Photography activities for developing students’ spatial orientation and spatial visualization

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Abstract. Spatial orientation and spatial visualization are the foundation of students’ spatial ability. They assist students’ performance in learning mathematics, especially geometry. Considering its importance, the present study aims to design activities to help young learners developing their spatial orientation and spatial visualization ability. Photography activity was chosen as the context of the activity to guide and support the students. This is a design research study consisting of three phases: 1) preparation and designing 2) teaching experiment, and 3) retrospective analysis. The data is collected by tests and interview and qualitatively analyzed. We developed two photography activities to be tested. In the teaching experiments, 30 students of SD Laboratorium UNESA, Surabaya were involved. The results showed that the activities supported the development of students’ spatial orientation and spatial visualization indicated by students’ learning progresses, answers, and strategies when they solved the problems in the activities.

1. Introduction

Spatial ability is widely known to be positively related to student’s performance in learning mathematics [1, 2, 3, 4]. Many also have confirmed this positive correlation between spatial ability and achievements in mathematics for both young learner and also higher level students [3, 5]. Considering its importance, we must pay more attention to it so that students can develop their spatial ability maximally.

According to Hendroanto et al., spatial ability is related to student’s mental ability in manipulating, understanding, or interpreting information related to the use of space [6]. Spatial ability consists of two major aspects that determine student’s spatial ability [7]. These two aspects are spatial orientation and spatial visualization. Spatial orientation is about how good student’s to not get confused if the different perspective of certain objects presented [8]. Based on this definition, it suggests that spatial orientation do not need mental movements or imagery manipulations. On the other hand, spatial visualization is more about mental movements and manipulations of mental images [7, 9]. For instance, students create mental images of a cube and the rotate them or even construct its net in mind. If students have good score on these two aspects of spatial ability than it can be concluded that the students have a good spatial ability. Therefore, all efforts in developing student’s spatial ability shall focus on the development of student’s spatial orientation and spatial visualization.
Some studies have tried to develop student’s spatial ability through creative activities and learning such as the study of Risma et al. and Revina et al. [10, 11]. The result showed signs of development of student’s spatial ability. In the study, they used physical objects and asked students to observe them by looking and drawing its views from many different perspectives. Therefore, to support student’s spatial ability, activities involving physical objects are better than having theoretical and passive activities. Furthermore, the use of many different perspectives of an object also will trigger student’s development of spatial orientation and spatial visualization.

In the explanation above, developing spatial orientation and spatial visualization requires a good activity in which it involves the use of physical objects and different perspectives or views. One of the activities that have all these requirements is photography activity. Photography is an activity of capturing moments, pictures of objects, or sceneries by using tools as a camera [12]. This activity always involves physical objects to capture and perspective in order to get a good result. In addition, photography nowadays becomes the most popular activity in the world as the technological advances provide people with gadget like compact cameras, smartphones, or tablets. These gadgets have a camera as their main feature to take pictures. Almost every people take selfish every day and post them on their social media. Hence, students nowadays are really familiar with photography activities. This familiarity can be an advantage for designing a learning activity.

The current study aims to design learning activities involving spatial orientation and spatial visualization based on the context of photography activity to support the development of student’s spatial ability. In addition, the result is also meant to contribute to the local instruction theory of developing student’s spatial ability. The design is based on the theory of Realistic Mathematics Education (abbreviated as RME) which has five tenets. They are the use of context, the use of model, the use of students’ contribution, students’ interactivity, and intertwinement [13, 14, 15].

2. Method
In order to achieve the aim, this study uses design research as the research approach. There are three advantages of using design research to design learning activities. First, design research enables the researcher to develop both activities and instruction theory at the same time [16]. Second, design research has a direct link between theory and its application [17]. Third, design research gives the researcher a possibility to have a deep analysis of student thinking [18]. In the other words, design research makes researcher’s mind and student’s mind into one. Therefore, it enables the researcher to understand further students thinking, learning, and their development.

There are three phases of the study: preparation and designing, teaching experiment, and retrospective analysis [16, 18, 19]. A series of activities is developed in the preparation and designing phase. In addition, an initial Hypothetical Learning Trajectory is developed. In the teaching experiment, two cycles of implementation are conducted involving 30 second-grade elementary students of SD Laboratorium UNESA, Surabaya. The first cycle involves 6 students as a pilot experiment and the second involves 24 students and 1 homeroom teacher. The first and the second cycle were conducted in March and April 2014. Data collection uses three sources from recorded classroom observations, student’s written works, unstructured interviews, and the result of students’ pretest and posttest. These data are analyzed qualitatively to support one another. To ensure validity and reliability of data collection, all materials are consulted with 5 experts of RME.
3. Result and discussion
There are three phases in this study from designing process until teaching experiment phase. The
discussion of each phases are discussed in detail below.
3.1 Preparation and designing
To begin the process of developing the activities, an initial Hypothetical learning trajectory (HLT) and
initial tasks were designed as can be seen in Table 1. Afterwards, three activities were design based on the
photography activity and the tenets of RME. The first lesson, playing with the camera part 1, aims to give
students experiences of the spatial orientation. This is also a preliminary activity to do mental movements
and creating mental images. The second activity is called playing with the camera part 2. Students were
asked to investigate photos of object from many different sides to assist student’s ability to create mental
images. The last activity is a drawing activity based on the context of reporting on newly discovered
temples. This activity is to develop spatial visualization ability and to help students moving from using
physical objects into using its distant representations.

Table 1. Initial design of the activities

| Task               | Activity                                   | Hypothesized Results                                                   |
|--------------------|--------------------------------------------|------------------------------------------------------------------------|
| Spatial orientation task | Observing physical objects                  | - Students will develop initial concept of spatial orientation and visualization
|                    | Finding the position of given standard views of 3D objects | - Students will develop spatial orientation ability by investigating the position of standard views.
|                    |                                            | - Students will be familiar with 3D objects.                            |
| Spatial visualization task | Drawing standard views of 3D objects         | - Students will develop spatial visualization by drawing the standard views from given object. |

3.2 Teaching experiment
Two teaching experiments were conducted in this phase. First, involving 6 students in two small groups in
order to test the initial HLT and the activities whether it works or not. The findings of the first cycle are
published in the SEA DR Conference, Palembang in 2015. In first and second activity, students
experienced and developed spatial orientation indicated by their developing strategies to solve the
problems in the activity. Moreover, students were also able to differentiate correct photos from wrong
photos in the second activity. Students also slowly worked without the use of camera to view the object.
This shows a progress in their mental movements and images. In lesson 3, students’ strategies to identify
the view slowly change into work without building block indicating that they performed mental
movements based on distant representation of the objects. However, the students failed to perform this
ability in the posttest. Therefore, we conclude that more bridging activities are needed to help students
moving from concrete objects to representations.

Based on the result in cycle 1, the activities were revised and redesign to further help students
developing their spatial ability. The initial HLT was also revised to include students’ progress in cycle 1.
Afterwards, the activities were implemented in a mathematics class consisting of 24 second-grade students
and 1 homeroom teacher. All the activities were done in small groups of 4 or 5 students. The result of
cycle 2 is discussed in details below.
Activity 1: Playing with the camera part 1

There are three problems presented in this activity. First, students have to determine visible buildings viewed from many different perspectives by using a model of camera. Second, students describe in words the position of building in the photo. Third, students have to find positions where they could capture two, three, or all the buildings. During the discussion, students used both a model of camera and digital camera to help them looking the buildings. How the buildings set on the table can be seen in Figure 1. To investigate them, students moved around the table and used the camera model to see the building as if they took pictures of them from each position. On the other hand, some groups preferred to use the digital camera to capture the view of the buildings. But, most groups agreed that using the camera model was easier. To describe the position of each building in the second activity, students used their body orientation such as “on my right”, “on my left”, or “in the back since I cannot see”. They did not use cardinal directions like “on the north”, “west”, or “east”. At this level, students really need the camera to help them visualizing the images. Without the camera, they confused to differentiate the view from the bird eye angle from standard view.

![Figure 1. Model of buildings and students’ investigations](image)

Activity 2: Playing with the camera part 2

In the second activity, students were given a problem of finding the original position where some certain photo being taken. There were 12 photographs to investigate, but among these 12 photos, there were 4 misfit photos. Therefore, students have to be careful in order to pick the correct photos and find their position. At the beginning, the teacher gave each group objects in the photo, camera models and a digital camera. However, during the investigation, digital camera was not used as it was for discussion session to confirm their answers. Students’ strategy to find the position of the photos, mostly were moving around the objects while holding the photo. They looked for a match or similarity between what they saw on the photo and the view of the real object in front of them. At first, all students used the camera model to see the object. After several photos, they began to stop using the camera model and directly see the object from bird eye view. To distinguish the wrong photos, students firstly looked for their positions by moving around. If they did not find a similarity between the photos and the view, they would consider the photos wrong. On the other hand, some of them found the wrong photos by identifying the difference between the photos and the object from a certain perspective. One of the examples is in Figure 2 where students points a part of the object on the photo and wrote “terbalik” or in English it means “reversed”.

![Figure 2. Example of distinguishing wrong photos](image)
Activity 3: Reporting new temples
There were two problems about drawing standard views in the third activity. The first problem is about drawing standard views of a temple constructed by students using exactly 8 cubes. In the second problem, the students were asked to determine and draw the standard views of an object in a photo as can be seen in Figure 3. In the investigation, some students used the camera model to guide their drawing while the others did not use it. Some students drew the standard views of their temple like the view from bird eye perspective. They confused to imagine the views of the object to draw. To help them, the teacher asked the students to use camera model and compare their drawing with the view from the camera. By doing this, they realized their mistakes and began to perceive standard view of the object from a correct angle or stand point. One of the examples for the first problem in activity 3 is in Figure 3.

To do drawing in the second problem, students built the object by using building blocks so that they can see directly from each position. However, some confused to count the number of the blocks needed to build the object because the underneath parts were not visible in the photo. Based on the observation, students drew the object’s standard views by seeing the model they built from desired positions and then they compared the view to the view of the object in the photo. After getting the image of the standard views, they drew the views slowly from one cube to another until the views were complete.
3.3 Retrospective analysis

Based on the description of the teaching experiment, several points about student’s spatial ability can be identified. Before describing student’s development during the activities, we have to come back to what spatial ability is. As mentioned in the introduction, spatial ability is determined by two major aspects. They are spatial orientation and spatial visualization [7]. Thus, to determine student’s development of their spatial ability, one must show the progress of student’s spatial orientation and spatial visualization. Therefore, in this retrospective analysis, the discussion is focused only on student's spatial orientation and spatial visualization.

In activity 1, students moved around the table and used the camera model to see the building as if they took pictures of them from each position and to describe position, they used terms like “on my right”, “on my left”, or “in the back since I cannot see”. Students really need the camera to help them visualizing the images. Without the camera, they confused to differentiate the view from the bird eye angle from standard view. This activity helps students experience early concept of spatial orientation and spatial visualization. The camera model indeed guides them to get the view of the object. Without the camera, they lost to bird eye images. In the second activity, they develop further by beginning to work without the camera and they can directly identify the views to solve the problem. This indicates that students had been able to visualize the images just by looking from the bird eye perspective. Thus, students develop basic spatial visualization ability because they manipulate the images of the object in their mind and visualize the standard view. Misfit Photos also helps students to develop their spatial orientation as they identify the views of the objects from different perspectives in the activity. Some students demonstrate that they make relation they got from photos and the object which suggest a development of spatial orientation. According McGee, spatial orientation ability means the ability to understand and operate relationships of different information in space with respect to the observer’s position [7, 8].

In the last activity, the model bridge students to get pass their problem of visualizing the views of an object in a representation or a photo. This means concrete objects became a shortcut for the students to imagine the object in the photo. By looking the concrete object, they got the presence of the objects, explain and reason their drawing just by looking the photos. Slowly, students develop mental movements by imagining their strategy of moving around in the first activity. This can be proved by comparing the result of their pretest and posttest.
Prior to the teaching experiments, students attended pretest to have an insight of their initial spatial ability. Related to the students’ spatial orientation, they were asked to find the position where given photos were captured. The result showed that only 7 out of 24 answered correctly. These 7 students were known to be high achievers in the class. This result suggested that students have low spatial orientation ability because they got confuse when the perspective was changed [8]. On the other hand, regarding students’ spatial visualization, they were asked to draw standard views of a given object in a photo. One of the most common answers of this problem is in Figure 5. The figure shows that students could not visualize the view of the objects which suggest they have poor ability to do mental manipulation of the objects.

![Figure 5. Students’ answers for one of the problem in the pretest](image)

The results in the pretest are very different from the posttest as there were 15 students answered correctly the first problem. Meanwhile, there were 19 students drawing correctly the second problem. We must emphasize that during the investigation in the third activity, students were able to draw standard views by using concrete model the built as guidance. On contrary, in the posttest, they were not provided with such a thing. This means students in the posttest shows an ability to determine the object’s views without the use of model. This finding suggests that they performed mental movement by imagining the model in their mind. Table 2 illustrates the summary version of the findings of student’s development in each activity.

| Task                        | Activity                                      | Results                                                                 |
|-----------------------------|-----------------------------------------------|------------------------------------------------------------------------|
| Spatial orientation task    | Observing physical objects                    | - Preliminary experiences of spatial orientation and spatial visualization  |
|                             |                                               | - Preliminary experiences of mental movement and creating mental images  |
|                             | Finding the position of given standard views  | - Supporting students spatial orientation                              |
|                             | of 3D objects                                 | - Preliminary support for spatial visualization                         |
|                             |                                               | - Preliminary experiences of mental movement and creating mental images |
| Spatial visualization task  | Drawing standard views of 3D objects           | - Supporting students spatial visualization                             |
|                             |                                               | - Supporting students’ ability to do mental movement and create mental images |
4. Conclusion

Based on the description of the result and the retrospective analysis, photography activities indeed support the development of students’ spatial ability. During the investigation in the activities, students shows a progress of their developing ability in spatial orientation and spatial visualization. This progress can be looked in their performance during the activities of when they solved problems of investigating photographs.

For instance, observing objects from different positions in activity 1 and finding the positions of photos in activity 2 greatly contribute to develop student’s spatial orientation ability. Moreover, the activities gave students preliminary experiences about mental images and mental movements. Drawing standard views in activity 3 develop student’s spatial visualization ability. The activities helped them visualizing the views and working with the objects’ representations.

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