conducted at a university in Bandung, Indonesia. It involved 62 prospective *Madrasah Ibtidaiyah* teacher candidates as samples, which categorized into two classes, 32 class B as an experimental class and 30 class A as a control class. The findings show: There is a higher increase in mathematical spatial abilities of students who obtain challenge-based learning than students who obtain expository learning based on the overall student sample and students' initial mathematical knowledge. There was an interaction effect between type aspects (challenge-based learning and expository learning) and initial mathematical knowledge on students' mathematical spatial abilities. Challenge-based learning can facilitate the process of conflict, discovery, social interaction, and the reflective process of students. The material is easy to understand and exciting to learn. Thus, spatial ability is better than expository learning.

1. Introduction

The relevance of life surrounded and shaped by plane and solid geometric forms. Geometry is essential to be studied by prospective teacher students. The proportion of mathematics class at school is 40% contain geometry class. It is beneficial for developing mathematical thinking skills, reasoning, developing spatial intuition in daily life. Mathematical thinking ability used various three-dimensional contexts with different levels of difficulty [1]. Statements and perceptions of cognitive processes that used are transformed, combine, or operate knowledge in the context of the spatial dimension. Furthermore, the primary purpose of learning geometry is enabling students to have a good understanding of spatial concepts and procedures encountered in their life so that they can solve these spatial problems in their real-life situation [1, 2].

Nevertheless, empirical studies on geometry learning and teaching in both Indonesia [3, 4]. These studies show that students' low competence of mathematical spatial visualization is due to some reasons; (1) Students were unable to conceptualize 3D in 2D objects. Data reveal that students perform an error when drawing three-dimension into two-dimension objects or vice versa; (2) lack of creative spatial sensing leading to mistake in spatial meaning; (3) considering spatial pictures as flat where intersecting lines are considered parallel; and (4) constructing a spatial representation in mind, on paper, or using technological devices, two-dimensional into three dimensional objects seen from different points of view without sufficient learning supports.

Actually, the various problems can be proportionally handled and minimized by external factors. One of which is by designing learning materials that can develop students' autonomy in class management, media project making, thinking and doing activities relevant with their environment [5, 6]. Students' perceptions on areas of study will established depending on the tasks or problems that they need to solve. Students do not develop good understanding about something through repetition but through active learning and making by building past experience trough group work or activity. Furthermore, spatial ability is not a geometry ability which is genetically inherited or a given ability but a competence which should be trained through a long social construction [7, 8]. This ability can only be developed when students are involved in empowering learning activities or face the problem in real life experience.

Learn geometry provide students with an attitude or habit of spatial and the relationship between elements and characteristics on plane and solid geometrical. Students have an opportunity and sufficient supporting learning media so they can observe, explore, and find out geometrical principles through informal activities before applying what they have informally learned into their formal learning activities. Students cannot properly differentiate the relationship among elements of spatial objects without the assistance of concrete media, and students who are not equipped with concrete media but rely solely on their visualization ability are prone to misconception. More specifically, students can develop their visualization ability by gathering sufficient information [9]. It means, they already have comprehensive knowledge on the logic of spatial concept and representation supported by relevant learning media.

There are various learning media on developing the mathematical spatial ability to improve their motoric ability or develop their spatial process on their mental images. The exercises like forming origami, utilizing geoboard, making *mekorama*, drawing on a pop-up book, and operating the GeoGebra improve students' metacognitive knowledge. This media easily to understand and exciting for students. The utilization of multimedia GeoGebra as a medium for studying mathematics in challenge-based learning will facilitate students in achieving their learning intentions in the cognitive, affective, and psychomotor. Challenge-based learning on android applications to improve the abilities of students' mathematical representation [10]. Interactive multimedia-based mathematical learning improve mathematical communication skills [11]. The curriculum about spatial ability is required and should accommodate in every geometry class. Indicators of spatial ability in this study are:

1. Ability of imagining and illustrating a geometry object after experiencing rotation, reflection, and dilatation.
2. Ability of deciding a picture object which is suitable with its certain position of series of spatial geometry objects.
3. Ability of predicting accurately a real form at spatial geometry object perceived in the certain perspective.
4. Ability of deciding simple object picture which is stacked to more complex picture.
5. Ability of constructing a model related to spatial geometry object.
6. Ability of drawing and comparing logical relation of spatial form components.

Consequently, the teaching and learning method experiences are exciting to examine. One model which can address students' problems in spatial is Challenge-based learning. This inquiry-based learning stimulates students to learn from their assigned tasks, learning materials, and the project of learning media making by constructing their own divergent and contextually-stimulated problems. In turn, these can stimulate students' challenge them to explore their projects in the classroom. This study elaborates on learning using students' assignments while providing experience for mathematics educators in the involvement in achieving the task to solve the problem and challenges. The education quality constantly transformed as needed by society which involving student potential development [12].

Challenge-based learning syntax are the big idea, essential questions, the challenge, guiding questions, guiding activities, guiding resources, solution, assessment, and publishing [13]. The challenge-based learning, math education acknowledged through stimulating assignments that friction. It is essential that in mathematics, teachers can elevate learning opportunities by involving students in the challenging tasks [14]. Challenge-based learning is a model that stimulating, challenging and interactive. It drives students engaging in reasoning process. The process is developing their creativity and objectivity relevant to their expertise, engagement, psychological, and cognitive advancement. The learning integrated from the thinking process, which requires problem-solving. A learning process is notable. It can stimulate students' impulse and interest with a new output [15, 16]. A documentary video can be used to resolve further comprehension of a concept and multimedia-based learning to reveal new concepts that can decrease cognitive conflict.

Therefore, challenge-based learning considered as learning method which can answer students' needs to work hard and exploit their thinking when facing a problem which contradicts their cognitive structure. The conflict due to different cognitive structure will finally lead to a shift in understanding so that students can develop a new understanding or knowledge [17].

In the context, mathematical knowledge discovered by people through stimulating assignments that cause challenges [18]. It can formulate and develop knowledge through tasks, not solely from a teacher's instruction due to the teacher is not the only source of knowledge. Individual knowledge depends on social construction from peers or teachers. They can reconstruct new learning ideas to overcome new challenges. Therefore, the exercises are required to meet the challenges that resulted from the problem.

In addition to the abovementioned empirical evidence, another factor also contributes to spatial ability that is mathematical entry knowledge, which is categorized into three levels: smart, adequate, and low. The different categories emerge as the result of various smart school backgrounds (Islamic, natural science, social science, language, and vocational smart school). It then causes varying levels of students' mathematical entry knowledge. The purpose of prior mathematical knowledge is to observe the similarity between the experiment group and the control group that considerably homogeneous. Moreover, the categorization of prior mathematical knowledge examines diverse approaches towards students in each category during learning.

Aim of the research investigation are:

1. The influence of challenge-based learning to the improvement of students' mathematical spatial abilities smarter than that of students exposed to expository learning as seen from overall students
2. The influence of challenge-based learning to the improvement of students' mathematical spatial. Abilities smarter than that of students exposed to expository learning as seen from prior mathematical level of knowledge (smart, adequate, low).
3. The influence interaction between types of and types of prior mathematical knowledge levels (smart, adequate, and low) towards students' spatial ability in mathematics.

2. Method

This research is experimental with a sample of 62 prospective elementary school teacher candidates for a university in Bandung, Indonesia, consisting of two homogeneous classes. 32 people in class B as an experimental class with challenge-based learning. 30 people of class a conventional learning as a control class. This study uses a pre and posttest control group design. Meanwhile, the instrument used was a spatial ability test and a student's initial mathematical knowledge test. Analysis of quantitative data used the Independent t-test, Mann–Whitney U test, and Adjusted Rank Transform, two-way ANAVA test.

3. Results and Discussion

Students experienced epistemological obstacle analysis in explaining a pattern to identify the relationship between spatial representation and construction reasoning complex drawing objects in geometry. Spatial abilities are cognitive processes that achieve specific epistemological functions in geometry, alongside construction, and reasoning [1, 19]. Refer to observations, students do not retain the mathematical concepts that have been learned, short and instant learning won't last long in students' memory. They must examine the problem according to their experience.

The research began by conducting a scientific initial knowledge test for the two groups to distribute students' initial mathematical abilities at the smart, adequate, and low levels. The placement results indicate that the average initial mathematical knowledge of students was adequate. Based on pre-test statistics before the study, the spatial ability of students from the two groups was relatively different, the mean pre-test of the experimental group was 13.29, and the control group was 13.57. The mean pre-test score indicates that the initial spatial ability of students was low.

After challenge-based learning, there was an increase in the average of students' mathematical spatial abilities. On average, the overall post-test scores of the experimental group students had a mean of 74.34 and the control group 64.43. This states that the average post-test score of the mathematical spatial ability of experimental group students both overall and based on the PAM category (smart, sufficient, weak) had smarter diversity than students of the control group.

The difference in spatial ability improvement in the two groups was known through normalized data-gain. The descriptive normalized gain for spatial ability in Figure 1.

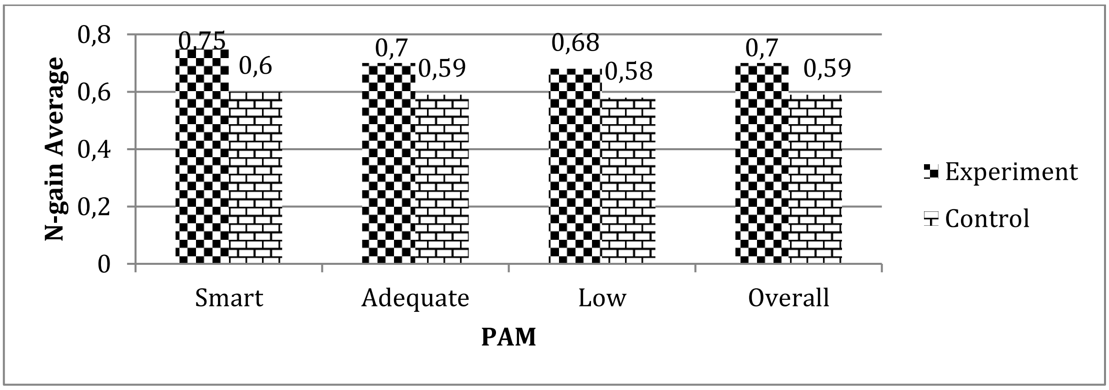

Figure 1. The average value of <g> the spatial ability of the experiment and the control group

The average <g> of the entire experimental group was 0.70, including the smart category, smarter than the <g> control group of 0.59 is in the moderate category. Based on PAM, the experimental groups averaged <g> in sequence: (0.75; 0.70; 0.68). Early mathematical knowledge of smart and adequate is in the smart category. While, the low level is in the adequate category and smarter than the control group with the average <g> (0.60; 0.59; 0.58), which belongs to the adequate category. The difference in improvement indicates that challenge-based learning provides better contributions from expository learning to improve students' mathematical spatial abilities. Challenge-based learning provides the knowledge needed to solve problems, involving all forms of challenges from the tasks given to construct knowledge [20]. It's needed to solve problems and develop students' mindset and mental skills.

The pretest difference in the spatial ability of the experimental group and the control group. If the value of sig (1-tailed) 0.973> α of 0.05, then H0 is accepted, there is no difference in the spatial ability of students in the experimental group and the control group. Before the material was studied, the initial mathematical spatial ability of the experimental group and control group students was statistically identical.

There was a difference in the ability of the two groups to improve through the spatial difference <g> of the experimental group and the control group Sig (1-tailed) value of 0.000 less than 0.05, mean H0 rejected. It states that the increased mathematical spatial ability of students who take learning challenge-based learning is smarter than students who take expository learning.

The difference test of mathematical spatial ability based on initial mathematical knowledge of smart, adequate, and low levels, respectively, has Sig values (0.002 and 0.000 and 0.005) smaller than 0.05, Ho rejected. This shows an increase in the spatial ability of the experimental group students smarter than the control group students. The difference in this increase indicates that learning challenge-based learning contributes better than expository learning, in improving spatial ability based on initial mathematical knowledge at the smart, adequate, and low levels.

Interaction Test between challenge-based learning and expository learning, as well as initial mathematical knowledge, has a significant influence on spatial ability with Sig. (0.000) smaller than 0.05. The interaction test of the level of mathematical initial knowledge and learning of spatial ability states that the value of Sig. (0.007) is smaller than 0.05, so it denies Ho. There is an influence of the interaction of the relationship between the type of challenge-based learning and expository learning with the student's initial mathematical knowledge (smart, adequate, low) to the spatial ability of students. Challenge-based learning builds knowledge through assignments and not only passive learning [18, 21]. The lessons to make students actively learn by applying concepts based on content, context, activities, and objectives while implementing the learning process [22-24]. Susilawati [21] revealed that challenge-based learning could improve meaningful thinking. Reasons and types of thinking that involve solving problems with a variety of solution strategies, and various logical solutions, formulating conclusions, dealing with the algorithmic process, and making decisions using meaningful and practical skills in the context of the assignment.

4. Conclusion

Challenge-based learning facilitates conflict processes, discovery processes, social interaction processes, and student reflective processes to improve students' mathematical spatial abilities better than expository learning, while the material is easily understood and exciting. Based on students' initial mathematical knowledge, challenge-based learning affects the improvement of students' mathematical spatial abilities. There is an influence of interaction between learning types (challenge-based learning and expository) and mathematical prior knowledge levels (smart, adequate, and low) on students 'mathematical spatial ability

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References

[1] Susilawati W, Suryadi D, and Dahlan J A 2017 *International Electronic Journal of Mathematics Education* **12** 155-166.
[2] Lappan G, Fey J, Fitsgerald F S, and Phillips E 2002 *Getting to know connected mathematics: An implementation guide* (New Jersey: Prentice Hall).
[3] Ives D L 2003 The development of seventh graders' conceptual understanding of geometry and spatial visualization abilities using mathematical representations with dynamic models *Dissertation* (Montclair: Montclair State University).
[4] Risma D A, Putri R I I, and Hartono Y 2013 On developing students' spatial visualisation ability *International Education Studies* **6** 1-12.
[5] Susilawati W, Karyadinata R, and Sugilar H 2019 Cognitive conflict strategy to the improvement of students' lateral mathematical thinking ability *Journal of Physics: Conference Series* **1175** 012174.
[6] Nohda N 2010 *Proceedings of the PME-24 Conference* (eds. T. Nakahara & M. Koyama) **1** 39-53. (Hiroshima: Hiroshima University).
[7] Ben-Chaim D, Lappan G, and Houang R T 2008 *American Educational Research Journal* **25** 51-71.
[8] Nemeth B 2007 *Annales mathematicae et informaticae* **34** 123-128.
[9] Downs R M 2006 *Learning to think spatially* (Washington: The National Academic Press).

[10] Jihad A, Susilawati W, and Sobarningsih N 2019 Improving mathematical understanding ability student through study of mobile learning mathematics base on the Android *IOP Conference Series: Materials Science and Engineering* **434** 012008.
[11] Susilawati W, Maryono I, and Maimunah S 2019 *IOP Conference Series: Materials Science and Engineering* **434** 012011.
[12] Shaidullina A R, Evsyukova N Y, Mikhailov V A, Gazizova F S, Masalimova A R, Khairullina E R, and Galimzyanova I I 2015 *Mediterranean Journal of Social Sciences* **6** 202-208.
[13] Johnson L F, Smith R S, Smyte J T, and Varon R K 2009 *Challenge-based learning: An approach for our time* (Austin, Texas: The New Media Consortium).
[14] Diezmann C M 2005 *Australasian Journal of Gifted Education* **14** 50-57.
[15] Baddock M and Bucat R 2008 *International Journal of Science Education* **30** 1115-1128.
[16] Lam S, Cheng R, and Ma W K 2009 *International Journal of the Learning Sciences* **37** 565-578.
[17] Lee G, Kwon J, Park S S, Kim J W, Kwon H G, and Park H K 2003 *Journal of Research in Science Teaching* **40** 585-603.
[18] Maron A I 2016 *IEJME International Electronic Journal of Mathematics Education* **11** 3339-3350.
[19] Duval R 1998 *Geometry from a cognitive point of view* (Dordrecht: Kluwer Academic).
[20] Masalimova A R and Sabirova L L 2014 *American Journal of Applied Sciences* **11** 1054-1058.
[21] Susilawati W 2017 Pengaruh pembelajaran berbasis tantangan dengan strategi konflik kognitif terhadap peningkatan kemampuan visualisasi spasial, berpikir lateral dan kegigihan matematis mahasiswa *Unpublished Dissertation* (Bandung: Universitas Pendidikan Indonesia).
[22] Muhtadi D, *et al.* 2017 Sundanese Ethnomathematics: Mathematical Activities in Estimating, Measuring, and Making Patterns *Journal on Mathematics Education* **8** 185-198.
[23] Widodo S A, *et al.* 2018 Teaching materials of algebraic equation *Journal of Physics: Conference Series* **943** 012017.
[24] Ahamad S N S H, *et al.* 2018 Implementation of problem-based learning in geometry lessons *Journal of Physics: Conference Series* **943** 012008.