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To cite this article: A Jaelani *et al* 2019 *J. Phys.: Conf. Ser.* **1320** 012048

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The design of sketchup software-aided generative learning for learning geometry in senior high school

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Abstract. Geometry learning needs to be observed by teachers and researchers because students often experience difficulties. At present, learning mathematics that utilizes technology is a challenge for them. This paper describes design of SketchUp software-aided generative learning for learning geometry about distance and angle in space in Senior High School. The data were collected from learning observation and interview with lecturers, teachers, and students. Its analyses were data display, data reduction, and drawing conclusion. Research procedures were designing, validation, revising, conducting learning trial, and revising. It had produced the technical structures and descriptions of learning and learning instruments including SketchUp files supporting them and was ready to disseminate in larger students learning communities in senior high school.

1. Introduction

Geometry is important and supports many abilities of students. National Council of Teachers of Mathematics [1] explained goal of geometry learning which was the mastery of students in using visualization, developing visual reasoning skills, and solving geometric problems. Kennedy, Tipps, & Johnson [2] said many experiences in learning geometry supported development of problem solving, reasoning, and relating to other mathematical topics. The Regulation of the Minister of Education and Culture of Indonesia Number 24 of 2016 [3] stated that one of the contents of mathematics subjects for grade XII was the solid geometry. So, those contents should be developed to supports ability elevation of students.

Topics in geometry were generally identified as difficult topics for both students and teachers and became topics that often occurred in learning mathematics [4]. For many students, geometry was difficult in concept and boring because it followed many sets of rules that had no exceptions [5]. Fabiyi [6] stated that the causes of learning difficulties in geometry concepts were teacher learning methods, unavailability of learning material, insufficient time allocation, student gender, complexity, and misconceptions.

There were many aspects of geometry that were useful to investigate and researchers, teachers, and curriculum should be more serious to pay attention to the needs of learning geometry [7]. The use of computer technology in learning should be conducted and developed by persons and communities interested in education. Mathematics teachers were expected to develop their learning using technology as a tool to improve their students' geometric thinking skills [8].



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Recent studies show the use of technology in learning can increase students' potential and abilities in various aspects. One of the attractive functions of technology was reinforcement of certain learning tasks [9]. Karatas [10] explained that mathematics learning using a computer strongly supports students to find new relationships intuitively regarded by students in mathematics. Toptas, Celik, & Karaca [11] stated that there was significant differences in spatial relationship, mental rotation, and spatial visualization abilities between students who experienced learning using SketchUp and those who did not use it. Pranawestu, Kharis, & Mariani [12] had conducted research in the form of computer-assisted geometry learning and the results showed there was an effect of Cabri 3D assisted learning on students' spatial abilities. Hercht, Russo, Lauckhardt, & Hacker [13] reported that students (grade 8 of middle school) who had experiences using computer programs felt confidence in their mathematical abilities. In addition, Chou & Wu [14] stated that students who received learning using Google SketchUp had better performance than students who received traditional learning. Kurtulus & Uygan [15] stated that there was a significant difference in the spatial visualization abilities possessed between the mathematics teachers learning using SketchUp and was not using it.

Currently, in urban areas, teachers and students are common using computers technology. Office application softwares must be installed and used routinely by them. However, the use of other softwares that can actually help teaching and learning is still lacking to explore. Teaching and learning processes in class is often implemented to display material that students learn. This cannot help students to add a variety of ways to improve their thinking skills because their use is only treated like markers and whiteboards. One of softwares that can be used to help students develop their mathematical abilities through leaning geometry is SketchUp. It is a 3D modelling software commonly used by engineer but it can also be used to study solid geometry. Solid figures can sketch easily using this software. The difference between SketchUp and mathematical softwares, such as Cabri and GeoGebra, are sketch that is made by SketchUp is not related to formal mathematics. SketchUp has a free version for educational purposes so that we do not necessarily pay and can use it legally.

Generative learning is selected for learning about it because there are many definitions should be generated by students and this is rich in relationship between prior knowledge about geometry and its new concepts. Although, education curriculum in Indonesia encourages students to learn constructively but in fact constructing their mind is not common. Students look uncomfortable when they do not experience direct learning as they usually do. Nevertheless, students recently are familiar with the use of computer technology so that this is their potential they can use for learning methematics. Generative learning strategies will be advantages in assessing meaningful learning outcomes [16].

Generative learning was an effective instructional procedure that could produce a high increase in understanding [17]. Wittrock [17] said that the generative learning model initiated by Wittrock itself consisted of 4 main processes, namely attention, motivation, knowledge, and preconceptions, and generation. Furthermore, he said that this learning model focused on learning processes (such as attention), motivational processes (such as attribution and interest), knowledge creation processes (such as preconceptions, concepts, and beliefs), and processes of generation (for example analogy, metaphors, and summaries) [17]. The basic idea of generative learning was the process of getting a connection between one concept and another and among experience, previous learning, and new information [17]. In Ulusoy & Onen [18], it was stated that the generative learning model was first suggested by Osborne and Wittrock in 1983. They proposed a teaching of generative learning model organized in four phases, namely the preliminary / preparation, focus, challenge, and application [18].

Chou & Wu [14], Kurtulus & Uygan [15], Turgut & Uygan [19], Erkoç, Gecü, Erkoç [20], Panorkou & Pratt [21], and Wahab, Abdullah, Mokhtar, Atan, & Abu [22] only used SketchUp as an activity that was not integrated with a topic in mathematics learning material. The activities they designed was direct exercises to improve spatial abilities. Meanwhile, this study involved SketchUp in learning so that this required challenges to design it related to how students use it, how students construct their knowledge, and how to manage their time. Its contribution was to inform and enrich the design that combined the learning model and application of computer technology. This was also a new design of generative learning that added SketchUp as a tool for learning mathematics about distance and angle in space. The

hope was students could construct their own understanding of distance and angle in space and applied it using SketchUp's built-in image displays.

2. Research Method

The design contained three stages of development, namely defining, designing, and developing. Interviews were with lectures, teachers, and students and about the level of readability learning instruments for students, the validity of mathematical content, and its compatibility with the learning theories. The data of learning observation were about how learning could work, whether the design could be experienced by students, whether it could raise new concept and knowledges construction processes by students, whether students got obstacles in using SketchUp, and how students used SketchUp to help their visualization and cognitive obstacles. They had been analyzed through cross interpretation, data reduction, displaying data, and drawing conclusion.

3. Results and Discussion

The design was grouped into two types, namely the technical structures and descriptions of learning and the learning instruments. All of the learning instruments designed facilitated SketchUp software-aided generative learning. The technical structures and descriptions of learning were early made then the learning instruments were created.

3.1. *The technical structures and descriptions of learning*

The technical structures and descriptions of learning comprise learning steps, the order of learning materials, and the relationships between previous knowledges and the topics of learning materials.

3.1.1. *Learning steps* The learning steps is based on the phases in the generative learning model syntax and SketchUp is added as a tool in focus and challenge phase. They seem no flexibility in students and teacher activity so that there are no changes in the arrangement. Steps of it designed are (1) Teacher asks learning material that will be learned to students to get their perspectives, (2) teacher presents prior knowledges through slides of learning material and discuss it with students, (3) students explore learning materials through learning material sheets, student worksheets, and SketchUp files and teacher guides them, (4) students share the results of their exploration one another according to their perspectives and teacher directs and referees them, (5) students and teacher make conventions of new concepts they have been learned, (6) students apply those in other contexts and teacher guide them.

3.1.2. *The order of learning materials.* The learning materials are about distance and angle in space. In the initial design, learning materials arranged were based on the grouping of mathematics objects. Those were distance and angle and were further grouped in others mathematical objects such as point, line, and plane. They corresponded mathematical objects which formed the sub-topics of learning materials so that they were separated into distance of two points, distance from point to line, distance from point to plane, distance of two parallel lines, distance of two intersect lines, distance of line is parallel to plane, distance of two parallel planes, angle of two lines, angle of line and plane, and angle of two planes.

After validation processes by mathematics teachers, there were the topics of learning material that could be removed because they were not graduate competences standar that were determined by ministry of education and culture and their level were too high for senior high school students such as distance of two intersect lines and distance between line and plane. The order of learning materials that would be learned by students shifted after expert validation by lecturers. The validator suggested to regard interrelationship among topics of learning materials such some topics could become prerequisite of other topics. Therefore, the order of learning materials starts from distance of two points until distance from point to plane. Topics about distance of two points should be mastered students before they learn topics about all of types of distance. Moreover, angle of two points should be understood by students before they study about angle of two planes and angle of line and plane. Before students learn about angle

between line and plane and distance from point to plane, they early should be learn about angle of two planes because students could identify them through perpendicular angle of two planes.

3.1.3. Relationship between prior knowledges and topics of learning material. Cubes was choosen as a context to learn all types of distance and angle in space. Prior knowledges involved in learning to help students learning new concept about distance and angle in space which were segment, ray, line, Pythagorean theorem, face diagonal, space diagonal, perpendicular lines, theorem of triangle area, perpendicular planes, properties of square, rectangle, and triangle, and projection. Those had been learned by students and should be mastered by students for learning about distance and angle in space. Pythagorean theorem, knowledges about face diagonal and space diagonal were needed by students before determining the value of the distance in space and trigonometry was the prior concept for students to find the measure of angle in space. Reasoning and proving about distance and angle in space could be eased by understanding perpendicular line and plane, properties of square, rectangle, and triangle, and projection. After the process of learning trial, structure of this shifted because it was added knowledge about theorem of triangle area and altitude of pyramid. Determining the length of distance from point to line will be easier after they have determine the altitude of pyramid (See Table 2).

3.2. Learning instruments

The learning instruments comprise slides of learning material, learning material sheets, student worksheets, and SketchUp files.

3.2.1. Slides of learning material contains example of concept (Slides type A) The phases of generative learning mention there is a preliminary as the initial stage of learning to find out the students' initial perspectives of the new concepts. Slides of learning material are used for it. The method is to give questions to students using the slides but the teacher has not confirmed the validity of the students' answers. The teacher allows students' answers to be known by other students. There are no changes in the learning material slides that have been made.

3.2.2. Slides of learning material contain prior knowledge (Slides type B) The slides of learning material contains prior knowledge experienced by students and is related to new concepts that will be learned. Star, Rittle-Johnson, Lynch, & Perova [23] stated that prior knowledge had an important role and provides nuances in strategy flexibility. Furthermore, Bringula, Basa, Cruz, Rodrigo [24] said that one of the factors that influence students' mathematical skills was prior knowledge. The contents were delivered to students through presentations by the teacher. The content conveyed by the teacher through this slides is the same as the content in the learning material sheet.

3.2.3. Learning material sheets The learning material sheets do not contain the concepts learned but instead they contain prior knowledge that can help students to discover new concepts because generative learning is constructivist and uses prior experience and knowledge to get new concepts. Zuya & Kwalat [25] stated that the knowledge that was passed does not consider from the teacher even though it could help in gaining new knowledge of students. The learning experience of students will be recalled through this learning material sheets so that it strengthens references and makes it easy for students to make connections between prior knowledge and new concepts and use them to help them find new concepts.

After experiencing the validation process, there were changes about how to present it. Before the trial of learning, the material was displayed through slides and explained to students. However, students could not understand and capture the material contents because they did not experience their own writing activities. Therefore, previous learning materials were provided by explaining it through a blackboard and were written by students. Nevertheless, this method would certainly waste time.

3.3. Student worksheets.

Student worksheets are structured to support students' thinking activities. Keymacki [26] stated that worksheets were practical, economical, and useful tools in learning activities. There are two kinds of

student worksheets in this design, namely student worksheet that used when students explore new concepts by reinventing and constructing the new concepts themselves (Student worksheet type A) and student worksheets that are used when students apply new concepts (Student worksheets type B).

3.3.1. Student worksheet who are in the focus phase This directs students to confirm their invention themselves about new concepts. First, students are given several questions to give examples of concepts of distance or angle on the cube so that students have been supposed that they are right about the example that has been proposed. Next, students construct definition of concepts through their own sentences. This is one of the major processes in generative learning. Major & Mangope [27] mentioned that it can be able to apply theories and practice communications and connections. In this worksheet, students require SketchUp for viewing and exploring cube images to help them answer questions.

3.3.2. Student worksheet who are in the application phase This student worksheet contains questions that lead students to apply the new concepts. These are related to counting, showing examples, giving reasons, sketching, and proving. At this stage, students are given the options to them whether to use SketchUp or not.

3.4. SketchUp soft files

Danton [28] stated that dynamic geometry software could improve understanding. SketchUp had been used by Erkoc, Gecu, Erkoc [20] and Turgut & Uygan [19] in their research to study about spatial ability and this paper is also for addition research about it. Besides, Bortolossi [29] advised to use software in learning activities for a certain period of time. SketchUp files used in this research contained cube images that were used to study the distance and angle in space by students. Initially, SketchUp files were created by students but they waste time in drawing solid figures. Moreover, students were too focused in the picture and did not focus to their thoughts. So, in the next design, SketchUp files that contained cube images were provided by researchers to be explored by students. The changes that occur in SketchUp files were also change in font size and color of vertex name of the cube.

The learning design described above had encountered research development procedures, namely design, validation, revisions, learning trial, and revisions. Next, the design was tried to be implemented in the classroom. The results based on stages of generative learning are described in the following explanation.

At the beginning, when the teacher asked questions about examples of new concepts through presentations, students could simultaneously answer them correctly. Moreover, there were variation answers conveyed by students when the teacher asked the reason. This means that students was actually able to intuitively determine a truth even though they have not learned it. The following conversation shows this.

Next, students were invited by the teacher to recall the knowledge they had learned. All students still remembered the knowledge of Pythagoras well, but they were weak and did not fully understand the characteristics of plane figures. Even though this was useful for giving arguments about the properties of distance and angle in space. It was shown that when students were asked to mention the properties of a square and rectangle, many students did not answer correctly. They could not mentioned that the diagonals of square was perpendicular each others while the rectangle was not. In this step, teachers who revived their learning retention is important because it will be required to construct new knowledge and answer questions related to it.

Teacher : What are the properties of a square related to the diagonals?

Students D: Face diagonals intersect each others at one point.

Teacher : Does the square have face diagonals?

Students E : The diagonals divide sizes equally.

Teacher : Sizes or area?

Students : Area

Teacher : How about the position of the diagonal of square each others?

Student F : it is skew.

Teacher : Now, I rotate the square with 45 degrees like this, is the diagonals still skew?

(Finally, the teacher himself said that the diagonals of square is intersect perpendicularly each others.)

The next step was students explored new concept through student worksheets and cube images in SketchUp files. The result was students could focus on their work to construct it. Students also did not seem to have difficulties using SketchUp. For example, they could create lines themselves which are space diagonals and face diagonals of the cube in SketchUp. Interview with one of the students about using SketchUp is presented in the following dialogue.

Teacher : What do you think about using SketchUp to learn geometry, does it help you?

Student : Yes, Sir. It can help us.

Teacher : How does it help you?

Student : Yes, Sir. We can look around the parts and we don't need to imagine. We are easy to know which ones are perpendicular.

Teacher : OK, Good. But, that is only for learning this time. Nevertheless, It practice you to visualize object so that you should not visualize at all.

Teacher : Besides, what else?

Student : It is easy to draw, Sir.

Teacher : When you construct a definition, can SketchUp help you?

Student : Yes. As I said before that we are easy to see which is perpendicular. From the perpendicular one, we can then determine the angle or distance.

Teacher : Do you get obstacles when using SketchUp?

Student : Just in the beginning, Sir. It is only for a moment. After that, I enjoy using it.

In the challenge phase, the students shared, discussed, and debated in learning to convert a truth about the new knowledges. Teacher helped to provide a scientific logical perspectives. In the initial learning material, students were still debated because there were two different answers. However, after some lesson meeting, the student's answer is uniform because it may be accustomed. The point is the same with different sentences so that the truth of concept was immediately agreed. The examples of debate conducted by students were in the following conversation.

(An image of cubes ABCD.EFGH and P is in the middle of BC was presented)

Teacher : Which is the distance between E and BF?

Student A : EB

Teacher : Is it other answers?

Student B : EP

Teacher : Why?

Student B : Because P is in the middle.

Teacher : Do you agree?

Student A : No Sir.

Teacher : What is the reason?

Student A : It is not perpendicular to BF.

Teacher : Why do you choose EB as the distance?

Student A : It is perpendicular to BF.

Teacher : Now like this. it is located in the middle is special and it is perpendicular to BF is also special. Are there any special features of them?

Students : EP is longer than EB, Sir.

Teachers : Now, if we learn distance, which will be chosen?

Students : EB

Teacher : Well. It means we agree that the distance is EB because it is perpendicular to BF and is closest.

In application phase, students could answer questions about calculation of distance between point and plane. Student answered them based on prior knowledges presented by teacher in preliminary phase. They determined the length of the distance using the equality of triangle area. This was also available in learning material sheets.

4. Conclusion

The design had produced a structures and technical descriptions and instruments of SketchUp software-aided generative learning to study about distance and angle in space in senior high school and had been validated and revised. Its revisions were the order of learning materials, the prior knowledge, contents of the learning material, student worksheets, and cube images in SketchUp files. Therefore, all of them are ready to be used for further testing in an experimental study. It means the design can facilitate students to construct their new knowledge about distance and angle in space and apply to answer questions about example, calculation, and reason of them.

5. Suggestions

When researchers and teachers design learning which concepts are constructed by students and it uses computers, some suggestions can be considered. Those related to technical implementation of learning are (1) considering the order of learning materials, (2) completing full prior knowledge that can be used to support the concept construction process for students. These related to learning instruments should be considered are (1) refreshing the students' prior knowledge, (2) considering the time allocation because of difficulties, and (3) providing facilities in which students can focus on thinking processes rather than thinking to technical obstacles in using learning tools.

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