Developing Students' Creativity in Building City Mathematics through Project Based Learning

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Abstract. The major objective of this study was to develop, implement, and evaluate the use of the Project Based Learning model in improving students' creativity in building their own city using mathematics (geometry, area, and volume). This study used mixed methods to collect, describe, and interpret the data. The data were collected through focus group discussion, classroom observations, project, and the lecturer's research journal. The participants in this study consisted of 34 students enrolled in the School Mathematics 2 course during term 1, 2020. In this project, students went through several steps including designing, measuring, calculating, cutting, color, and using math problem-solving skills to construct their own city. This study analyzed the creativity displayed by student participants while performing the project result. The students' group project met all components of the creative dimension (novelty, resolution, and elaboration). Particularly, the results of the study concluded that the model could improve the creativity of students in building a city through mathematics concepts.

Keywords: Project Based Learning, Creativity Dimension, Geometry

1. Introduction

Various efforts to improve critical thinking skills, problem-solving and creativity were developed because classrooms using conventional approaches were not as effective as desired by many teachers. As a result, many teachers have switched to innovative learning models, including project-based learning; learning based on Science, Technology, Engineering, and Mathematics (STEM) to enhance these skills and encourage student interest in the STEM field [1]. This is relevant to the latest curriculum standards that encourage students to achieve higher-order thinking and problem-solving skills. This has caused some problems for teachers as the majority of textbooks are designed to teach students specific mathematical techniques and procedures rather than helping students develop the thinking skills necessary to analyse the kind of quantitative information they will encounter in their lives [2]. The focus of this research is to demonstrate how to make use of a project-based learning model to help students better understand concepts such as geometry, area, volume, and to demonstrate higher-level thinking and problem-solving skills. In particular, the project was made is to create a city using geometry, area, and volume as an effort to teach students to train their creativity in using mathematical concepts involving city buildings.

Creative thinking is very important in the era of global competition. Meanwhile, one way to hone creativity is to get used to critical thinking. Mathematics has an important role in shaping and developing logical, systematic, and critical thinking skills.

2. Literature Review

2. 1 Project based learning

Project-based learning typically involves the following steps: learning begins with essential questions, namely questions that can give assignments to students in carrying out an activity; planning is done collaboratively between teachers and students. Thus, students are expected to feel ownership of the project; Teachers and students collaboratively arrange a schedule of activities in completing the project; Assessment is carried out to help teachers measure the achievement of standards, play a role in evaluating the progress of each student, provide feedback on the level of understanding that has been achieved by students, assist teachers in developing subsequent learning strategies; At the end of the lesson, the teacher and students reflect on the activities and results of the project that has been carried out. The reflection process is carried out both individually and in groups.

2.2 Creativity

As [3] stated that creative thinking is the highest level of a person in thinking, other levels of thinking as recall, basic, and critical thinking. Hierarchically, this level of thinking is presented in the following Figure.

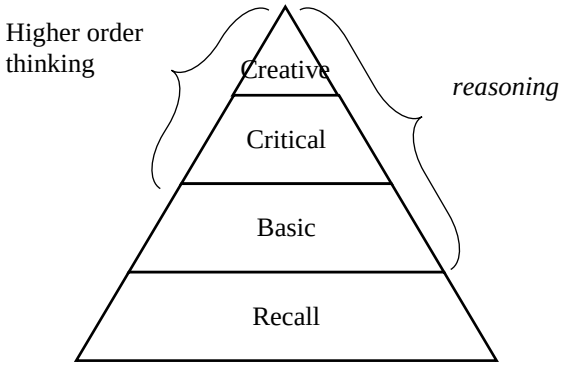

Figure 1. Level of thinking

Particularly, creative thinking enables students to study problems systematically, face millions of challenges in an organized way, formulate innovative questions, and design original solutions. Furthermore, creative people are those who are engaged in a task because the source of motivation lies inside and pleasure drive by the activity.

Bessemer [4] has developed a model called the Creative Product Analysis Model (CPAM) and later on become Creative Product Semantic Scale (CPSS) in 1989. This model is composed based on three creativity dimensions: Novelty, Resolution, and Elaboration. The first dimension is a novelty.

In the first time people see the product of project based learning, the novelty is one of the attributes in judging the creativity. Novelty comprises the originality and newness in making the product which involves materials, ideas, processes, and concepts. The second dimension is resolution. A product that is high in resolution and novel means that it is a creative product. The term 'resolution' defines a well-functioning product, easy to use, well-crafted, beneficial, and meets the needs of the problematic situation. The last dimension is originally known as elaboration. This dimension values the aesthetics qualities of a product, the complexity of the product, and how it can enhance the people's impression to make it as a creative product.

2.3 Implementation of project based learning on the topic of geometry

Project-based learning models are very suitable to be applied to the basic concepts of geometry and measurement. With the hope of equipping students about concepts with their needs and interests, producing products, and thinking creatively, critically, and skillfully investigating, concluding material, and connecting with real-world, authentic problems and issues. Meanwhile, in project-based

learning, students plan and carry out investigations on several topics or themes that use cross-subject or cross-material. By applying this model, students will have a lot of experience in the application of quality mathematical concepts and are skilled in creating the work needed.

Mathematics learning is the process of providing learning experiences to students through a series of planned activities so that students gain competence about the mathematics material being studied. Therefore, the learning experience is provided by the teacher to enable the students understand mathematics material, solve problems in mathematics, and develop their creativity.

For many students, it is difficult to make real-life connections between mathematics and their everyday lives. By applying the Project Based Learning approach, students learn that geometry is not only theoretical but also practical and necessary. Students will move beyond the basic understanding of concepts to creativity. The project in this training is designed for geometry material with the consideration of students' freedom in creativity. More specifically, this project is designed to assist students in applying their knowledge of geometry, area, volume, and other mathematical concepts.

Table 1. The instrument for Creative Product Analysis Matrix (CPAM)

Creative Dimension	Criterion	Score		
		1	2	3
Novelty	Germinal	The lower level of germinal: The product is inspiring others with the creation	Medium level of germinal: The product is inspiring others to try something new	High level of germinal: The product is inspiring others to try something new by directly give ideas to develop more product design
	Original	The lower level of originality: Students mostly use the previous finding as their product idea	Medium level of originality: Students use the previous finding as their idea, but they modify the product	High level of originality: The product idea comes from their own understanding
Resolution	Valuable	The lower level of Valuable: The product is not compatible with the purpose and not relates to the concept	Medium level of Valuable: The product is compatible with the purpose and not relates to the concept	High level of Valuable: The product is compatible with the purpose and relates to the concept
	Useful	The lower level of Usefulness: The product can be used once	Medium level of Usefulness: The product can be used continuously with a certain requirement	High level of Usefulness: This product can be used continuously without any requirement
Elaboration	Well Crafted	The lower level of Well Crafted: The product is done well	Medium level of Well Crafted: The product is done well with the good looking design	High level of Well Crafted: Students take an effort to give interesting product design by using some materials
	Expressive	The lower level of expressive: The product is presented with lacking body language and need to control speaking tone, not understandable	Medium level of expressive: The product is presented with lacking body language and need control speaking tone, but understandable	High level expressive: The product is presented communicatively (using effective body language and clear voice and understandable manner

Source: [5]

3. Research Method

3.1 Research participant

The participants were limited to one class of 36 students who took a School Mathematics course in the even semester of the 2019/2020 academic year in the mathematics education program of FMIPA UNM Makassar.

3. 2 Research instrument

This study aims to investigate the impact of STEM project-based learning on students' creativity in building a city by using mathematics. Data collection technique that used is observation, students' project, and lecturer's research journal. Students' creativity is measured based on students' product which is building a city. The students' creativity is assessed by using the Creative Product Analysis Matrix (CPAM) that adapted from [4]. The data is obtained through the Creativity Product Analysis Matrix (CPAM). Three creativity dimensions used in this study are resolution, elaboration, and novelty dimensions as described in the table 1.

4. Result and Discussions

During the study of project-based learning, the class is divided into three groups that consist of twelve students to create the project. All group members should cooperate in building a city with mathematics. In the preparation stages, students are freely allowed to investigate the project and find some information that is needed to solve the problems. Preparation involves a preliminary analysis of the city, defining and setting up the building. Preparation stages also allow students to discuss with their group in determining the project based on information the interest of the group member. The discussion is used to stimulate students in delivering their idea. Moreover, students independently design real and feasible products or present their research accomplishments in their spare time. The students' product and the description after implementing the project-based learning can be shown in the following Figure.

Group 1's work

Figure 2. City of Education

A future education city with good learning facilities to support education for future generations. The mosque in the center of the park. A complete library to support studying in this educational city, students are more enthusiastic about learning more. Book and pencil/pen monument as the symbol for the book and pencil will still be needed. A mall as the symbol for entertainment is also necessary. The role of mathematics in this city of education is that students are required to better understand geometrical spatial shapes, not only general spatial shapes such as cubes, blocks, but also other space structures with various other creations. Another mathematical role is students can create spaces into even more imaginative forms.

Group 2's product in making a city with mathematics

Figure 3. Famous Buildings in the World

The description of the product of the project according to Group 2 is the following: with the miniature "Famous Buildings in the World" students can find out that there are famous buildings in the world that use the concept of geometry. Some of the famous buildings that use geometric concepts include Ka'bah, Tower of Pisa, Pyramid, Lego Building, and Monjali. Ka'bah is symbolized as a building in the form of a cube. In Islam, the ka'bah is the most sanctified place which is the determination of the direction of the Qibla. The Tower of Pisa is a bell tower built near the Cathedral and The Baptistery (part of the church used for baptisms) which is located in the city of Pisa, Italy. The tower building has a structure like a tube. This building is also one of the tourist attractions that always attracts tourists from various parts of the world because it has its own features. The building is sloping and looks like it will collapse always attracts tourists. Whereas, the Egyptian pyramid is one of the 7 Wonders of the World, both modern and ancient versions. And it is also the highest pyramid in Egypt which has a total of 118 pyramids. Lego buildings are blocks shaped like colorful Lego blocks. This building is located in Madrid, Spain. When we see this building, we will think about toys in childhood, namely lego toys. Monjali or Monument Jogja is a historical museum of the struggle for independence of the Republic of Indonesia in the city of Yogyakarta. This cone-shaped monument museum with 3 floors is equipped with a library and multipurpose room. The Monument Jogja museum again is also a tribute to the heroes who reclaimed the independence of the Republic of Indonesia from the hands of the Dutch colonialists.

Group 3's product in making a city with mathematics

Figure 4. The Importance of Education in Rural Areas

Miniature with an area of 100cm X 80cm is a region consisting of mountains, mosques, libraries, buildings, parks, and others. Education in rural areas is very necessary to support future generations. Even though the library is incomplete, it can still be a support for studying. There is a reading park and children's playground so that education in this village is not left behind and the insight of the

generation opens. The mosque is on the beach as a balance between studying and religion. The job of local people is as a fisherman who can provide good nutrition to their children by consuming the fish they catch so that children's thinking can run smoothly. The role of mathematics in this miniature is that students can better understand geometrical spatial shapes not only spatial shapes in general but also other spatial shapes with various creations.

The result shows the data that was obtained based on the creativity rubric. CPAM is grouped into three creative dimensions which are resolution, elaboration, and novelty. The data is obtained based on the criterion of each creativity dimension. Each criterion is scored with a rubric scale from 1 until 3 based on several requirements. The recapitulation of students' creativity for each group is presented in Table 2.

Table 2. Creative Group Product Analysis

Creative Product Criteria	Criterion	Group 1			Group 2			Group 3		
		1	2	3	1	2	3	1	2	3
Novelty	Germinal			√		√				√
	Original			√		√				√
Resolution	Valuable			√		√			√	
	Useful			√			√		√	
Elaboration	Well Crafted			√			√			√
	Expressive			√			√			√

Based on the result in Table 2 and students' presentation, there are different achievements of creativity for each group. Group 1 obtained 100%, group 2 obtained 50 %, and group 3 obtained 66.67%. The following traits are identified as an important factor of the students' creativity in this project such as interest and cooperation. This is in line with [6] states that intrinsic motivation, broad interests, independence of judgment, creative self-concept as several important variables fostering creativity. Research has also found that creative students are energized by challenging tasks, a sign of high intrinsic motivation [7].

Three creativity dimensions of all groups have a different percentage. Group 2 has the lowest percentage of three creativity dimensions compared with other groups. Resolution dimension obtained 83%, elaboration dimension obtained 100% and novelty dimension obtained 89%. The average score of each dimension creativity after implementing the project-based learning is obtained 91% which categorized as very high. Research has also found that creative students are energized by challenging tasks, a sign of high intrinsic motivation [7].

5. Conclusion

This study mainly aimed to explore the effects of the project-based learning (PBL) model and to analyze the creativity displayed by the student participant while performing these activities. The students who implemented the project-based learning in the building the city by the implementation of mathematics concept have good creativity in the dimension of resolution, elaboration, and novelty. The creativity result obtained as much as 91% which is categorized as very good. Therefore, project-based learning can be used as alternative teaching strategies.

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