HYDROGEN
JURNAL KEPENDIDIKAN KIMIA
https://e-journal.undikma.ac.id/index.php/hydrogen/index

February 2026. 14(1)
e-ISSN: 2656-3061
p-ISSN: 2338-6487
pp. 219-227

Development of MolGrid (Molecule Grid) on Molecular Shape Topics Based on VSEPR Theory

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Article History
Received: 14-01-2026
Revised: 08-02-2026
Published: 28-02-2026

Keywords:
Development; MolGrid; e-puzzle; Molecular Geometry.

Abstract
Molecular geometry is a chemistry topic which often perceived as difficult by students because of its abstract nature. This study was completed to develop MolGrid (Molecule Grid), a digital puzzle-based learning medium on molecular geometry based on VSEPR theory, and to determine its validity and students' responses. The study obtained a Research and Development approach along with the ADDIE model. It is limited into the analysis, design, and development steps. The product was validated by two content experts and two media experts and tested on Grade XII students of SMA Negeri 5 Pontianak. Data collection was performed by utilizing validation sheets and student responses through the questionnaire. The results revealed the validity of the content reached 100% and media validity reached 98.61%, both categorized as highly valid. Students' responses in the initial and main trials obtained average scores of 91.41% and 88.18%, respectively, which fall into the very good category. These findings indicate that MolGrid is highly valid and well received and is therefore suitable for a moleculare shape learning media.

How to Cite: Ehya, S. U., Erlina, & Ulfah, M. (2026). Development of MolGrid (Molecule Grid) on Molecular Shape Topics Based on VSEPR Theory. Hydrogen: Jurnal Kependidikan Kimia, 14(1), 219-227. https://doi.org/10.33394/hjkk.v14i1.19315

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INTRODUCTION

Chemistry can be said to be a branch of natural science taught for the senior high school. Chemistry subjects include facts, theories, principles, and laws of the scientific work process (Wasonowati et al., 2014). Molecular shape is a commonly difficult chemistry topic. Students are tend to hardly understand it. Some initial research have demonstrated how this difficulty is caused by the abstract nature of the concept (Behmke et al., 2018; Erlina et al., 2018; Siregar & Harahap, 2020). Aligned with Anshori et al. (2021) statements, students address challenges in understanding molecular shape concepts followed by the difficulty in drawing molecular shapes with an average score of ability to understand molecular shapes of 61.3, the average value of visualizing molecular shapes is 35 with an average category.

Several previous studies have developed learning media related to molecular geometry, such as chemistry puzzle games, card games, and digital simulations, which have been reported to improve students' understanding and motivation (Yolanda & Iswendi, 2019; Siregar & Harahap, 2020). However, most of these media focus on visualization or game elements separately, and few integrate structured puzzle mechanisms with systematic visualization based on VSEPR in a single digital medium. In addition, previous studies did not specifically emphasize the development of learning media that train students' visual-spatial reasoning through gradual manipulation of molecular representations.

Therefore, this study positions MolGrid (Molecule Grid) as an innovative puzzle-based digital learning medium that integrates molecular geometry content based on VSEPR theory with structured grid puzzles, encouraging active learning and visual-spatial reasoning. The development of MolGrid is also in line with high school chemistry learning outcomes and 21st-century learning demands, which emphasize visualization skills, active student participation, and mea-

ningful use of digital technology.

One of them uses the theory of Valence Shell Electron Pair Repulsion (VSEPR). This topic has quite a lot of molecular shapes. To understand and decide the compound molecular shape, it requires memorization skills and appropriate comprehension regarding molecular shape topic (Oktaviani, 2020). VSEPR theory states that molecular geometry is determined by the reluctance between pairs of electron, causing them to reduce reluctance and form shapes which are predictable, such as linear, trigonal planar, and tetrahedral (Erlina et al., 2018).

The abstractness of molecular structures demands clear visual-spatial guidance; thus, visualization through 3D models or interactive simulations becomes crucial (Pitaloka et al., 2025). Studies likewise demonstrate that interactive media improves students' comprehension and motivation in molecular geometry (Behmke et al., 2018; Yolanda et al., 2019). As a result, if the teacher presents the topic in the learning process in an inappropriate or monotonous way, students can quickly feel bored and have difficulty understanding the concepts in the topic (Lestari et al., 2020).

The interview results from one of the chemistry teachers at SMAN 5 Pontianak, stated that the chemistry learning process used the lecture method. The use of media in the chemistry learning only uses textbook teaching topics. As a result, learning looks monotonous, where students primarilly listen to the explanation and there is limiteduse of learning media makes students feel less interested and consider the learning process to be boring (Winel et al., 2023). This condition results in a lack of student motivation to learn and understand learning topics, as aligned to Priuntari & Stevanus (2022) which show that learning media affects student learning motivation.

The lecture method that is often used by teachers has a weakness because it only makes students as listeners and note takers, thus making students have low abilities (Lontoh & Sihombing, 2022). Effective learning occurs when students have interest and motivation in learning. To get increased student learning outcomes, teachers are expected to be creative and able to create a learning atmosphere that can motivate students (Arianti, 2018).

The utilization of learning media is potential to foster students to improve their activeness along with being creative (Munir, 2015). One of the efforts to make students understand the topic will certainly require teachers to utilize learning media in helping the teaching and learning process (Agustini & Sari, 2018).

Game-based learning media is possible to create an enjoyable learning atmosphere. The right type of learning media in the form of games can help make learning more active and provide a pleasant learning experience, so that it may improve their learning interest (Accraf et al., 2020; Siskawati, 2016). In Afifah & Hartatik (2019) research, stated that game-based learning media can increase students' learning motivation. Therefore, a learning media in the form of a game is needed, especially for those known through interviews that they like to disscus in groups and like games.

Learning media is one of the external factors that can be used to improve students' learning efficiency (Pratiwi & Meilani, 2018). Learning media that can be an alternative is e-puzzle, because this game challenges students' creativity and memory. So that it can bring motivation to always try to solve problems but still fun. E-puzzle is a game media that utilizes the internet and electronic devices as a way to use it (Tiyana, 2021). In research by Ferbriyanita & Wardhani (2020) puzzle media can increase students' learning motivation, which after using puzzle media has increased by 35%.

Although molecular geometry plays an important role in chemistry learning, teaching practices and learning media at SMA Negeri 5 Pontianak are still dominated by textbooks and lecture methods, which provide limited visualization and interactivity. As a result, students have difficulty understanding and visualizing molecular shapes based on VSEPR theory and show low motivation to learn. Therefore, interactive and visually oriented learning media are needed to facilitate conceptual understanding and student engagement. Based on this need, this study aims to develop MolGrid (Molecule Grid) as a digital puzzle-based learning media to support students' understanding of molecular geometry based on VSEPR theory.

METHOD

This research employs the Research & Development (R&D) method through applying the ADDIE model, involving the steps of analyz-

ing, designing, developing, implementing, and evaluating (Sugiyono, 2019).

This research was conducted only up to the developing stage. However, this study was limited to the development stage, therefore, the focus was on product validity and student responses. As a result, this study did not examine the effectiveness of MolGrid on student learning outcomes or learning achievements.. This developing produces an E-Puzzle on Molecular Shape Topic Based on VSEPR Theory. The population involve students who already took chemistry lessons on the Topic of Molecular Forms at SMAN 5 Pontianak.

In the analyze stage, identification of student learning problems and needs analysis were completed by interviewing chemistry teachers and students at SMAN 5 Pontianak so that information was obtained in the field regarding the problems and needs of students, which could be used as a guide for developing media.

During the stage of designing, product design is brought up. The steps here are by determining the media to be developed and making a storyboard for the media (Sugiyono, 2019). This stage also makes validity test sheets and student response questionnaires.

The development intends to realize the design of the product and validate the media. The developed media will be validated to decide the level of the product validity. This test involves two expert lecturers for topic validation and two expert lecturers for media validation, where the validity assessment sheet has been validated by these experts.

Furthermore, formative revisions were made based on suggestions and input from the experts. After conducting a validity assessment, an initial response test was carried out by students on a small scale, namely 9 respondents, then revised if necessary according to the results of the initial response test. Then the researchers conducted the main response test on 25 respondents.

This study uses data collection techniques through indirect communication techniques, namely interviews with teachers and students to collect information needed in the study. Then using indirect communication techniques, using a questionnaire sheet for validity assessment and Students response.

Validity Assessment Analysis of Molecular Shape E-Puzzle Based on VSEPR Theory

Validity is the extent to which an instrument or product measures the object before being administered in the field (Sugiyono, 2015). The validity assessment analysis process is carried out by calculating the total score for each item, then the percentage score per item can be calculated using the following formula.

$$P = \frac{\Sigma}{\Sigma Xi} \times 100\%$$

While, P = % of score acquisition; ΣX = number of scores (total score) per item; ΣXi = ideal score (highest). Furthermore, the average % of overall validity can be calculated using the following formula.

$$V = \frac{\Sigma P}{n}$$

While,V = average % of validity; ΣP = the sum of the % scores in every aspect; n = number of every aspect measured. Then from the calculation of the validity assessment, the media is classified in the criteria in Table 1.

Table 1. Product Validity Level Criteria

Range (%)	Category
0 – 40	Invalid
41 – 60	Less valid
61 – 80	Valid
81 -100	Highly valid

(Source: Riduwan, 2015)

Analysis of the Assessment of Studentss' Response to the E-Puzzle of Molecular Shapes Based on VSEPR Theory

To find out the students' response to the E-Puzzle of Molecular Shapes Based on VSEPR Theory, an assessment was completed by filling out a questionnaire by students. The assessment uses a Likert scale which invole scores 4 (strongly agree), 3 (agree), 2 (disagree), and 1 (strongly disagree). This Likert scale includes positive and negative assessments, which are shown in table 2.

Table 2. Likert Scale Score Criteria

Category	Positive Statement	Negative Statement
SA	4	1
A	3	2
D	2	3
SD	1	4

(Source: Riduwan, 2015)

Then the calculation of the acquisition of the test results of each item is done by calculating the percentage using the following formula.

$$P = \frac{\Sigma X}{\Sigma Xi} \times 100\%$$

While, P = % of score acquisition; ΣX = number of scores (total score) per statement; Σxi = number of ideal scores (highest score). Furthermore, the overall average percentage of students' responses to the media was calculated using the following formula.

$$P_{total} = \frac{\Sigma P}{n}$$

While, P_total = % of total response; ΣP = the sum of the % of scores for each aspect; n = number of aspects assessed. Then the Students response criteria are determined based on the categories in table 3.

Table 3. Students Response Criteria.

(%)	Criteria
0 – 20	Very less
21 – 40	Less
41 – 60	Fair
61 – 80	Good
81 – 100	Very good

(Source: Riduwan, 2015)

RESULTS AND DISCUSSION

This research and development is based on ADDIE development steps, which include Analyze, Design, Development, Implementation, and Evaluation stages. However, only Development was carried out for this research

Analysis

Based on interviews with a chemistry teacher, the learning method used for molecular geometry is mostly lecture-based, with textbooks as the main learning resource. As a result, student interaction during the learning process is limited, creating a monotonous learning atmosphere. This condition is connected to Sani et al., (2024) research findings, who stated that lecture-based instruction tends to place students in a passive listening role.

In addition, interviews with students showed that they preferred learning activities that involved discussion and games, which is consistent with the findings of Nur Afifah (2019), who found that game-based learning media may grow student motivation to learn. These conditions indicate that learning media have not been optimally utilized to support students' comprehension of molecular geometry based on VSEPR theory and to create a more engaging learning atmosphere.

Design

This stage is carried out making plans regarding the product to be developed. The steps taken by researchers are making learning media designs, compiling game instructions, making puzzle designs, and questions. The game product developed was named MolGrid (Molecule Grid).

Figure 1. Cover View and Game Instructions

The beginning of product design concept of the game media is basically the same as an ordinary puzzle game, which is to arrange the pieces of the picture which will later become a complete picture. However, the puzzle game media that researchers design is possible to apply through electronic tools like smartphones and laptop.

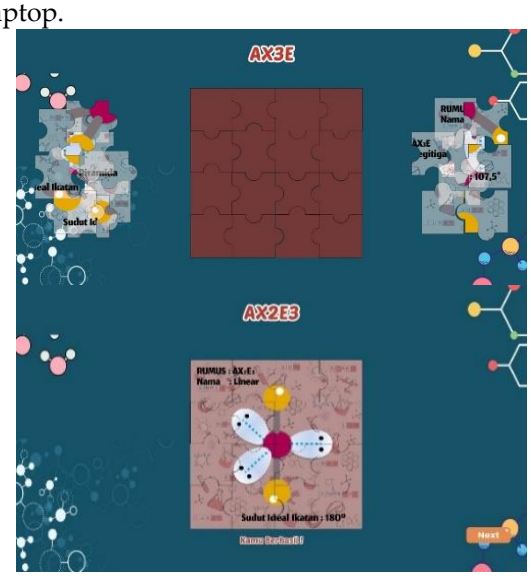

Figure 2. Puzzle View

The puzzle pieces will be on the side around the piece installation box. The pieces will form a complete picture of a molecular shape along with some other information. The puzzle is made 4 x 4 so that there are 16 pieces to be arranged and 13 molecular shapes to be arranged. After completing the entire puzzle, students will get different questions for each group.

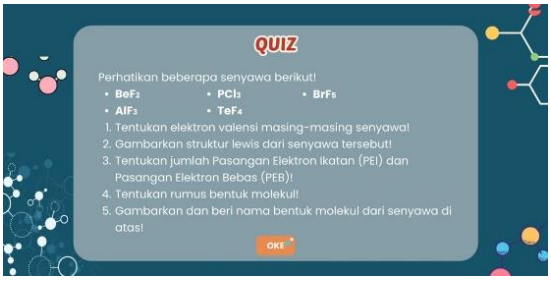

Figure 3. Question Display

Development

The development stage is the realization of the product that has been designed. At this stage, the validity assessment of the product is carried out, filling in the response questionnaire by students for the initial trial and main trial.

Validity Assessment

The validity assessment by experts is seen from the media and topic aspects. These two aspects were each assessed by 2 validators. Indicators of validity assessment on topic aspects can be seen in Table 4.

The validity assessment results for each content aspect indicator are presented in Figure 4.

Table 4. Indicators of Topic Aspect Assessment.

Indicator	Description
Educators	1. The information presented is in accordance with the topic in the Learning Outcomes 2. The information presented is in accordance with the topic in the Learning Objectives 3. The information conveyed in the game media is in accordance with the concept of the VSEPR Theory mole shape 4. The accuracy of the use of language that refers to the Refined Spelling
Usefulness of Media in Learning	5. Facilitate the teaching and learning process. 6. Simplify it for students to learn

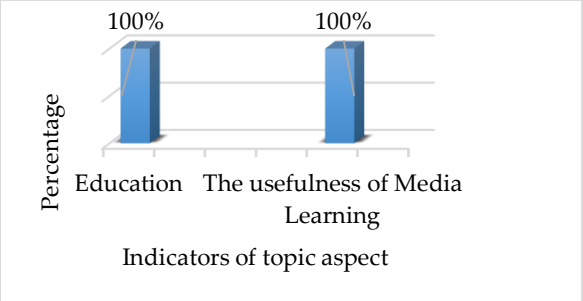

Figure 4. Validity Assessment of Topic Aspects

The education and usefulness indicators obtained the same average score of 100%, resulting in an overall average content validity score of 100%. According to Riduwan (2015), products with a validity percentage in the range of 81–100% are categorized as highly valid. Therefore, the content aspect of MolGrid can be classified as highly valid

For indicators of media aspect validity assessment is found in Table 5.

Table 5. Indicators of Media Aspects Assesment

Indicator	Descripsion
Media Display	1. The color combination in the media design is harmonious 2. The suitability of the contents of the media composition with the topic 3. Appropriateness of font size in the media 4. The media display is attractive and fits the theme of the topic
Media Usage	5. Game media is easy to use by students 6. Game media can be used on smartphones and laptops 7. Game media can be used anywhere and anytime
Media Quality	8. Digital game media is interesting 9. The game media is safe to use by students 10. The digital game media display is clear

The results of the validity assessment of each indicator of media aspect assessment can be seen through Figure 5.

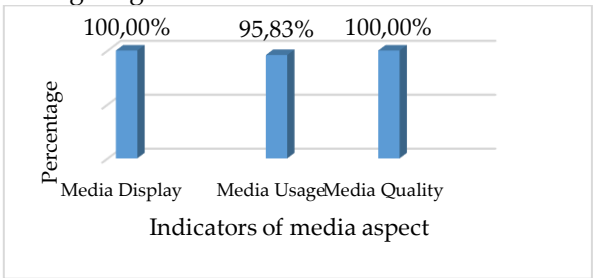

Figure 5. Media Aspect Validity Assessment

The validity assessment results for the media aspects of media display, media use, and media quality indicators obtained average scores of 100%, 95.83%, and 100%, respectively. The overall average score for the media aspect was 98.61%.

Table 6. Recapitulated Value of Validity by Experts

Aspect	Percentage	Criteria
Content	100%	Highly valid
Media	98,61%	Highly valid
Average	**99,30%**	**Highly valid**

According to Riduwan (2015), products with a validity percentage in the range of 81–100% are categorized as highly valid. Therefore, MolGrid

media can be classified as highly valid in terms of the media aspect. In table 6, it can be seen that the content aspect is considered highly valid with a score of 100%. Then the media aspect gained a score of 98.61% with a highly valid criteria. It presents how the MolGrid media developed obtained an average score for all aspects of 99.30%, so it is categorized as highly valid to use.

During the assessment process, there were improvements and suggestions from experts on the game instructions and the page leading to the puzzle games which are described as follows.

1) On the game instructions section, there are improvements to writing errors, the foreign languages (*italic*) usage, and the addition of game instructions points, as demonstrated in figure 6.

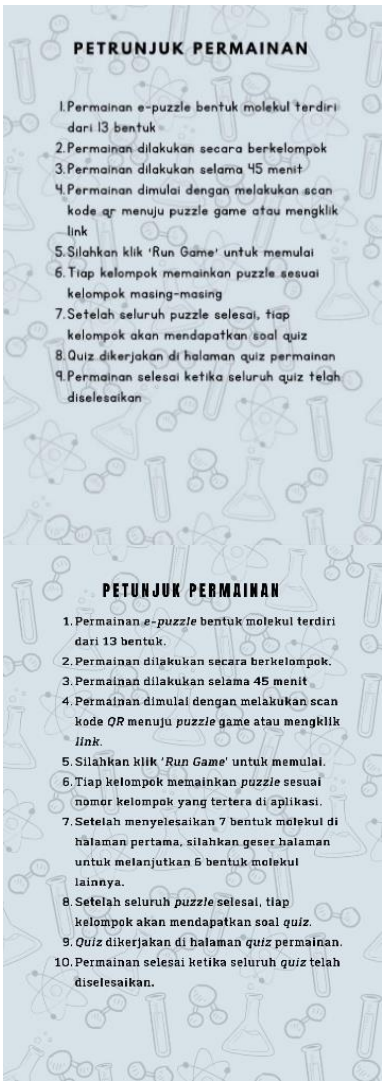

Figure 6. Game Instructions Section before and after The Improvement

2) On the page leading to puzzle games, there are improvements to the writing of foreign languages (*italic*), font size, and the use of left-aligned should be center-aligned, as demonstrated through figure 7.

Figure 7. Section of The Page Leading to Puzzle Games before and after Improvement

The Result of Student Respons

After conducting a validity assessment, the next stage is to conduct a response test involving 34 students of class XII SMA Negeri 5 Pontianak who have taken lessons on chemical bonding topic, especially molecular shapes so that students can find out whether MolGrid media on VSEPR theory molecular shape topic is suitable for use. This response test is divided into an initial response test conducted on 9 students and 25 students of the main response test. Each statement item can be seen through table 7.

Table 7. Response Test Statement Items on Students

Aspect	Statement
Media	1. The color combination in the design is appropriate.
	2. The appearance of the E-Puzzle media is interesting.
	3. The writing on the media looks clear.

Aspect	Statement
	4. The game media is easy to use.
	5. The instructions for using the game media are clear.
Content	6. The content of the game media with the topic is appropriate.
	7. The language used is difficult to understand.
	8. I feel happy when using the game media.
	9. Game media makes learning chemistry difficult.
	10. I feel motivated when using the game media.
	11. Game media makes me more interested in learning.

The initial response of students to MolGrid media on VSEPR theory molecular shape topic can be seen in table 8 and table 9.

Table 8. Initial Response Test Results on Students

Response Aspect	Skor (%)	Criteria
Media	88,33%	Very Good
Content	93,98%	Very Good
Average	**91,41%**	**Very Good**

In the initial response test, the media aspect gained a percentage of 88.33% with a very good criteria. In summary, MolGrid media owns an appealing visual display and is easy to use. This aligns with previous studies showing that attractive color combinations, clear layout, and user-friendly interfaces can increase students' attention and willingness to interact with learning media (Plass et al., 2014; Yolanda et al., 2019). Students' high scores in this aspect indicate that MolGrid successfully meets these criteria.

The content aspect scored 93.98% with a very good category. This indicates that the content presented is relevant and useful for students. Means that the language used in the media is easy to understand (Yolanda et al., 2019b), as well as the game media is fun to use and helps learning chemistry (Miola Anggreini et al., 2019).

The overall average score of the initial response test results obtained was 91.41% with a very good category, which means that the media developed was accepted well. Thus, MolGrid media should be continued at the main response test stage without improvement.

Table 9. Main Response Test Results on Students

Response Aspect	Score (%)	Criteria
Media	87,60%	Very Good
Content	88,67%	Very Good
Average	**88,18%**	**Very Good**

In the main response test conducted on 25 students obtained a score of 87.60% in the media aspect in the very good category, which can be seen that MolGrid media has an attractive overall display and can be easily used. In the content aspect, the score was 88.67% which was also in the very good category. In short, the media can help facilitate chemistry learning, motivate students and make game users feel fun. These results show consistent student acceptance, indicating that MolGrid remains effective even when tested on a larger group, supporting previous findings that interactive game-based media sustain motivation and engagement during learning.

Discussion

Based on the data found, the overall student response to MolGrid media in the initial response test reached 91.41%, and in the main response test reached 88.18%. As cited from Riduwan (2015), a percentage score in the range of 81–100% is decided very good. These results indicate that students responded very positively to MolGrid, suggesting that the MolGrid media based on molecular geometry in accordance with VSEPR theory is feasible and acceptable for use in learning. This positive response can be interpreted as evidence that MolGrid provides a learning experience which matches the characteristics of students from high school, who tend to prefer interactive activities, games, and visual-based learning. The puzzle-based model allows students to actively manipulate molecular structures while observing the spatial relationships between atoms, which supports spatial visual reasoning in understanding molecular geometry.

Furthermore, these findings are consistent with multimedia learning theory, which states that interactive and visual media can reduce cognitive load and facilitate understanding of abstract concepts such as molecular geometry. The consistently high response scores indicate that MolGrid is effective because it combines structured visualization with active manipulation, allowing students to construct their own understanding rather than just passively receiving information. These results can be aligned to prior research reporting that puzzle-based and game-based chemistry media may improve student motivation and conceptual comprehension (Yolanda & Iswendi, 2019).

In the response questionnaire comments section, some students suggested adding sound effects during puzzle assembly and providing visual reactions or decorations when the puzzle is completed. Although this media was not revised in this study because it had already achieved an excellent rating, these suggestions indicate students' expectations for richer feedback features. Therefore, future research could focus on enhancing MolGrid by integrating audio and animation elements to further improve engagement and learning experiences.

CONCLUSION

After analyzing the findings from this completed research, MolGrid (Molecule Grid) is categorized as a highly valid tool and can be applied for learning media for molecular geometry according to VSEPR theory. Student response tests also showed very positive results, namely that MolGrid has an attractive appearance, is easy to use, and supports an enjoyable learning experience. The impact of these findinds include the availability of alternative puzzle-based digital learning media that can facilitate students' visual-spatial understanding of molecular geometry and increase learning engagement. The uniqueness of this research lies in the development of MolGrid, which integrates molecular geometry content based on VSEPR theory into a structured digital puzzle format, combining visualization, active manipulation, and game-based learning in one medium through an approach that has not been applied in previous studies.

RECOMMENDATION

In line with the findings, the researcher stronly suggest that MolGrid media on molecular shape topic based on VSEPR theory can be used as further research topic regarding the effectiveness of use in learning. MolGrid media on molecular shape topic based on VSEPR theory is recommended to be developed and innovated on other learning topics by modifying the media according to the conditions and needs of students, and can add sound during the game as well as ornaments or reactions after completing the game.

ACKNOWLEDGMENT

The author is grateful to the expert lecturers who have validated assessment sheet, response questionnaire, and MolGrid (Molecule Grid) media on molecular shape topic based on VSEPR theory. In addition, the researcher also thanks the school both teachers and students, as well as all those who have participated in this study

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