



Enhancing Students' Visual-Spatial Abilities through the Use of Bonat Berakal Media in Understanding Shapes of Molecules

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Abstract

Students in 10th grade often get low learning outcomes on one of the chemical concepts, the shapes of molecules. Based on the test results, it can be seen that most students have difficulty on understanding and drawing the shapes of molecules. Many students have difficulty drawing shapes of molecules because shapes of molecules cannot be observed directly using the sense of sight, so students cannot project molecular images on their minds. The inability of students to understand molecular drawings in predicting the shape of molecules may be related to spatial visual abilities. The study aimed to investigate the effectiveness of using *Bonat berakal* media in enhancing tenth-grade students' visual-spatial abilities in understanding shapes of molecules. The students from classes A, B, and C in academic year 2022/2023 at SMAN 1 Tuban participated in the study. The research design was one group pre-test post-test. The instruments used were a teaching module on shapes of molecules and a spatial visual test. The data was analyzed using N-Gain score. The results showed that the pre-test average of students' spatial visual abilities was low but improved to a high category post-test. The study concluded that the use of *Bonat berakal* media was effective in improving students' visual-spatial abilities in shapes of molecules concepts, as indicated by an N-Gain score of 0.620.

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INTRODUCTION

Chemistry is a branch of science that explores the composition, structure, properties, and transformations of matter (Artini & Wijaya, 2020; Dewi et al., 2016; Priliyanti et al., 2021). The field is divided into two main areas: products and processes. The two areas are interdependent and cannot be separated (Saputra et al., 2017; Herawati et al., 2013; Susanti et al., 2019).

In teaching chemistry, two main levels of representation are commonly used: macroscopic and symbolic (Nastiti et al., 2012; Rahmawati, 2016). The macroscopic level involves direct observation of phenomena through experiments or real-life experiences (Dindha Amelia, 2020; Indrayani, 2013). On the other hand, the submicroscopic level represents the abstract nature of chemistry, providing explanations using atomic and molecular images to explain macroscopic phenomena (Rahmawati, 2016). The symbolic level involves the representation of macroscopic phenomena using symbols, formulas, equations, graphs, and analogies (Indrayani, 2013).

However, the submicroscopic level is often neglected or studied separately in isolation (Safitri et al., 2019; Nastiti et al., 2012). To ensure comprehensive understanding of chemistry, all three levels of representation should be integrated in chemistry education (Rahmawati, 2016). Additionally, the concepts of chemistry are hierarchical, requiring gradual and stratified teaching of basic concepts before moving on to more advanced ones. Students with limited

understanding of basic concepts may struggle to understand subsequent concepts (Rahmawati, 2016). Moreover, students' prior knowledge and experiences may also influence their understanding of scientific phenomena, leading to misconceptions that can be reduced by incorporating all three levels of representation (Nastiti et al., 2012).

One concept in chemistry that students often struggle with in 10th grade is the shapes of molecules. This concept is related to electron configuration, free electron pairs, and bond electron pairs, and serves as the foundation for subsequent concepts such as hydrocarbons and macromolecules (Rahmawati, 2016). The success in understanding and describing shapes of molecules is influenced by students' understanding of supporting theories such as bond electron pairs, free electron pairs, valence shell electron pair theory (VSEPR), and electron domain theory (Rahmawati, 2016). The results of the shapes of molecules concept tests have shown that many students struggle with determining bond and free electron pairs, understanding VSEPR and electron domain theory, and predicting the shapes of molecules (Table 1).

Table 1. Preliminary test results of the concept of the shapes of molecules

Indicators	Number of students who do not understand	Presentation (%) (total number of students 112)
Determining bond electron pairs (PEI) and free electron pairs (PEB)	59	52, 68
Understanding valence shell electron pair theory (VSEPR) and electron domain theory	76	67,85
Forecasting the shape of the molecule	88	78,57

The preliminary results of a study on students' understanding of the concept of the shapes of molecules indicate that more than 50% of the participants still struggle to comprehend the concept and describe the shape of molecules. The lowest performance was observed in the ability to predict the shapes of molecules, which was 78.57%. Interviews with students revealed that the difficulty in understanding the the shapes of molecules is due to their inability to visualize the three-dimensional location of each atom. The shape of molecules cannot be directly observed by the senses, making it challenging for students to form a mental image of the molecule (Anshori et al., 2021).

The understanding of submicroscopic concepts in chemistry requires the ability to reason about relationships in three dimensions, making spatial visual ability a crucial factor (Anshori et al., 2021). The ability to understand, process, and think in visual form and translate these mental images into two or three dimensions is also linked to spatial visual ability (Rosidah, 2014). The results of a spatial visual test showed that the average score was 38.06, while the average score for the concept of the shapes of molecules was 45.14. These results suggest that students' spatial visual ability is correlated with their learning outcomes. The correlation between the spatial visual results and the results of the the shapes of molecules concept was 0.779, indicating a strong relationship between the two.

The concept of the shapes of moleculless and their spatial-visual abilities is abstract and can be challenging to understand. To address this issue, the authors conducted an interview with a chemistry teacher at SMAN 1 Tuban. The results showed that the concept of shapes of molecules is mainly taught through lecture methods and image media presented on blackboards, viewed by students or shown on slides. Molymod is an alternative learning media that occasionally used to help students understand the the shapes of moleculless, but its limited availability and number and type of atoms limit its usage.

Therefore, the authors developed a new learning medium in the form of solid balls as atoms, which can be used as a substitute for molymod. The balls were made using clay, skewers or toothpicks, and dyes, which are easily accessible materials. The clay balls were made simply without the use of adhesives or molds and the basic material, clay, is widely available in the Coral area of Tuban Regency.

The authors chose to use learning media based on local wisdom, which is rarely done in the development of chemistry learning resources. The study was conducted on 10th-grade students at SMAN 1 Tuban as the researcher was a teacher there and the the shapes of molecules material was taught in the 10th grade. The study aimed to evaluate the effectiveness of *Bonat berakal* (clay balls) media in improving students' spatial visual ability on the concept of shapes of molecules.

METHOD

This study aimed to evaluate the effectiveness of the use of the learning medium, *Bonat berakal*, for teaching the concept of the shapes of molecules in tenth-grade students of state senior high school (SMAN) 1 Tuban during the 2022/2023 academic year. The study employed a one-group pretest-posttest design according to Sugiyono (2013), as depicted in Figure 1. The sample consisted of three classes (A, B, and C) selected from the 10 homogeneous and normal classes, based on their summative value of the concept of shapes of molecules, representing 30% of the total population.



Figure 1. *One Group Pretest-Posttest Design*

The study was conducted from August 12, 2022, to October 5, 2022, and the instruments used included a the shapes of molecules teaching module as the treatment instrument and a spatial visual problem test as the measurement instrument. The test was verified and validated by two Chemistry Subject Teachers at SMAN 1 Tuban to ensure its validity and reliability. The validity of the content was assessed based on the representation of measurable concepts and communicative sentences in the test questions. The validity results were analyzed using the percentage analysis technique.

The research instruments consisted of a learning device in the form of a the shapes of molecules teaching module, which was validated and verified by two chemistry subject teachers from SMAN 1 Tuban. The treatment results were measured using assessment tools, which consisted of tests. The tests consisted of spatial visual problems based on the concept of the shapes of molecules. The tests were first evaluated for validity and reliability.

The validity of the tests was determined by two chemistry teachers from SMAN 1 Tuban and evaluated the extent to which the test instruments accurately represented the ability being measured. The content validity criteria were based on the questions having clear, measurable concepts and communicative sentences. The results of the validity tests indicate that the compiled tests are suitable for measuring spatial visual ability. The validity results will be analyzed using a percentage analysis technique.

$$P = \frac{\text{score of validation}}{\text{maximum score}} \times 100\%$$

The eligibility criteria for test instruments can be seen in Table 2.

Table 2. Test instrument eligibility criteria

Presentase	Makna
0%-20%	Bad
21%-40%	Poor
41%-60%	Fair
61%-80%	Good
81%-100%	Excellence

(Source: Supranata, 2004)

In this study, the validity of the content was determined by means of correlation of the product moment Person, utilizing the SPSS 19 for Windows program. The validity of the questions was interpreted as follows:

- Questions with a correlation coefficient (r) greater than the critical value (r-table) at a significance level of 0.05 were considered valid
- Questions with a correlation coefficient (r) less than the critical value (r-table) at a significance level of 0.05 were considered invalid

Analysis of the validity of the questions showed that four questions (5, 10, 13, and 20) were considered invalid, as they had a correlation coefficient (r) less than the critical value (r-table) at a significance level of 0.05. These invalid questions were revised by considering the suggestions of the validators, who analyzed the possible misunderstandings students may have had related to the questions. The overall test reliability criteria can be seen in Table 3.

Tabel 3. Criteria of test reliability

Angka korelasi	Makna
0,800 < r < 1,000	Strongly high
0,600 < r < 0,800	High
0,400 < r < 0,600	Medium
0,200 < r < 0,400	Weak
0,000 < r < 0,200	Strongly weak

(Sumber: Arikunto, 2006)

The test reliability analysis results provide a test reliability criterion of 0.738. The results of the test reliability criteria stated that the twenty spatial visual questions have high test reliability criteria. Determination of the position of students' spatial visual abilities was carried out by determining the category of spatial visual ability based on averages and standard deviations. The average and standard deviation were calculated using the following formulas.

$$Mi = \frac{\sum xi}{n} \quad SD = \sqrt{\frac{\sum fi x (xi-x)^2}{(n-1)}}$$

Note :

- Mi = Mean (rata-rata)
 SD = Standard of Deviation
 fi = frequency x of 1 to n
 xi = score x start i to n
 n = number of intervals

The result of the data calculation was obtained by the average value (M) = 35.06 where the Mean was based on the average value of the sample. The average (Mean) was divided by the number of individuals present in the sample. While the standard deviation (SD) = 11.06 where known as a static tool to describe the variables of a distribution and the variables of several distributions. Meanwhile, based on data on the student's spatial-visual ability, it was achieved at the ideal maximum score, the ideal minimum score, the ideal average (Mi) and the standard

deviation (SDi). After calculation, the ideal average price (M_i) = $1/2 (100+0) = 50$ and the ideal standard deviation (SD_i) = $1/6 (100-0) = 16.7$. Thus categories was created for the components of the student's spatial-visual ability data summarized in Table 4.

Table 4. Category of student spatial-visual ability

Score	Category
$M_i + 1 SD_i$ to $M_i + 3 SD_i$ $50 + 16.7$ to $50 + (3 \times 16.7)$ $66,7$ to 100	High
$M_i - 1 SD_i$ to $< M_i + 1 SD_i$ $50 + 16.7$ to $50 - 16.7$ $33,3$ to $< 66,7$	Medium
$M_i - 3 SD_i$ to $< M_i - 1 SD_i$ $50 + (3 \times 16.7)$ to $50 - 16.7$ 0 to $< 33,3$	Low

Determination of the effectiveness of the use of a learning medium for the concept of shapes of molecules, namely the *Bonat berakal* media was done by calculating the difference between the pretest value (initial assessment result) and posttest (final assessment result) using the N-Gain Score. The Normalized Score (N-Gain Score) can be calculated with the following calculation guidelines.

$$N\text{ Gain} = \frac{\text{score of posttest} - \text{score of pretest}}{\text{maximum score} - \text{score of pretest}} \times 100\%$$

Table 5. Categories for interpretation of the N-Gain effect

Percentage (%)	Interpretation
< 40	Ineffective
40-55	Less Effective
56-75	Quite Effective
>76	Strongly Effective

(Source: Hake R.R, 1999)

RESULTS AND DISCUSSION

Based on the results of the spatial visual ability pretest obtained, the lowest and the highest scores were 15 and 65, respectively. The results of students' visual and spatial abilities are summarized in Table 6.

Table 6. Description of student spatial-visual ability data

Lowest score	15,000
Highest score	65,000
M_i	50,000
SD	16,700
Main of Pretest	33,194
Main of Posttest	74,630

Based on the data of the average results of the pretest and posttest, spatial-visual ability obtained results are presented in Figure 2.

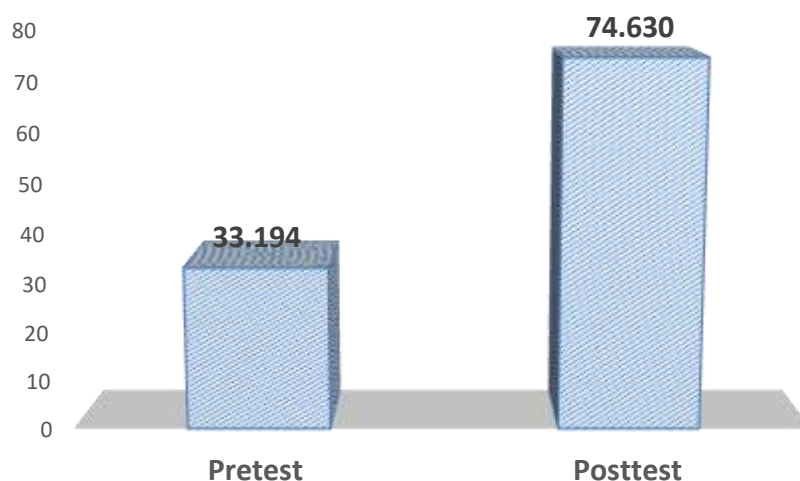


Figure 2. Students' spatial visual average results on the concept of shapes of molecules

The results of the pretest indicated that the students' spatial visual abilities on the concept of shapes of molecules were initially low. Conversely, the results of the posttest showed that the students' spatial visual abilities had improved and were now in the high category. The effectiveness of the *Bonat berakal* learning medium was measured by calculating the difference between the pretest and posttest results using the N-Gain Score. The results of the pretest and posttest are presented in Table 7.

Table 7. N-gain description of student spatial-visual ability

Score of pretest	33,194
Score of posttest	74,630
Ideal score	100,000
N-Gain	0,620
Category	Quite effective

The results of the analysis indicate that the use of the *Bonat berakal* media was effective in enhancing students' visual-spatial ability in the concept of shapes of molecules. Before using the media, the students' spatial visual abilities were in the low category, but after using the *Bonat berakal*, they were in the high category. The visible difference between the pre- and post-use of the media is demonstrated by the n-Gain score calculation.

Prior to using the *Bonat berakal* media, students only acquired the concept of shapes of molecules through drawings from books or through teacher demonstrations on the board. Although some students had the ability to visualize geometric shapes in three dimensions, not many students possessed this skill, which aligns with Piaget's theories on cognitive development. According to Piaget, students at the junior high school level should already be at the stage of abstract thinking or formal operational, yet many students are still at the concrete operational stage (Shoimah, 2020).

The use of the *Bonat berakal* media provided students with hands-on experience in constructing shapes of molecules through forming clay balls. Before they began forming the clay balls, they were required to have preliminary knowledge of bond electron pairs (PEI) and free electron pairs (PEB), electron domain theory, and VSEPR. Additionally, they needed to compare the atomic size and color of each atom they intended to create. The students worked collaboratively to form the clay balls, as depicted in Figure 3.



Figure 3. Making clay balls



Figure 4. Arranging clay balls into the model of molecule shape



Figure 5. Coloring clay balls to mark atomic differences

The aim of the study was to assess the effectiveness of the *Bonat berakal* media in improving students' visual-spatial abilities in understanding the shapes of molecules. Students were tasked to make atomic balls of various sizes, arrange them into shapes of molecules using a covalent bond in the form of a toothpick, and color the clay balls with atom-appropriate colors. Figures 3, 4, and 5 illustrate the activities carried out by the students.

The activities shown in Figures 3, 4, and 5 demonstrate that students possess sensitivity to colors, lines, shapes, spaces, and buildings, and have the ability to imagine things, recognize the identity of an atom from different perspectives, and estimate the distance and presence of atoms (Prasetyoningrom et al., 2015; Rosidah, 2014). Additionally, manipulating materials, as shown in the figures, can improve students' visual and spatial abilities (Putriana et al., 2022). This factor is believed to be responsible for the improvement in students' spatial visual ability from a low to high category.

The student-made media was stored in a plastic jar container for future reference, in case students had trouble imagining the shapes of molecules they created. The result of the activity was 5 shapes of molecules, as seen in Figure 6.

In comparison to the commonly used "molymod" media, *Bonat berakal* offers several advantages. "Molymod" is limited in the number and types of atoms it can represent, making it unable to associate the shapes of molecules of inorganic compounds with electron domains around the central atom numbering 3, 5, and 6. In contrast, *Bonat berakal* is capable of representing these inorganic compounds, which are not possible with "molymod".

The effectiveness of *Bonat berakal* was analyzed using n-Gain, which showed a value of 0.620. This result suggests that *Bonat berakal* is effective in improving students' visual-spatial abilities in understanding the shapes of molecules. This is in line with the opinion of Anshori et al. (2021), who stated that the shape of molecules cannot be directly observed through vision, and students must rely on their visual-spatial abilities to understand the molecular picture and predict the shape of the molecule.

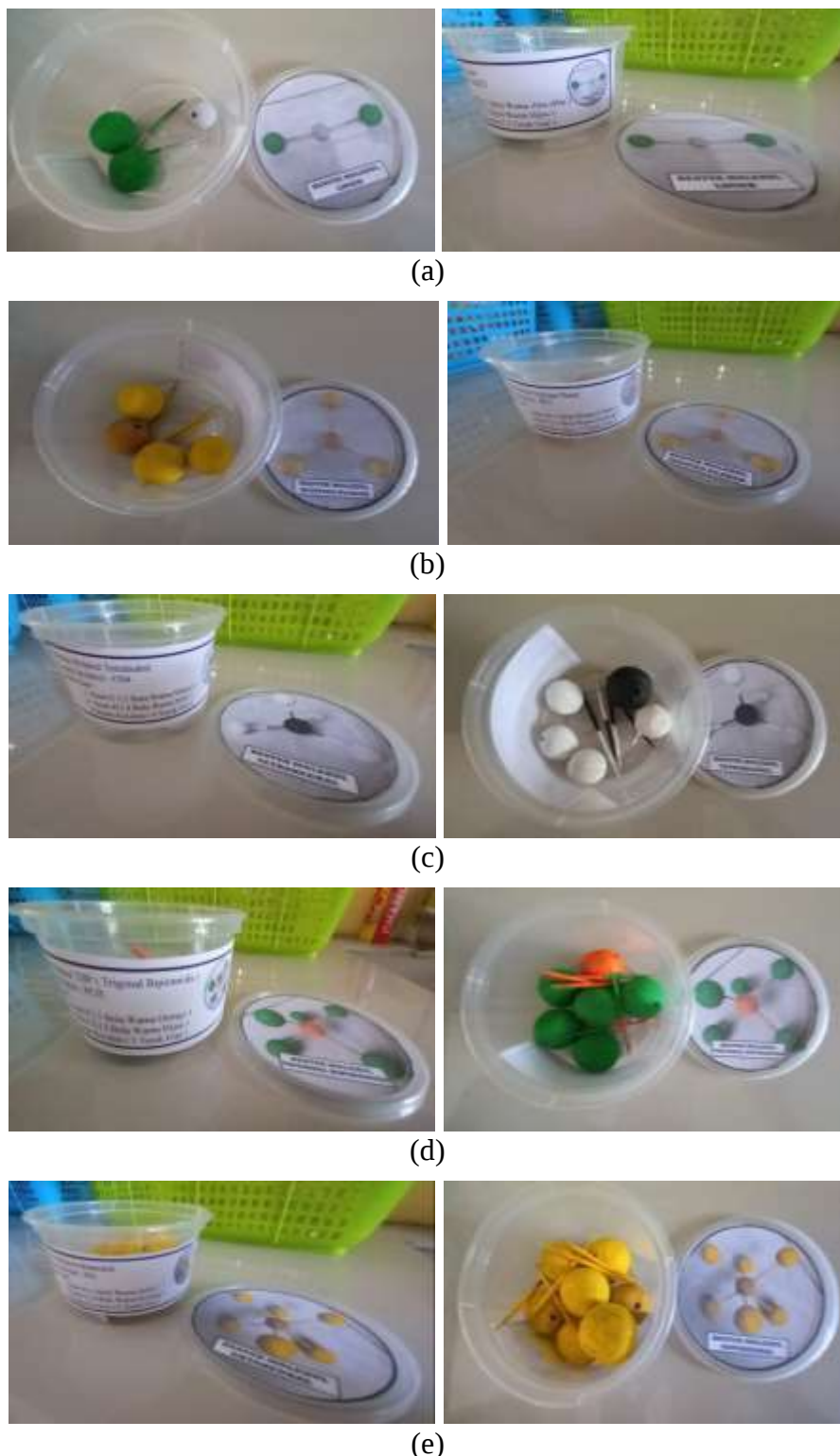


Figure 6. Student created (a) linear; (b) triangular planar; (c) tetrahedral; shapes of molecules; (d) trigonal bipyramidal; and (e) octahedral model of Shapes of molecules

Overall, the *Bonat berakal* media is an effective tool in improving students' visual-spatial abilities in understanding the shapes of molecules. The ability to understand the molecular picture and predict the shape of the molecule requires good spatial visual ability, and the *Bonat berakal* media provides an engaging and hands-on approach to enhance these skills.

CONCLUSION

In conclusion, the use of *Bonat berakal* media as a teaching tool has shown to be effective in improving students' visual-spatial abilities in understanding the shapes of molecules. The activities performed using *Bonat berakal* media develop students' sensitivity to colors, lines, shapes, spaces, and buildings as well as their ability to imagine, recognize the identity of an atom, estimate distances and presence of atoms, and manipulate materials. The results of the study, analyzed using n-Gain, showed a value of 0.620, indicating a significant improvement in students' visual-spatial abilities. These findings support the notion that shapes of molecules are abstract and cannot be directly observed through the sense of vision, making it important for students to have good visual-spatial abilities to understand and predict the shapes of molecules. The use of *Bonat berakal* media is recommended as an alternative teaching tool to overcome the limitations of traditional molymod media in teaching the shapes of molecules of inorganic compounds.

RECOMMENDATIONS

This research only knows the improvement of spatial visual ability. Further research may determine the relationship between spatial visual ability and student learning outcomes using the medium of clay balls that have been developed.

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