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Enhancing senior high school students' visual imagery creativity in geometry through Geoboard

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ABSTRACT

This study examines innovative learning tools to enhance students' understanding of geometry subjects. The research aims to describe the use of Geoboards in fostering the visual imagery creativity of 12th-grade students in geometry learning. The method used is descriptive qualitative, with subjects consisting of six students selected through purposive sampling. The results show that students with high visual imagery creativity possess good abilities in fluency, diversity, originality, and detail aspects. Students with moderate creativity still require guidance, while students with low creativity experience difficulties and need intensive practice. Using Geoboards has proven effective in enhancing visual imagery creativity, making learning more interesting and meaningful, and facilitating understanding of three-dimensional geometric concepts. The implications of this research suggest that Geoboards can be an effective learning tool in mathematics education.

Meningkatkan kreativitas visual imaji siswa SMA dalam geometri melalui Geoboard

Kata Kunci:

Geoboard
Geometri
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ABSTRAK

Penelitian ini mengkaji penggunaan alat bantu pembelajaran inovatif untuk meningkatkan pemahaman siswa dalam mata pelajaran geometri. Penelitian ini bertujuan untuk mendeskripsikan penggunaan Geoboard dalam memunculkan kreativitas visual imaji siswa kelas XII pada pembelajaran geometri. Metode yang digunakan adalah deskriptif kualitatif dengan subjek enam siswa yang dipilih melalui purposive sampling. Hasil penelitian menunjukkan bahwa siswa dengan kreativitas visual imaji tinggi memiliki kemampuan yang baik dalam aspek kelancaran, keragaman, keaslian, dan perincian. Siswa dengan kreativitas sedang masih memerlukan bimbingan, sedangkan siswa dengan kreativitas rendah mengalami kesulitan dan membutuhkan latihan intensif. Penggunaan Geoboard terbukti efektif dalam meningkatkan kreativitas visual imaji, membuat pembelajaran lebih menarik dan bermakna, serta memudahkan pemahaman konsep bangun ruang tiga dimensi. Implikasi dari penelitian ini menunjukkan bahwa Geoboard dapat menjadi alat pembelajaran yang efektif dalam pendidikan matematika.

1. INTRODUCTION

Mathematics does not only contain symbols (x, y, or z) and numbers (1,2,3, ...) but also concepts. Therefore, learning media can properly support knowledge [1]. Human thinking must be developed because it is indispensable in life [2]. The introduction of numbers and symbols in playing and learning activities is a reference for good and fun mathematical knowledge. Thus, mathematics is essential to master since it is found at the basic education level and has been in life since childhood [3], [4].

Mathematics learning aims to help students develop understanding and solve problems through teacher direction [5]. In this learning, students are expected to improve their skills in processing the information received. Through learning creativity, teachers guide students to reflect, explore, discuss, and conclude the meaning of the information [6]. Mental imagery is the process that occurs in students' memories and can be reactivated by a stimulus.

Visual imagery ability is a person's ability to imagine situations or events in everyday life [7]. This ability involves using visual media to form images in the mind. Research conducted shows that individuals who experience depression or depressive symptoms tend to have low levels of mindfulness, which can be reflected in the social view one has of oneself or from the perspective of others [8]. Thus, social views of oneself or from the perspective of others can play a role in influencing one's state of depression or stress. In addition, field research shows that if students dislike mathematics and are forced to learn it, they tend to reduce their motivation and interest in learning [9].

Visual imagery skills are less used because school teachers do not fully understand what visual imagery is. Indonesia lacks visual imagery skills because teachers' teaching style is operational or by memorizing, not understanding the material [10]. Visual imagery is more realized in special schools. According to research, autistic students tend to see rather than listen [11]. They eliminate the meaning of symbols and remembering (rote leaner), look externally (gestalt leaner), and prioritize vision over functioning ears (visual learner).

However, when teaching at high schools in Pontianak, some problems were found, and actions were taken to anticipate them. The method was comparing two teachers who teach mathematics. Interviews conducted briefly with six students revealed that the learning model used so far is too uniform and focused on the teacher's role. This issue hurts students' learning ability and leads to unsatisfactory results.

After interviewing a twelfth-grade mathematics teacher in Pontianak, it was known that several factors affect visual imagery ability, namely the lack of skills in the learning process. The mathematics teacher explained that many students had difficulty imagining shapes and sketches in the third-dimensional material. In addition, they often had difficulty drawing and naming angles correctly when asked about the shape of a block. From this finding, it can be concluded that students do not understand the learning objectives in the third-dimensional material.

Based on home teaching experience (tutoring), students tended to check the problem model, compare them with existing problems, and often performed poorly when finding different problems. The students did not pass their daily tests. The cause of this problem was the lack of visual imagery skills in solving problems. For example, in the mathematics daily test, only 8-10 students out of 30 reached or exceeded the Minimum Completion Criteria (KKM) set. If this problem continues, students' knowledge will become shallow due to a lack of understanding.

Observations at senior high schools in Pontianak showed that students had weak mental imagery skills. These skills refer to a person's ability to form images in their mind. Unfortunately, students' mental imagery ability was not used as a problem-solving training program. Therefore, it is essential to develop mental imagery's ability to solve geometry problems in the third dimension so that students can improve their problem-solving skills.

In education, visual imagery creativity skills are very important for students. However, they often have difficulty showing good visual imagery creativity. Therefore, a design that uses Geoboard is needed to bring out high visual imagery creativity in students.

According to Bruner, there are three stages in recognizing and understanding the environment: enactive, iconic, and symbolic [12]. The enactive stage involves knowing the environment directly through physical actions and interactions. Individuals examine broader goals or concepts in the iconic stage through visual representations such as pictures. Finally, the symbolic stage is reached when an individual can explain concepts and ideas with language and logic, transforming subject matter into a more abstract and symbolic form.

Research shows that an athlete's mental image can influence their sport anxiety [13]. The results of this study also found that the use of visual imagery and mental imagery can have an impact on the level of anxiety experienced by individuals. Students who have negative visual images, such as traumatic experiences, tend to experience higher anxiety. Therefore, using Geoboard in this study can help students visualize and understand geometry concepts concretely and improve their visual-spatial and mathematical problem-solving skills.

Visual imagery is the ability to create and manipulate mental images in one's mind. It involves using the sense of sight to visualize objects, situations, or concepts that are not physically present. In the context of mathematics education, visual imagery plays a vital role in understanding and solving geometry problems.

Geoboard can improve visual imagery skills in mathematics education [14]. The Geoboard app provides a digital platform for students to create and manipulate geometric shapes, allowing them to visualize and explore mathematical concepts more interactively and engagingly [14], [15]. Using the Geoboard application, students can develop visual-spatial skills, improve the ability to mentally manipulate geometric figures, and improve problem-solving skills [16]. Therefore, Geoboard was chosen as a tool in this study because it can help students visualize and understand geometry concepts concretely. The Geoboard also involves manipulation and exploration of geometric shapes so that it can improve students' visual-spatial skills and mathematics problem-solving [17]–[19].

Research has been conducted on the use of Geoboard as a learning media in teaching mathematics, especially the perimeter and area of rectangles and triangles in elementary schools [20]. This study found that using Geoboard as a learning media can improve students' learning outcomes and increase their enthusiasm for learning geometry. The research was conducted through hands-on training for fourth-grade students in an elementary school.

The results showed that the use of Geoboard learning media positively influenced students' learning outcomes in mathematics [21]. In this study, the experimental group that used Geoboard as a learning medium significantly improved their learning outcomes compared to the control group. These results show the importance of innovative teaching methods in mathematics education to improve students' understanding and achievement.

Creativity is something that can be learned and improved [22]. In this case, students can broaden their horizons and abilities in creating and expressing their visual ideas more creatively. Therefore, the Geoboard will make it easier for students to hone their visual imagery skills and provide a more interactive and fun learning experience in their learning process. By improving their visual imagery creativity skills, it is expected that students will be able to improve their learning outcomes at school and make them more prepared to face the world of work in the future.

This research is expected to describe the ability of students' visual imagery in mathematics learning and can be a reference or consideration for teachers to be even better in the world of education.

Many studies have been related to the use of learning media in mathematics, including the use of Geoboard learning media [23], to increase interest in learning mathematics[25] and learning outcomes [26]–[28]. However, no study has examined using Geoboard to bring out visual imagery creativity.

This study aims to determine the effect of using Geoboard on students' visual imagery creativity in learning geometry at the high school level. In contrast to previous studies that use conventional learning media or without the help of special media, this study uses Geoboard as a visual aid. Using Geoboard is expected to increase visual imagery creativity, make learning more interesting and meaningful, and facilitate understanding of three-dimensional space.

Contribution to the literature

This research contributes to:

- Add insight into using Geoboard as an innovative learning media in mathematics education, especially in geometry material.
- Provide a model of teaching methods that teachers can apply to improve students' visual-spatial skills and problem-solving abilities in mathematics.
- Provide practical guidance for teachers in designing and implementing learning activities utilizing Geoboard to improve students' concept understanding and creativity in mathematics.

2. METHOD

This study employed the qualitative descriptive approach to holistically understand the phenomenon of using Geoboard in bringing out the creativity of visual imagery of the twelfth-grade students in geometry learning. The research subjects comprised six students selected through purposive sampling based on previous grades and recommendations from mathematics teachers. In the preparation stage, pre-research was conducted through interviews with mathematics teachers and initial observations of student learning outcomes. In this stage, the researchers also prepared and tested the validity of research instruments, which included grids, visual imagery creativity test questions, assessment rubrics, and interview guidelines.

The implementation stage involved licensing, determining the research schedule, and conducting the visual imagery creativity test. Students were grouped based on the level of visual imagery creativity (high, medium, and low) and analyzed through written tests and interviews. Data was collected through observation of the learning process, written tests to measure visual imagery creativity, and in-depth interviews to explore students' understanding and experience using Geoboard. Data were analyzed descriptively, describing the results of observations, tests, and interviews in narrative

form, focusing on indicators of fluency, diversity, originality, and detail in visual imagery creativity.

3. RESULTS AND DISCUSSION

The results of the data analysis showed that 30 students were grouped based on their level of visual imagery ability. Two students from each category (high, medium, and low) levels of creativity were selected for the interviews. Further discussion of the data was carried out to clarify the results of the data analysis. This study presents a discussion related to research problems by referring to the results of data analysis and interviews given to representatives of students according to their level of mathematical ability. The interviews helped researchers investigate students' visual imagery creativity at each level of mathematical ability.

3.1 The Visual Imagery Creativity of High-Category Students

The following discussion describes the visual imagery ability of students with high mathematics ability levels.

3.1.1 Students' Visual Imagery Creativity in Describing Spatial Shapes on the Geoboard

In the fluency aspect, the students showed their abilities to smoothly and skillfully produce drawings from various points of view without too much hesitation or difficulty. They understood the characteristics of the shapes. In the flexibility (diversity) aspect, the students could produce various views of shapes from different perspectives, thus creating variety and diversity in their work. Furthermore, in terms of originality, students could produce unique works, thus creating high artistic and creative value in their work. In the elaboration (detailing) aspect, the students showed the ability to detail the drawing of a spatial building on Geoboard paper that they produced, thus creating a more complete and detailed work.

One question was posed to see students' ability to provide information and get information about 3-dimensional shapes material. The information was based on students' achievement in providing answers following the assessment rubric. The two students did not achieve. One of the two did not fully achieve the indicator, so it was less than optimal. The non-achievement of this indicator was because the students were not careful in answering.

3.1.2 The Visual Imagery Creativity in Describing or Showing the Results of Work on the Geoboard Board by Connecting Each Rubber

In the fluency aspect, the students easily and skillfully connected each rubber to create shapes according to the instructions. They had no difficulty in connecting the dots on the Geoboard board. Regarding flexibility (diversity), the students showed their ability to create different shapes using the rubbers provided from different sides and angles, thus creating variation in their creations. In terms of originality, the students showed creativity in producing unique and unprecedented shapes. Thus, they created works that had high artistic and creative values. Finally, in terms of elaboration (detailing), the students detailed every detail in the shapes they created. In this case, they could create complete and detailed works.

From the interview data, students with high mathematical creativity are quite capable of explaining the answers when given questions that lead to the test, although students do not fully understand each problem. So, it can be said that high-ability level

students still lack the skill of logically and rationally connecting elements of a 3-dimensional dimension because the number of students who achieve this indicator is still lacking.

3.1.3 The Visual Imagery Creativity in Showing the Shape of the Drawings on Geoboard Paper and Geoboard Board

In the fluency aspect, the students could easily shape the images they created on the Geoboard paper and Geoboard board. They smoothly and skillfully showed each shape or pattern they created on the media used. Regarding flexibility, the students showed their ability to create different shapes and patterns using different media, such as Geoboard paper and Geoboard board. They showed flexibility in creating images on different types of media. In terms of originality, the students showed uniqueness and originality in the shapes and patterns they created. Thus, they add artistic and creative value to their work. Finally, regarding elaboration (detailing), the students showed their ability to detail every detail of their drawings on the Geoboard paper and Geoboard board. They ensured that every detail was visible and easily understood by others.

The interview data with students with high levels of visual imagery creativity shows that they had the courage to explain their thoughts and ideas to bring up new creativity in working on 3-dimensional shapes. So, it can be attributed that students at the visual imagery creativity level can already guess the shape of the problem's results precisely from a certain direction.

3.2 Students with Medium Visual Imagery Ability

Two students with a moderate level of creativity were observed. Based on certain indicators, the following discussion describes the students with a moderate level of creativity.

3.2.1 The Visual Imagery Creativity in Describing Spatial Shapes on the Geoboard Paper

In terms of fluency, although in the learning stage, the students could smoothly produce images from various perspectives. Typically, at this stage, students need to practice recognizing geometric shapes' characteristics to produce images fluently and easily. As for flexibility, the students created images based on the instructions and had not yet developed their ability to create variations in their work. Regarding originality, the students were in the learning process. Therefore, it was rare to see unique and original creations. However, they could demonstrate creativity in arranging and finding new ways to produce images from different perspectives. Finally, in terms of elaboration, the students were in the practice stage to detail every aspect of the geometric shapes they produced on the Geoboard paper. In this regard, they were still struggling to provide complete details.

The interview results indicate that the students could explain and justify their reasoning based on the questions at a moderate level of ability. Similarly, they accurately clarified the given problems. The outcomes were closely tied to the students' ability to process and produce what they were thinking once they had experienced ways to process information from the questions. Therefore, the students could not describe the process and outcomes of visualizing and processing 3-dimensional information at a moderate level of creativity, as the number of students reaching this indicator was insignificant.

3.2.2 The Visual Imagery Creativity in Depicting or Demonstrating Their Work on the Geoboard by Connecting Rubber Band

The students were still in the learning process, so they needed time to demonstrate fluency in connecting each rubber band on the Geoboard. However, they continued practicing to improve their skills. Regarding flexibility, the students created images based on the instructions and had not yet developed their ability to create variations in their work. However, the students learned to introduce variations in connecting each rubber band on the Geoboard at this stage. In terms of originality, the students were still learning, so it was rare to see unique and original patterns. However, they demonstrated creativity in arranging and discovering new ways to connect each rubber band on the Geoboard. Finally, in terms of elaboration, the students were still learning to organize every detail in the images they created on the Geoboard. They began to understand the importance of detailing every aspect of their images.

The interview results show that students found it challenging to explain the questions posed by the researcher. For instance, they struggled with describing the surface shapes of observed objects or the elements that made up those objects. Therefore, students at a moderate level of mathematical ability could not logically and rationally connect the elements of 3-dimensional shapes, as the number of students reaching this indicator was very low.

3.2.3 The Visual Imagery Creativity in Displaying the Shapes They Have Created Using Geoboard Paper and the Geoboard Board

The students were still learning and needed time to show fluency in presenting the shapes they had created on Geoboard paper and the Geoboard board. However, they continued to practice to improve their ability to display shapes more visually. Regarding flexibility, the students created images based on the instructions and had not yet developed their ability to introduce variations in their work. At this stage, they learned how to introduce variations in showing shapes on Geoboard paper and the Geoboard board. In terms of originality, the students were still learning, so it was rare to see unique and original patterns.

Nevertheless, they demonstrated creativity in arranging and finding new ways to express shapes on Geoboard paper and the Geoboard board. Finally, in terms of elaboration, the students were still learning to organize every detail in the images they created on Geoboard paper and the Geoboard board. However, they began to understand the importance of detailing every aspect of their images to make them easily understandable to others.

The interview data with students of moderate ability shows that they struggled to elaborate and explain their opinions directly. Responses from students at this ability level only provided a general overview. Additionally, the students at the moderate ability level could not accurately visualize 3-dimensional shapes from various angles, as many students have not met the indicator for this skill.

3.3 Students with Low Visual Imagery Ability

The data analysis on students with low ability levels reveals that their responses during tests and interviews were similar. Low creativity is associated with weak visual imagery skills in 3-dimensional material. The following discussion outlines the students with low visual imagery abilities based on certain indicators.

3.3.1 The Visual Imagery Creativity in Depicting Three-Dimensional Shapes on the Geoboard Paper

Students with low visual imagery creativity may struggle to depict three-dimensional shapes on the provided Geoboard paper. To improve fluency, students can try drawing more three-dimensional shapes on the Geoboard paper within a limited time. Repeating this exercise multiple times will help them become accustomed to creating images quickly. To enhance flexibility, students can experiment with altering the size or shape of the three-dimensional objects they have previously drawn. To improve originality, students can attempt to create variations of shapes that differ from the standard or provided examples. They might consult reference sources or allow their imagination to produce unique forms. In terms of technique and elaboration, students can focus on more accurate details of the three-dimensional shapes they draw. With continuous practice, they will become more skilled at depicting shapes with greater detail and precision.

Based on the interview data, students at a moderate ability level were fairly capable of expressing their opinions when asked questions by the researcher during problem-solving. However, students in the low-ability group struggled to grasp the information and understand the intent of the questions. This aspect is related to the student's ability to process and interpret what they imagine when handling data. Therefore, students with low ability levels have not yet been able to visualize the steps for solving and processing information in 3-dimensional shapes, as the number of students meeting this indicator is fewer than 15.

3.3.2 The Visual Imagery Creativity in Depicting or Demonstrating Their Work on the Geoboard Board by Connecting Rubber Band

Regarding Fluency in creating images on the Geoboard, students can try to make more patterns or shapes within a limited time. This practice will gradually help them draw more easily and quickly. Regarding flexibility in pattern or shape creation on the Geoboard, they can experiment with combining different shapes or rotating each rubber band at various angles. Experimenting with these ideas will help them familiarize themselves with new creative concepts. Third, for originality, students can try to create patterns or shapes that differ from the examples or standards provided. They can let their imagination generate more unique patterns or shapes. Finally, regarding technique and elaboration in creating images on the Geoboard, students can pay attention to small details, such as the relationships between each rubber band in their images. This will help them improve their ability to create clearer and more detailed drawings.

From the interview data, students with moderate ability did not fully understand the questions posed in the given problems, and the low-ability group was even less able to explain how the process was achieved. Although not all students were observed comprehensively, it can be said that students with low ability can still not relate the elements of 3-dimensional space effectively and accurately, as many students have not yet reached this indicator.

3.3.3 The Visual Imagery Creativity in Demonstrating the Shapes They Have Created by Forming Them on Geoboard Paper and the Geoboard Board

With continuous practice, students will become more accustomed to and skilled at demonstrating shapes on Geoboard paper or the Geoboard board with greater ease and precision. Hopefully, these suggestions will help them improve their visual imagery creativity skills.

Based on the interview data, students with low ability levels have difficulty developing and explaining their answers to the given problems. Forgetfulness of the material and a lack of understanding of the intent of the questions are challenges for these students. Although the images provided in the questions are clear, students still struggle to grasp the meaning of the questions. Therefore, it can be said that students in the low-ability group have not yet been able to visualize images accurately from various angles, as fewer than 15 students have met this indicator.

The data shows that the student's visual imagery creativity is moderate and low. Despite significant differences in the achievement of indicators among individual students, those with low ability are far from meeting the criteria. Specifically, these students cannot transform a real 3-dimensional image on the Geoboard and present the problem and the images seen in the solution. Their skills in understanding the material are similarly lacking, as they struggle to grasp the intent of the given questions.

However, students with low creativity levels are categorized as "good" because they are willing to attempt solutions. During free time, the researcher asked a few questions to gather information from the test results. The brief interview data revealed that, despite being at a low ability level, several factors contributed to their poor test results, which were used as a basis for categorizing their mathematical ability levels.

3.4 The Effectiveness of Geoboard to Enhance Visual Imagery Creativity among 12th-Grade High School Students.

The Geoboard can be an effective learning medium for developing visual imagery creativity among high school students. By using the Geoboard, students can learn to visually draw geometric shapes and develop the ability to create different shapes and patterns through combinations of various geometric forms on the Geoboard. Students will be trained to think creatively and produce engaging visuals during this learning process. To use Geoboard effectively to enhance students' visual imagery creativity, a teacher or instructor must plan and organize engaging, meaningful activities that stimulate students' interest in mathematics. The teacher or instructor should help students understand geometric concepts and provide opportunities to explore and create with the Geoboard. In addition, using Geoboard should be combined with other supporting technologies and media that can enrich students' learning experiences. Teachers or instructors can use geometry simulation applications, educational videos, or digital geometry software to expand learning activities and provide variety in using the Geoboard.

Based on the interview, Geoboard media positively impacted mathematics learning, particularly in understanding three-dimensional spatial concepts. The interviews showed that respondents felt pleased and understood the material using the Geoboard media. The respondents also gave positive feedback on the appearance of the Geoboard media, noting that it made it easier for them to grasp the content of the lessons. The Geoboard media also helped respondents develop visual imagery creativity and facilitated the identification of three-dimensional shapes.

However, some aspects need improvement, such as the ability to identify three-dimensional shapes based on the lengths of their sides. Nevertheless, the interviews indicate that Geoboard media effectively stimulates students' visual imagery creativity and helps them understand three-dimensional spatial concepts more easily and enjoyably. Thus, Geoboard media is effective in facilitating mathematics learning for 12th-grade high school students and can help them enhance their visual imagery creativity and better understand three-dimensional spatial concepts. This study aligns with previous research

that has demonstrated the effectiveness of interactive teaching media in improving spatial-visual skills and mathematical concept understanding [29]. This study supports previous findings regarding the importance of using visual aids like Geoboard to facilitate geometry learning. It reinforces evidence that a holistic and interactive approach can enhance student motivation and creativity in solving mathematical problems. The results of this study are also consistent with research showing that innovative teaching methods can make learning more engaging and meaningful, thereby making a significant contribution to the field of mathematics education [30].

4. CONCLUSION

Research shows that students with high visual imagery creativity have strong fluency, flexibility, originality, and elaboration abilities. They can smoothly produce images from various perspectives, create diverse and unique shapes, and detail every aspect effectively. In contrast, students with moderate visual imagery creativity still need time and practice to develop their works' fluency, flexibility, and originality. They tend to follow instructions and are learning to detail their images. Students with low visual imagery creativity struggle with all these aspects and require intensive practice to improve fluency, flexibility, originality, and detailing skills. Geoboard as a learning medium has proven effective in developing visual imagery creativity among 12^{th}-grade high school students. With Geoboard, they can learn to draw geometric shapes and create different patterns, making learning more engaging and meaningful. Students enjoy and find it easier to understand the material while also enhancing their visual imagery creativity. Although there are still aspects to improve, the Geoboard facilitates mathematics learning, boosts visual imagery creativity, and aids in understanding 3-dimensional geometric concepts. The implications of this research suggest that Geoboard can be an effective tool in mathematics education.

AUTHOR CONTRIBUTION STATEMENT

MH contributed to the conceptualization and design of the study, carried out the fieldwork, and prepared the background of the research. YJ contributed to the fieldwork, data entry, and statistical analysis, and also assisted in reviewing the literature and drafting the methodology section. Y contributed to the preparation and validation of research instruments, conducted interviews, and contributed to the drafting and revision of the manuscript.

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