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Abstract. Pursuing capabilities in the STEM (Science, Technology, Mathematics, and Engineering) needs spatial skills. However, previous studies indicated that students seem to have obstacles in learning mathematics because of low spatial skills. One of the strategies to enhance students’ spatial skills is providing various learning resources. This study aimed at developing HLT using various learning resources to support students’ learning of geometry. This study used design research method consisting of three phases namely preparation, teaching experiment, and retrospective analysis. Two Year 8 mathematics teachers from two public schools in Banda Aceh participated as the subjects of this study. This study focused on describing the differences and similarities of the intended and enacted learning performed by the teachers in the teaching experiment phase. Data collected from the video recording, field observation, and interviews were analysed descriptively. The result revealed that the two teachers mostly used the learning resources as intended in the HLT, even though there were some differences related to the time allocation, the flow of teachers’ instruction, the way of engaging students, and the use of the online game. It is indicated that the HLT developed could be implemented with some adjustment taken into account the differences.

1. Introduction

As one of the topics in mathematics, considerable attention has been put into geometry, in particular, spatial visualization [1]. Spatial skill is also called spatial reasoning, spatial ability, spatial intelligence or spatiality. This is defined as “the ability to recognize and (mentally) manipulate the spatial properties of objects and the spatial relations among objects” [2]. Mulligan [2] also argued that the skill may be established in the early years of students and continued to be developed over time, however, it will be deteriorated without enough support and challenges. Spatial skills, as part of geometry, should not be taught as being constraint to naming shapes, determining the number of sides and faces and the basic static 2D and 3D shapes, instead, it should engage students’ spatial reasoning using a dynamic approach to reveal students’ potential beyond the written curriculum [2,3].

Spatial thinking plays a vital role as the basis for developing geometry in the early years of learning, and spatial reasoning is often associated with mathematics achievement [4]. Research concerning spatial reasoning has also reported that such skill does not only contribute to the successful mathematics learning at schools but also mastery of the topics across disciplines as well as assisting students in their future careers associated with STEM (Science, Technology, Engineering, and Mathematics) [2,5,6]. However, this matter was considered a little importance despite its essential role in developing mathematical ability [2,7]. Some efforts have been put up for promoting the significance of spatial thinking or reasoning, yet the actual action is still inadequate [2]. It is possible to develop students' spatial thinking, and in fact, it is required to be delivered across all level at schools [8].
However, students seem to have obstacles in learning about spatial geometric as indicated by low spatial skills [1,9] and the spatial difficulty may intervene in the difficulty of other topics [10]. This indicates that new strategies and approaches are needed for enhancing students’ understanding of spatial and spatial skills. One of the strategies to be applied is providing various learning resources for easing students in grasping the concepts.

Resources are an integral part of learning and studies seeking for the effective use of learning resources have been conducted for decades. Teaching and learning at schools are likely to be more effective when the resources are sufficient which in turn can enhance students’ performance [11]. Learning resources refer to the sources used for learning activities conducted in the classroom including spoken, written or visual texts [12].

The establishment of the spatial skills in the learning process will be made possible through the appropriate resources and its utilisation in the classroom. The utilisation of the learning resources in the classroom is often modified in the classroom depending on the classroom situation and the teacher's decision. The intended use of a resource may be similar or different to the use of learning resources enacted in the classroom. The definition of intended and enacted learning in this study may be formulated from the definition of the enacted and implemented curriculum proposed by Kaur et al. [13]. The intended learning refers to the plan of what the learning resources to be used and how she/he plan to use it in spatial learning, while enacted learning refers to what learning resources used in the classroom and how both teacher and students use them. The enacted learning is based on teacher decision concerning the implementation of the planned resources in the lesson and is indicated by the engagement between students and teacher as well as the resources in the classroom [3].

The examination of the use of learning resources is remained to be important as the intended use of the resources are often different from its actual use in the classroom (enacted learning). Therefore, this article will examine and discuss the use of learning resources by teachers in spatial learning, in particular, examining the difference and similarities of the intended and enacted learning.

2. Method
The present study described the implementation of a Hypothetical Learning Trajectory (HLT) for the learning of cube and cuboid developed by Utami [14]. The HLT was developed based on Design Research approach [15] consisting of three stages namely 1) preparation, 2) teaching experiment, and 3) retrospective analysis. The designed HLT had been through two cycles; each cycle consisted of the three stages of design research. The HLT on the first cycle was called HLT 1 while that on the second cycle was called HLT 2.

The developed HLT consists of learning route of instructional activities along with description and rationale for each activity [16]. The learning route was designed for four sessions; each session took 120 minutes. However, this article will only discuss the third session of the teaching experiment phase of the second cycle.

The teaching experiment phase was conducted in two public schools in Banda Aceh, Aceh, Indonesia. The participants of this study were two Year 8 Mathematics teachers (T1 and T2) and their students. T1 was a teacher in a public school in West Banda Aceh while T2 worked in a public school in East Banda Aceh. Both teachers are potential female teachers from two different favourite schools with a lot of experiences in teaching mathematics. The teachers also have participated in some previous research; thus, they do not need many assistances in teaching as expected by the researchers.

As stated before, the purpose of this study is to examine teachers’ use of learning resources. The teachers’ enacted activities in using the learning resources were compared to the intended activities presented in the lesson plan; the lesson plan derived from the HLT 2. The data for this study were collected from the developed lesson plan designed by Utami [14], and videos were taken during the teaching experiment. The lesson plan provided instructions on how to use the learning resources along with the examples of questions and possible explanations or answers.
3. Result and discussion

The following section describes the results of our examination of the spatial learning process. We first describe the intended lesson based on the data collected. Furthermore, we describe our analysis of the enacted lesson taught by the two teachers.

3.1. Intended lesson on the HLT 2

Considering the Indonesian National Curriculum [17], a set of the lesson was designed to present opportunities for Year 8 students to learn about the surface area and volume of cubes and cuboids. Considering the recent reports on the teaching and learning geometry [4,18], the designed lesson was embedded with spatial activities and was enriched with the use of 3D objects and computer technology (see Table 1). The designed lesson plans provided the detailed scripts, included examples of questions for teachers, and possible explanations or answers of mathematical content. Furthermore, the lesson plans also include worksheets and their possible answers.

| Learning objectives                                      | Activities                                                                 | Learning resources                      |
|----------------------------------------------------------|---------------------------------------------------------------------------|-----------------------------------------|
| Finding the volume of a cuboid                           | Solving routine problems                                                  | Student worksheet 3A                    |
| Finding the relation between the surface area and volume of cuboid by comparing its layout (horizontal or vertical) | - Determine whether the volume of the cuboid formed from four cardboards placed horizontally equals to that formed vertically |
|                                                          | - Checking students’ answer by filling rice into cuboids formed from bridge cards |
| Solving problems related to the surface area and volume of 3D objects | - Visualizing a 3D object (formed from some unit cubes) into the 2D drawing: drawing how the 3D object seen from the front and the right side. |
|                                                          | - Visualizing a 3D object into the 2D drawing: using "game point out the view." |
|                                                          | - Finding the surface area and volume based on its point of view           |

Table 1. Lesson design for the third session of teaching experiment.

The HLT 2 for the third session consisted of three main tasks, namely: 1) finding the volume of cubes and cuboids, 2) working on the four bridge cards, and 3) examining the different perspective of cubes stack. The first task was designed to bridge students’ previous knowledge while the others designed to promote students’ spatial skills as they learn about the surface area and volume of cubes and cuboids. A brief description of each task is presented in the following section.

Task 1: Finding the volume of cube and cuboid. With the introduction of the lesson, based on the lesson plan, the teacher was required to recall students’ previous knowledge about the volume of cubes and cuboids through related routine problems. The developed lesson plan provided some example of questions should be asked by the teacher such as “Previously, you have studied the volume of a cube. What is the formula to find the volume?” After the class discussion, the teacher should distribute worksheet 3A of the routine problem; the worksheet is presented in Figure 1. The teacher should ask students to solve the problems in their groups. Then, through the classroom discussion, the teacher should ensure the students understand the difference between the capacity and volume.
Task 2: Working on the four bridge cards arranged vertically and horizontally. The next activity was intended to help students understand the relationship between the surface area and volume of cuboid by comparing its layout. Before giving worksheet about cuboids from bridge cards, the teacher should present a preliminary question using cardboards as media, “Suppose these four cardboards are arranged vertically and horizontally (while showing a glimpse of the arrangement), what is the volume? Is it the same or different? Explain!”. After waiting for some responses from the students, the teacher should experiment with filling rice into four bridge cards arranged vertically and horizontally. Some question such as “What did you find?” and “What can you conclude?” were intended to help students realize that the different layout means the different surface area and different volume. Next, the students instructed to work in groups to solve problems in the worksheet 3B (Figure 2a) to prove mathematically why the volumes can be different. Figure 2b presents one of the expected answers to the second question presented in the lesson plan.

![Figure 1](image1.png)

**Figure 1.** Problems for the first task.

![Figure 2](image2.png)

**Figure 2.** Bridge cards arrangement problems.
Task 3: Examining different perspective of cubes stack. The next activity used the stack of cubes as media (Figure 3). At first, the teacher was expected to explain how to visualize the front and the right side view of the stack using the real cubes, and the students were asked to draw it on A2 paper. After some exercises using the real cubes, a more abstract media (an online game) was used in the next activity. At first, in the HLT 1, the game proposed by the researchers was game of Isometric drawing tool. However, based on the retrospective analysis of HLT 1, the game was changed to a game of Point out the view (Figure 4). This online game can be accessed from the website of [19]. The lesson plan provided instructions on how to play the game as well as how to use the game. After providing an example of how to play the game as instructed on the lesson plan, the teacher should ask some students to play the game in front of the class. The purpose of playing this game was to examine the student's understanding of spatial orientation and visualisation.

Figure 3. Example of cubes arrangement for the 3rd task.  
Figure 4. Online game for the 4th task.

The last activity in session 3 was solving worksheet 3C about determining the surface area and volume of the stack of cubes. The worksheet provided the 2D picture of the front and the right side view of the cubes stack. The students were expected to solve the problems such as “determining the minimum and the maximum number of cubes needed to form the object,” “finding how much paint needed to cover the object except its floor” and finally the students were expected to conclude the relationship between the surface area and volume.

3.2. Differences between the intended and the enacted lesson
In line with previous studies [20,21], teachers could react differently toward the same textbook/task. In this study, the teachers’ performances that were different from the HLT included the time allocation (by T1 and T2); the flow of teacher’s instructions during the class discussion (T1 and T2); the use of contextual problem for differentiating the capacity and volume (T2); students’ engagement in the class discussion (T1 and T2); and the use of online game (T2).

The lesson plan derived from HLT 2 provided the time allocation for each activity. There was a significant difference in time allocation for the activity of solving the worksheet. Students of T1 (from now on SoT1) exceeded the time allocation for working on worksheet 3A and 3B by 7 minutes and 11 minutes respectively. On the other hand, students of T2 (hereinafter SoT2) exceeded the time for working on worksheet 3A and 3B by 2 minutes and 13 minutes respectively, while the time spent for working on worksheet 3C was 2 minutes less than what intended. Related to the worksheet 3A, the time spent by SoT1 and SoT2 to work on the worksheet was not too different from what was allocated in the lesson plan. However, the teachers (T1 and T2) used more time to ask their students to present
their answer on the worksheet. Therefore, the HLT 2 should be adjusted by adding an instruction to conduct group presentation for worksheet 3A.

Both teachers mainly followed the sequence of activities on the lesson plan. T1 generally acted as intended on the lesson plan, except for the introduction and group working activities on worksheet 3A as previously explained. In the lesson plan, the teacher was expected to deliver the objective of the lesson directly using PowerPoint. However, T1 presented it while referring to the learning media as cardboards, bridge cards, and cubes. On the other hand, T2 delivered the three learning objectives (see Table1) directly.

The lesson plan suggested the teachers ask about the difference between the capacity and volume before introducing the bridge cards problem. However, T1 asked the question after the problem. In contrast with T1, T2 followed the order as instructed in the lesson plan. T2 adjusted the question by relating it to students’ real life: the capacity and volume of mineral water. Comparing the responses of their students, on the one hand, somehow T1’s instruction was better than T2’s because T1’s students could directly relate the capacity and volume by relating to the rice fill in the bridge cards, which was the next resources intended to be used. However, T2 was not wrong since many studies suggested to link the lesson with the students’ daily life [22,16].

Related to students’ strategy to mathematically prove that different surface area means different volume, it was expected that students use the proof as presented in the lesson plan (see Figure 2b). However, both SoT1 and SoT2 performed almost similar strategy (Figure 5a presents the strategy from SoT1 while Figure 5b from SoT2). To make sure that the horizontal cuboids have a bigger volume than the vertical cuboids, the students chose numbers to substitute the length and width, and both teachers agreed with their students’ strategy. This indicates the need to insert this strategy to the conjecture of student’s answer on the HLT, suggesting that teachers need to help students to achieve a more formal proof, without using numbers, as presented in Figure 2b.

![Figure 5](image)

**Figure 5.** Students’ strategy to prove horizontal cuboid has a bigger volume than the vertical one.

T1 and T2 often invited students to participate in the classroom discussion actively. However, it seems that T1 did it more frequent than T2. For instance, in the experiments using the bridge cards and rice, T1 asked for students’ help while T2 did it by herself as written on the lesson plan. Moreover, T1
often rechecked students’ understanding of what has been explained. Based on the interview after the lesson, the teacher said that it was for exam preparation that would be held next week.

The use of game *Point out the view* was intended to help students to understand more about spatial skill. Differ from the stack of cubes, which was quite troublesome to use outside of the classroom; the online game is easier to be used anywhere. Recent studies suggested that online game promote students’ learning interest [23,24]. Therefore, the HLT was designed to accommodate the online educational game. However, due to some limitation such as power failure, T2 could not utilize the game point out the view. Although the researchers had interviewed the teacher about the accessibility of the internet and other tools for playing an online game, the occurrence of the power outage was out of control.

Each activity designed in the HLT 2 had its own goal. As suggested by Gravemeijer [25], the learning mathematics should be in line with the idea of horizontal and vertical matematization. Starting with real problems, using “real” stack of cubes (as in Figure 3), the learning activities in this study shift to more abstract problems. The real stack of cubes could be touched and moved by students. Therefore, they can easily see its view from the front or the right side. The online game was used so that the students could train their spatial orientation ability while playing it. It was expected that the students could solve problems in worksheet 3C easily.

SoT1 and SoT2 performed different work or solution while solving problems on the worksheet 3C, especially on the third problem about *determining the minimum number of cubes needed to form the figure* presented on the worksheet (see Figure 6). There were two different answers from SoT1: ten and eight cubes. On the other hand, SoT2 gave a more various answer: ten, nine, and eight cubes. The researchers conjectured that it happened because of SoT2 got fewer exercises than SoT1 because of the absence of the online game.

![Front view](image1.png) ![Right side view](image2.png)

**Figure 6.** The picture on worksheet 3C.

4. **Conclusion**

This study developed HLT consisting of a set of learning activities to promote spatial learning through various resources. Almost all the learning resources were used as intended in the HLT 2 by the participants (T1 and T2) in this study. The differences lie in the time allocation spent, the flow of teachers’ instruction, the method of engaging students, and the use of the online game. Considering the differences enacted by the teachers in this study, the HLT need some adjustments so that it accommodates more conjectures about teacher’s instructions and student’s reactions. Related to the online game, the HLT designers need to provide, for example, an offline game to alternate the online game when needed.

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