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Learning Cycle 5E through Interactive Simulator to Improve Understanding of Molecular shapes and Chemistry Identity

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Abstract
This study aims to improve students understanding of concepts and chemistry identity in molecular shape material through the application of the *learning cycle 5E* (LC 5E) model assisted by interactive digital simulator media. The research method used is classroom action research (CAR) with the Kemmis and Taggart model. The model has four stages, namely planning, action, observation, and reflection. The subjects in this study were 32 students from class X-3 SMA Brawijaya Smart School in the 2024/2025 academic year. The data obtained were analyzed descriptively. Based on the results of the study, it is known that in cycle I, the application of LC 5E assisted by interactive digital simulator media has not been able to improve understanding of molecular shapes and the percentage increase in students' chemistry identity is low. Therefore, improvements were made in cycle II referring to the results of the reflection, there was an increase in concept understanding from 68% to 82% with classical completeness reaching 81%. In addition, the n-gain value of 71.8% was obtained, indicating that the application of the LC 5E model assisted by interactive digital simulator media was quite effective in improving students' concept understanding on molecular shape material. There was also an increase in students' chemistry identity, especially related to the indicators of *mastery experiences* and *verbal persuasion*, 57% and 50% respectively. Thus, it can be concluded that through the application of the *5E learning cycle* model assisted by interactive digital simulator media on the material of molecular shapes is effective enough to improve students' concept understanding and chemistry identity.

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INTRODUCTION

In the 21st century, *Science, Technology, Engineering, Mathematics* (STEM) education has a significant impact on the development of a country both in the economic, social, and geopolitical fields which are the foundation for the creation of sustainable development (Brigid Freeman, Simon Marginson, 2019). Chemistry is included in the field of *science* in STEM education which plays an important role in preparing students to face global competition and problems in everyday life. Therefore, strengthening chemistry education will advance national development (Oztay et al., 2022). Chemistry is a science that studies the composition, structure, properties, and changes in matter, with an emphasis on mastering concepts through experience-based knowledge construction, not just memorizing (Alam, 2021; JUNEJO, Yasmeen and Mehmet, 2024).

In learning chemistry, especially the material of molecular shapes is generally still considered difficult by students. When studying molecular shape, it is known that it affects the physical and chemical properties of a compound such as polarity and reactivity (Underwood et al., 2021). However, in practice in the field many students have difficulty connecting the three levels of representation (macroscopic, submicroscopic, and symbolic), especially in visualizing the effect of free electron pairs on molecular shape (Nugraha et al., 2019). As a result, misunderstandings often occur such as not being able to calculate the coordination number correctly or the inability to analyse differences in molecules that are almost similar, for example NH3and BF3 (Rizkiana & Apriani, 2020).

This is triggered by the abstract characteristics of the material, which requires transfer in three levels of representation resulting in students only memorising the general formula (AXnEm) without understanding the process of forming molecular geometry (Nugraha et al., 2019). Students' difficulties in understanding molecular shapes are not only due to cognitive limitations, but also related to their affective dimensions. Referring to the results of the chemistry identity diagnostic assessment (pre-cycle) and interviews with students of class X-3 SMA Brawijaya Smart School, the average is in the medium category with low self-esteem and social recognition of them as "chemistry people". These findings are in line with Hosbein & Barbera's (2020a) chemistry identity theory which states that chemistry identity is formed by four main aspects: (1) low mas*tery experiences* observed from the perceptions of most students revealed that chemistry is a difficult subject; (2) weak *situational interest* known from their point of view that chemistry is less contextual in everyday life; and (3) limited *verbal persuasion & social recognition indicated* by the lack of social recognition. *recognition* is indicated by the lack of appreciation of chemistry skills from peers, especially during group learning; (4) which leads to low chemistry identity, namely the inner belief and social recognition that "I am a chemistry person" (Hosbein & Barbera, 2020a).

To overcome the problems that have been described, adjustments in learning are needed so that it is expected to increase students' understanding of molecular shape material and chemistry identity. *The Learning Cycle* 5-E (LC 5-E) *learning* model can be one solution because it focuses on helping students understand concepts deeply through building conceptual understanding that has been integrated with old and new knowledge, reflection, and direct application of concepts (Pedaste et al., 2015). In addition, the phases in the LC 5E model are also able to support the development of chemistry identity, for example, the *engagement* phase triggers *situational interest* from students and the exploration and *elaboration* phases provide space for them to experience success in completing tasks (*mastery experiences*) (Hosbein & Barbera, 2020b; Sugeng Suryanto, 2020).

To strengthen the improvement of students' concept understanding of molecular shape material, the application of the LC 5E model can be carried out with the help of interactive digital simulator media such as PhET because it allows students to manipulate molecular shapes based on the number of electron pairs and see real-time 3D visualization of molecular shapes (Stiawan et al., 2022). The integration between the Learning Cycle 5E (LC 5E) learning model and PhET media not only has an impact on improving conceptual understanding, but also supports the formation of students' chemistry identity. Thus, this Classroom Action Research aims to improve students' understanding of molecular shapes and chemistry identity through the application of the *Learning Cycle 5E* model assisted by interactive digital simulator media.

METHOD

The research employed Classroom Action Research (CAR) based on the model by Kemmis and Taggart (1988), which includes a cyclical process of planning, action, observation, and reflection, as illustrated in Figure 1.

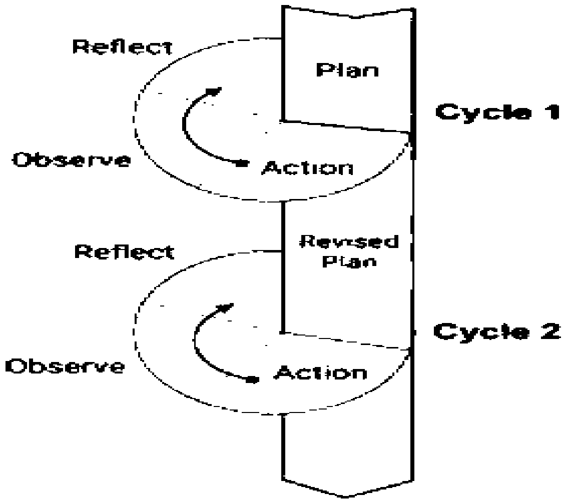

Figure 1 Schematic of classroom action research procedure (Semathong, 2023)

This research is a Classroom Action Research (PTK) with a model developed by Kemmis and Taggart (1988). Each cycle in this model consists of four main stages, namely: planning, action, observation, and reflection (Semathong, 2023). PTK was carried out for 2 cycles, namely in cycle 1 the material in the form of molecular shapes with central atoms only having bonding electron pairs (PEI) while in cycle 2 the material of molecular shapes with central atoms has PEI and free electron pairs (PEB). The design of the PTK model used is shown in Figure 1. Students' understanding of the sub-chapter of molecular shape material and chemistry identity is the variable measured in this study. In its implementation, it was selected *Computational Thinking* (CT) approach and *Learning Cycle 5E* (LC 5E) *learning* model combined with interactive digital simulator media.

The research was conducted in April 2025. This is in accordance with the Chemical Bond chapter for the molecular shape material subchapter which is delivered at the beginning of the even semester of the 2024/2025 academic year. The research was conducted at SMA Brawijaya Smart School, Malang, in April 2025 during the even semester of the 2024/2025 academic year. The subjects in this class action research were students of class X-3 SMA Brawijaya Smart School in the 2024/2025 academic year totalling 32 people.

Quantitative data collection techniques used include a description test for concept understanding as many as 10 questions each for *pretest* and *posttest* (5 questions of post-test cycle 1 and 5 questions of post-test cycle 2). Then the chemistry identity diagnostic assessment in the form of a Likert scale with score 1 (strongly disagree), score 2 (disagree), score 3 (neutral), score 4 (agree), and score 5 (strongly agree) (Nisa, A. A., 2023). Meanwhile, qualitative data collection techniques include observation, interviews, and documentation which are used as supporting data to verify students' understanding when working on questions/tasks on molecular shapes and to find out the development of their chemistry identity (Sugeng Suryanto, 2020).

Qualitative and quantitative descriptive approaches are used to analyse the data that has been obtained. Qualitative data analysis serves to explain the activities of students during learning. Increased understanding of molecular shape material is known by means of quantitative data analysis, namely comparing test results before and after learning using the following descriptive percentage formula.

$$\text{Concept understanding score} = \frac{\sum \text{answercorrect}}{\sum \text{overall question}} x100$$

Learners who get a score < 70 are declared to have learning difficulties, while learners who get a score ≥ 70 are declared to have completed learning. For classical learning, learning completeness must reach at least 75% of the number of students who have completed learning from all students in the class. The comparison of each cycle using the percentage of classical completeness is used in determining the success of PTK (Sugeng Suryanto, 2020). Then, the effectiveness of the application of the LC 5E learning model assisted by interactive digital simulator media in improving students' understanding of molecular shape material is known by calculating the N-gain value (Winata, 2024). The calculation formula is as follows:

$$\text{N}-\text{Gain} = \frac{PosttestScore - Pretest \quad Score}{IdealScore - Pretest \quad Score} \text{x}100$$

The interpretation criteria of the N-Gain calculation results are described in Table 1.

Table 1. N-Gain score criteria

Percentage (%)	Criteria
<40	Ineffective
40-55	Less Effective
56-75	Effective enough
>76	Effective

In addition, quantitative data on chemistry identity was also analysed through comparing test results before and after learning. The categories of students' chemistry identity scores were adapted from (Nisa, 2023) as shown in Table 2 (Nisa, A. A., 2023).

Table 2. Categories of students' chemistry identity scores

Score	Category
4-5	Very good
3-4	Good
2-3	Moderate/middle/medium
1-2	Less

Indicators on the chemistry identity diagnostic assessment in more detail are listed in Table 3.

Table 3. Indicators of learners' chemistry identity

Indicators	Description	Number of question items
Mastery experiences	An experience in which the individual succeeds in completing a task or challenge so that builds up confidence in their abilities	6
Verbal Persuasion	Encouragement or positive feedback from others (e.g., instructors, teachers, peers, family) that reinforces the individual's belief in their abilities.	6
Initial interest feeling-related	Emotional engagement (feelings of excitement, interest, curiosity) towards an subject at the beginning of learning	4
Initial interest value-related	Perception about importance or the usefulness of a subject at the beginning of learning	3
Identity	Self-perception and external recognition as a "chemistry person" in the context of (e.g. a classroom)	1

The calculation formula used to find the average percentage of achievement of each chemistry identity indicator (Nisa, A. A., 2023), namely:

$$\text{Score} = \frac{\sum \text{number of individuals achieving the indicator}}{\sum \text{total number of learners}}$$

RESULTS AND DISCUSSION

This class action research, starting from the planning, implementation, observation, and reflection stages. The classroom action used is the Learning Cycle 5E (LC 5E) model assisted by interactive digital simulator media on molecular shape material with a learning approach that is Computational Thinking. In an effort to apply the learning cycle 5E model assisted by interactive digital simulator media as well as possible, it must be done with a maximum of each stage according to the plan that has been designed.

Pre-Cycle

Before the application of the learning implementation with the LC 5E model, a pretest was conducted to determine their concept understanding in the pre-cycle condition. Then, it was used as one of the materials considerations in the division of groups learning that learners with heterogeneous cognitive ability levels (highest to lowest) as presented in Table 4.

Table 4. Molecular shape pretest results

Description	Pretest Score
Lowest score	12
Highest score	47
Number of students completed	0
Number of incomplete students	32
Average score	36
Percentage of completeness (%)	0%

Referring to Table 4, it can be seen that as many as 32 students who took the pretest did not reach the percentage of completeness in molecular shape material. This indicates that most students do not understand the concepts related to the shape of the molecule which will be studied. In addition, the initial condition of the learners' chemistry identity was also identified through the implementation of diagnostic assessment in the form of questionnaire filling. The data obtained is shown in Table 5 as follows.

Table 5. Pre-cycle learner chemistry identity

Indicators	Value	Category
Mastery Experiences	3.118	Medium
Verbal Persuasion	2.771	Medium
Initial interest feeling-related	3.229	Medium
Initial interest value-related	3.528	Medium
Identity	2.458	Less
Average	3.0208	Medium

Based on the results of the assessment, it was observed that the chemistry identity of the average learner was in the moderate category and there was one indicator in the deficient category. Thus, efforts need to be made to improve students' chemistry identity. This classroom action research is an exploratory study because chemistry identity is a new topic and previous research discusses the existence of a correlation between concept understanding and chemistry identity. Meanwhile, research related to efforts to improve concept understanding and chemistry identity has never been done so that it can be used as a basis for future research.

Cycle 1

Planning Stage

The planning stage was carried out starting from the preparation of teaching modules for 2 cycles, learner activity sheets (LKPD), diagnostic assessments, *pretests* and *posttests*, learning media (in the form of interactive digital simulators and power points), to teaching materials with provisions:

a. Learning Outcomes

The subject of chemistry phase F, specifically studies the nature, structure and interaction of particles in forming various compounds.

b. Learning Objectives

- Learners can determine the shape of a molecule with a central atom that only has a bonding electron pair (PEI) based on VSEPR theory correctly.
- Learners can determine the shape of a molecule with a central atom having PEI and free electron pairs (PEB) based on VSEPR theory correctly.

Implementation Stage

The implementation refers to the learning syntax in the LC 5E model which is implemented as follows.

1. *Engagement,* in this phase the teacher asks again related to the concept of atoms, how atoms achieve stability, and directs them to think if atoms bind together whether it only produces one form or various kinds. Then, the teacher also tries to foster interest and curiosity about the material to be studied by displaying a waste processing site in the area around the school that produces biogas where the main content is methane (CH_4) . The usefulness of methane as a fuel is closely related to the physical and chemical properties influenced by its molecular shape. Through this activity, the teacher as a facilitator directs students to ask questions related to the molecular shape of the compound.
2. *Exploration, the* teacher directs students to conduct discussions in groups to observe, understand, and analyze through material presentation and guiding questions. There are 5 groups of 6-7 members. Group division is based on pretest results. In the LKPD there is introductory material containing VSEPR theory and steps to determine the shape of molecules that can be used by students as a learning resource in understanding the theory. Furthermore, the first activity is to get to know VSEPR theory by analyzing a number of questions that guide them to build an understanding of concepts related to VSEPR theory. Then, in the second activity learners are invited to construct their understanding of molecular shapes with the help of interactive digital simulator learning media they can analyze the questions presented.
3. *Explanation,* writing answers to both *exploration* activities in cycle 1 is done in this phase to focus learners when explaining the results of their concept understanding construction. After that, the teacher provides verification and reinforcement of the results of the learners' presentations. In this activity, the teacher also asked the group leader to convey the contribution of each member during the discussion process.
4. *Elaboration,* learning activities contain applying the understanding of concepts that have been obtained from the previous phases to new situations aimed at expanding understanding and developing analytical skills, namely by answering questions related to determining the shape of the molecule and writing down the steps.
5. *Evaluation, the* teacher assesses students' understanding of molecular shape material while evaluating the achievement of learning objectives, namely students can determine the

shape of a molecule with a central atom that only has a bonding electron pair (PEI) based on the VSEPR theory correctly. The evaluation instrument in the form of a *posttest* contains concept understanding test questions

Observation and Test Phase

This stage aims to review teacher and student activities during the learning process as well as the effectiveness of using media in improving concept understanding and its impact on improving chemistry identity.

Understanding the concept of molecular shape

It can be seen based on the cognitive learning outcomes of students from the posttest after completing the learning activities in the first cycle. The test totaled 5 questions consisting of 1 multiple choice question, 1 matching question, and 3 description questions. The following is data on students' cognitive learning outcomes in cycle 1 as shown in Table 6

Table 6. Results of posttest cycle 1 molecular shapes

Description	Pretest Score
Lowest score	28
Highest score	100
Number of students completed	19
Number of incomplete students	13
Average score	68
Percentage of completeness (%)	59.4
Students with score <70 (%)	40.6

Based on the data in Table 6, it can be seen that all performance indicators have not been achieved during the *pretest*. The average understanding of concepts in cycle 1 is still 68 which has not yet reached the expected indicators, reinforced by the fact that there are still many students who get scores below 70, namely 40.6% and the classical provision has only reached 59.4%. The following are concepts that generally still cause misconceptions for students. 1) Some students have not been able to determine the electron configuration correctly while this ability is the basis for knowing the valence electrons of an atom so that it can determine the central atom, bound/substituent atoms, the number of electron pairs (PEI and PEB). This is in line with research from Rizkiana (2020), namely students have not been able to understand information related to the number of electrons contributed by bound/substituent atoms (Rizkiana & Apriani, 2020). Thus they have not been able to calculate the coordination number correctly which helps in determining the shape of the molecule obtained. 2) Learners draw the Lewis structure as a series of covalent bond lines instead of using electron dots as shown in Figure 2.

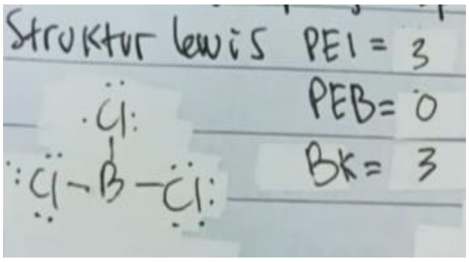

Figure 2 sample answers of students who still have misconceptions related to describing Lewis structures

In addition, they consider the Lewis structure to be the same as the shape of the molecule even though they have used PhET molecular geometry as an interactive digital simulator media. The cause is the difficulty to move the level of representation from symbolic to microscopic. In cycle 1, the discussion of the material focused on the shape of the molecule with the central atom only having PEI, causing them not to know the effect of the free electron pair (PEB) in the Lewis structure on the shape of the molecule, resulting in a missing 'conceptual bridge'. Then, without direct *scaffolding* to transform the symbolic representation to microscopic (3D molecular shape), they will assume the 2-D dot drawing directly presents the real molecular geometry as shown in Figure 3 (Kapici, 2023).

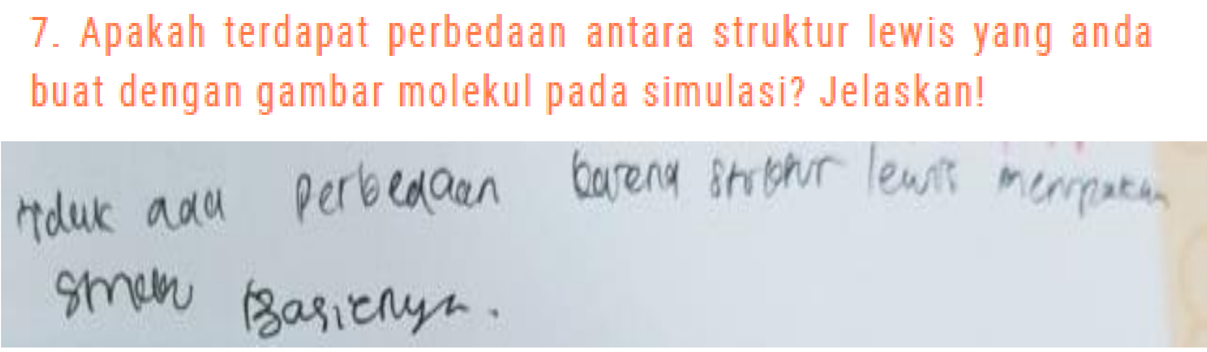

Figure 3 (left) question that identifies understanding related to the difference between Lewis structure and molecular shape, (right) sample answers of students who still have misconceptions.

3) Students still have difficulty calculating the coordination number (CN) because most of them calculate the number of PEI and PEB of all atoms, both central and bound/substituent, as can be seen in Figure 4. Whereas the coordination number is obtained from the number of PEI and PEB on the central atom as a result, they have difficulty when determining the shape of the molecule.

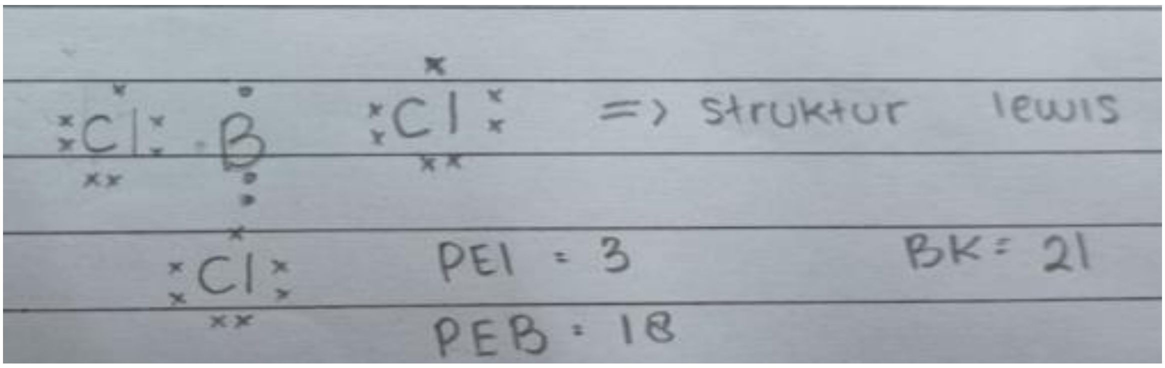

Figure 4 sample answers of students who still have misconceptions about calculating BK

In addition, some still find it difficult to distinguish PEI and PEB. Similar findings also occurred in research from Stiawan (2022) caused by students experiencing confusion to identify it in the Lewis structure. 4) Not understanding VSEPR theory in explaining the shape of the molecule obtained when there is a change in the number of PEIs on the central atom due to the presentation of guiding questions that do not direct learners to analyse the causes of changes in the shape and angle in the molecule.

Chemistry identity

Chemistry identity is an inner belief and social recognition that "I am a chemical person" (Hosbein & Barbera, 2020a). Based on the results of Nisa's research (2023) there is a positive and linear relationship between students' understanding of salt hydrolysis material and chemistry identity. Thus, if students' understanding increases, the same thing happens to their chemistry identity (Nisa, A. A., 2023). The current study shows the same findings, there was an increase in chemistry identity from 3.02 to 3.68 in cycle 1 as shown in Table 7.

Table 7. Results of students' chemistry identity in cycle 1

Indicators	Pre-cycle	Cycle 1	Δ Pre-cycle →Cycle 1 (%)
Mastery Experiences	3.118	3.804	22
Verbal Persuasion	2.771	3.325	20
Initial interest feeling-related	3.229	3.972	23
Initial interest value-related	3.528	4.375	24
Identity	2.458	2.95	20
Average	3.0208	3.6852	

This can be explained through cognitive social theory which emphasizes if self-efficacy The increase can be explained through cognitive social theory which emphasizes if self-efficacy is formed when students experience success which depends on the level of mastery of their concept understanding. Reinforced by research from Nzomo (2023), namely 82% of the increase in chemistry students' self-confidence was triggered by a better understanding of concepts. Then, this self-efficacy will encourage behavioural changes that ultimately improve students' chemistry identity (Nzomo et al., 2023).

Self-efficacy formed from *mastery experiences* depends on concept understanding. In cycle 1, the value of the increase in the *mastery experiences* indicator was quite low at 22% because during the exploration phase many students still did not gain a good understanding of the concept of molecular shapes. If students do not understand the concept, it causes failure in its application when working on problems, leads to *burnout* and difficulty achieving optimal conditions for learning which inhibits the formation of aspects of confidence in their abilities or competence and performance beliefs which have an impact on the *mastery experiences* indicator (Guo, Deng, et al., 2022). Weak competence and performance beliefs *also* has an effect on verbal persuasion. Based on the results of research by Guo et al (2022), it is known that verbal recognition only has a strong effect when students already have confidence in their competence, resulting in the *verbal persuasion* indicator experiencing the lowest increase of 20% in cycle 1. This is because students will consider the verbal recognition given invalid or just a meaningless remark, resulting in the absence of social confirmation that they are considered a chemical person (Guo, Hao, et al., 2022).

Meanwhile, the increase in *situational interest* consists of *Initial interest feeling-related* and *Initial interest value-related* by 23% and 24% respectively, indicating that in the *engagement* phase, the presentation of discussion activities regarding the shape of methane molecules affects its physical and chemical properties can attract learners' interest by triggering curiosity. Then, information about the process of generation and uses of methane gas can foster an understanding of the use of chemistry in everyday life (Habig et al., 2018). However, the identity indicator will be formed if someone has mastered the understanding of concepts, gained recognition from others, and is interested in chemistry so that the increase is low at only 20% (Hosbein & Barbera, 2020b).

Reflection Stage

Based on the results of reflections from observers' observations and discussions with collaborators, several shortcomings were found during the learning implementation process using the LC 5E model assisted by interactive digital simulator media including:

1) Many students still have difficulty in independently constructing an understanding of the concept of VSEPR theory and its application to determine the shape of molecules resulting

in them tending to memorize and misconceptions related to coordination numbers.

2) The division of group members of 6-7 people resulted in group discussions not running effectively. This is because there is a decrease in individual productivity as a result of *social loafing* where the tendency to participate is lower by feeling that even though they do not contribute, the group can still run considering the large number of members (Bonache et al., 2025).
3) Learning activities in the *exploration* phase should also include data collection rather than just constructing understanding. Meanwhile, with regard to teacher activities, it is known that they are still too fast in giving explanations.
4) The distribution of attention when guiding group discussions is uneven due to the large number of members/students in one group
5) The time allocation was not enough due to the lack of management of learning activities in the classroom.

From the results of evaluation and reflection in cycle 1, it shows that the understanding of the concept of molecular form in general has not been achieved. In addition, it has not fulfilled the achievement of the predetermined indicators, so it is still necessary to continue to cycle 2

Cycle 2

Planning Stage

Based on the results of observations, tests, and reflections in cycle 1, there were several improvements to the learning process including:

1. In the *exploration* phase, the teacher provides introductory material as a basis for constructing understanding related to molecular shapes before students independently strengthen their understanding of the material concepts.
2. Group reshuffling was carried out into 8 groups with the division of group members based on the results of the cycle 1 post-test where each group had 4 members.
3. Learning activities in the exploration phase are constructing concept understanding through collecting data to complete the table while the explanation phase contains concluding the data obtained as well as understanding the concept by answering guiding questions.
4. Designing learning activity management in the classroom in order to fulfil the allocation of teaching time while being calmer in delivering the material (not rushed due to time constraints).
5. Reducing the number of members in each group to four can help the teacher to spread attention more easily when guiding their discussions.

Implementation Stage

The implementation refers to the learning syntax in the LC 5E model in accordance with the results of the reflection on cycle 1 which is implemented as follows.

1. *Engagement*, in this phase the teacher first checks the students' understanding through asking again about the material in the previous meeting related to VSEPR theory and the steps to determine the shape of the molecule with the central atom only having (pair of bonding electrons) PEI. After that, the teacher fosters interest and curiosity by showing the use of methane (CH_4) and ammonia (NH_3) compounds in everyday life. Then, the teacher as a facilitator directs students to ask about the effect of the presence of free electron pairs on the shape of a molecule with flow thinking namely displaying Lewis structure and form the molecule → ask the number of PEIs and PEBs (free electron pairs) on the central atom → Calculate the coordination number (BK) → formulate the question why the BKs of the two molecules are the same, but the shapes are different.

2. *Exploration,* based on the results of reflection on cycle 1, when implementing this phase, the teacher provides introductory material in advance to strengthen concepts at the beginning as a provision in conducting exploration activities while minimizing the occurrence of misconceptions. As well as scaffolding to transform symbolic representation to microscopic (3D molecular form) with the help of PhET. After that, they conducted exploration activities in groups with new members. Based on the results of reflection and observation for this cycle, a reshuffle was carried out, namely there were 8 groups of 4 people with heterogeneous cognitive ability levels and gender.
3. *Explanation,* referring to the results of reflection for this phase, the core activity is to conclude the results of exploration, but with guiding questions. This aims to encourage students to use the understanding of concepts that have been obtained in the exploration phase to formulate conclusions, so that it is not just answering questions without exploration data base. After that, the teacher provides verification and reinforcement of the results of students' presentations. In this activity, the teacher also asked the group leader to convey the contribution of each member during the discussion process.
4. *Elaboration,* learning activities are the same as in cycle 1 but with different forms of questions because the learning objectives in cycle 2 are that students can determine the shape of molecules with central atoms having PEI and free electron pairs (PEB) based on the VSEPR theory correctly.
5. *Evaluation, the* teacher assesses students' understanding of molecular shape material while evaluating the achievement of learning objectives, namely students can determine the shape of a molecule with a central atom having (PEI) and a free electron pair (PEB) based on the VSEPR theory correctly. The evaluation instrument in the form of a *posttest* contains concept understanding test questions

Observation and Test Phase

During cycle 2 learning activities, observations were made to review teacher and student activities during the learning process as well as the effectiveness of media use in improving concept understanding and its impact on improving chemistry identity.

Understanding the Concept of Molecular Shape

The following is a recapitulation of data on the achievement of learner performance indicators from *pretest* to *posttest* cycle 2 as shown in Figure 5.

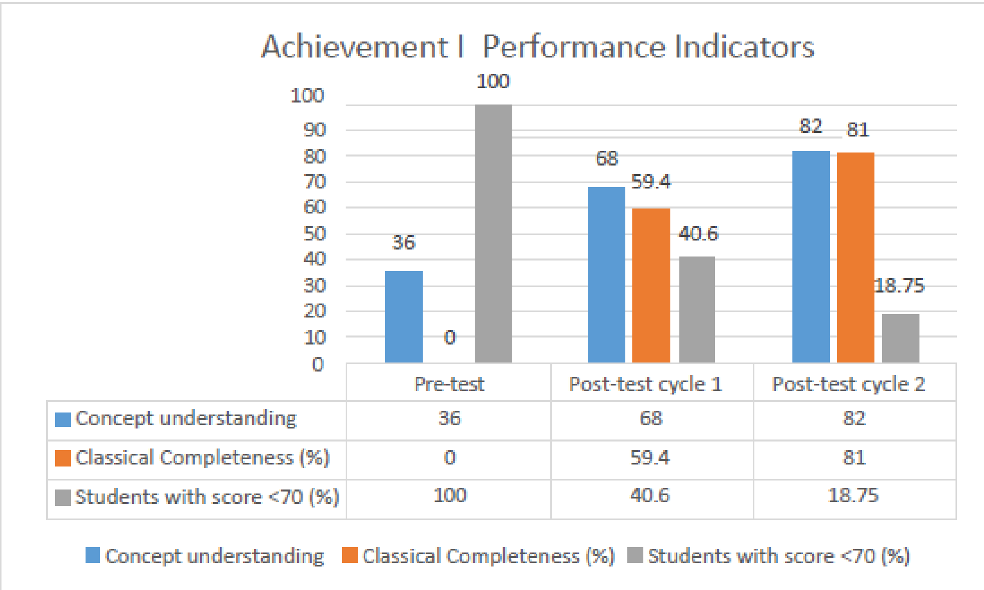

Figure 5. Recapitulation of the achievement of learner performance indicators *in pretest, posttest* cycle 1, and *posttest* cycle 2

It can be seen based on the cognitive learning outcomes of students from the posttest after completing the learning activities in the second cycle. The test totalled 5 questions consisting of 1 multiple choice question, 1 matching question, and 3 description questions.

After learning activities in cycle 2 according to the results of evaluation and reflection in cycle 1. There was an increase in the average understanding of concepts and achieving classical completeness of 62 and 82% respectively. This was reinforced by the reduction in the percentage of students scoring below 70 which was 18.75%. In addition, the use of PhET molecular shapes as an interactive digital simulator media contributed to the improvement for the following reasons:

1) 3D visualization turns abstract concepts into concrete where students more easily 'build' bonds and PEBs that affect changes in molecular shape and angle directly so that the concepts of PEI and PEB become concrete (Brown et al., 2021). Furthermore, 3D visualization helps students build imagistic reasoning, which is the process of imagining molecular shapes in their minds that makes it easier for the brain to learn to map abstract shapes into molecular shapes accurately (Kiernan et al., 2024).
2) 2) It facilitates self-directed inquiry and quick feedback when learners freely add/remove PEI, PEB, and then immediately see the effect (instant feedback) i.e. changes in bond angles and molecular shapes. Thus, they are able to construct cause-and-effect relationships that exercise their systemic thinking skills (Ika et al., 2021). The model triggers a cycle of prediction → test → reflection that bridges micro-macro-symbolic representations dynamically. In addition, learners can directly associate coordination numbers with shapes (Rahmawati et al., 2022).
3) Explicit representation of PEI and PEB, namely PEB as a larger 'cloud' and when added will reduce the bond angle in the shape of the molecule can explain the origin of electron repulsion in other words, understanding the VSEPR rule is not just memorising the general formula table AX_mE_n (Karnishyna et al., 2024). The increase in students' concept understanding on molecular shape material is calculated using the N-Gain value as shown in Table 8 below.

Table 8. Results of pre-test, post-test, ideal value of students' concept understanding of

pre-test score	36
post-test score	82
Ideal value	100
n-gain	0,718
Category	Quite effective

Based on the results of the analysis using n-gain, it was found that the application of the LC 5E model assisted by interactive digital simulator media, namely PhET *molecular shapes*, was quite effective in improving students' concept understanding on molecular shape material with an n-gain score of 71.8%

Chemistry Identity

The implementation of improvements in cycle 2 refers to the results of cycle 1 reflection with the results of an increase in students' chemistry identity as shown in Table 9 and Figure 6.

Improvements were made related to activities in the exploration phase with the teacher providing introductory material for strengthening concepts at the beginning as a provision in carrying out exploration activities and changing the number of group members. The results obtained are an increase in concept understanding significantly due to the *scaffolding* provided, namely in the form of introductory material as a conceptual framework when students face problems when exploring while minimizing misconceptions. Without *scaffolding*, students have a tendency to build a wrong understanding based on their non-scientific intuition. Then, the introductory material is able to reduce the burden of thinking from students during exploration so that existing cognitive resources can be used for higher-order reasoning, thus improving their concept understanding. In addition, changing large groups (>5 students) into small groups (3-4 students) is able to facilitate more in-depth discussions that allow misconceptions to be corrected through these peer discussion activities (Vincent-Ruz et al., 2020).

Table 9. Results of students' chemistry identity in pre-cycle, cycle 1, and 2

Indicators	Pre-cycle	Cycle 1	Cycle 2	Δ Pre-cycle→Cycle 2 (%)
Mastery Experiences	3.118	3.804	4.895	57
Verbal Persuasion	2.771	3.325	4.156	50
Initial interest feeling-related	3.229	3.972	4.521	40
Initial interest value-related	3.528	4.375	4.586	30
Identity	2.458	2.95	3.073	25
Avarage	3.0208	3.6852	4.2462	40.4

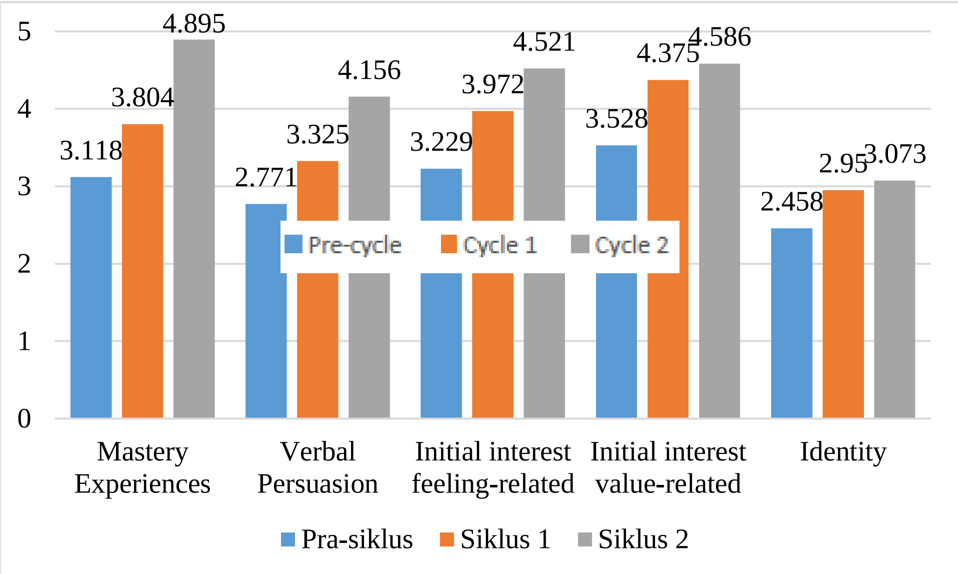

Figure 6. Improvement of students' chemistry identity on each indicator

Mastery of concept understanding is the main factor in the *mastery experiences* indicator experiencing the highest increase of 57% because it is able to build their confidence in their own competence to complete chemistry tasks (Rüschenpöhler & Markic, 2020). When the belief in the ability of self in students is strong, verbal recognition (*verbal persuasion*) given by the teacher and group leader by conveying the participation of each member during the discussion process becomes meaningful or acceptable. This phenomenon explains the cause of the 50% increase in *the verbal persuasion* indicator. Social recognition that students are considered chemical people can help them live the role of chemistry in their identity (Guo, Hao, et al., 2022).

Then, the *Initial interest feeling-related* indicator increased by 40% because in the *engagement* phase the presentation of discussion activities regarding the analysis of differences in the shape of methane and ammonia molecules can interest students, especially in cycle 1 they have used PhET simulator media to help visualize molecular shapes so that curiosity if used or applied to other molecules is even greater. In addition, information about the uses of methane and ammonia is presented so that it can foster an understanding of the use of chemistry in their daily lives and is more contextualized. This process takes place quickly even before students reflect on the value or long-term benefits of learning the material. Therefore, the increase in the *Initial interest valued-related* indicator is in the order after *Initial interest feeling-related*, which is 30%. This indicator requires learners to connect the usefulness of the material in everyday life and requires time so that the increase in two cycles is still relatively low (Habig et al., 2018). The indicator with the lowest increase is identity because it will be formed when someone has mastered the understanding of concepts, gained recognition from others, and is interested in chemistry. The percentage increase for chemistry identity as a whole is 40% which is still low because the identity formation process takes a long time, but the duration of the study only lasted quite short (Hosbein & Barbera, 2020b).

Reflection Stage

It is known that the implementation of learning in cycle 2, based on the evaluation results from cycle 1, provides a positive increase in concept understanding which has an overall impact on students' chemistry identity. This is due to several factors below:

1) Direct *scaffolding* at the exploration stage to transform symbolic representation to microscopic (3D molecular form) with the help of PhET conducted by the teacher to students can overcome the missing 'conceptual bridge'. This is because they can understand the effect of free electron pairs (PEB) in the Lewis structure on molecular shape. Thus, students can use the conceptual understanding of VSEPR theory and its application to determine the shape of the molecule.
2) The change in the number of group members of 3-4 people resulted in group discussions that can run effectively which allows the correction of misconceptions through discussion activities between peers (Bonache et al., 2025).
3) The distribution of attention when guiding group discussions can be done evenly because the number of members in one group consists of 3-4 students.
4) The management of learning activities in the classroom has been carried out well so that the time allocation is sufficient to carry out learning activities and the teacher can be calmer or unhurried when giving explanations.

Then, supported by responses from students, namely the use of interactive digital simulators helps them visualise the shape of molecules so that it is very helpful in the learning process concept construction. Therefore, the application of the LC 5E model assisted by interactive digital simulator media can be effectively used to improve students' understanding of molecular shape material. However, there are still limitations, especially related to the chemistry identity variable where the increase has not been maximised due to the limited time of research implementation.

CONCLUSIONS

Based on the results of class action research (CAR) conducted in class X-3 SMA Brawijaya Smart School, it can be concluded that:

1. The application of the *5E learning cycle* model assisted by interactive digital simulator media on molecular shape material in this study can improve the understanding of concepts and students in learning and their chemistry identity is shown through the acquisition of an N-gain value of 71.8% with a effective enough category.
2. Concept understanding after the application of the *learning cycle 5E* model assisted by interactive digital simulator media increased from cycle I to cycle II by 68% and 82% respectively. This means that the problems faced in cycle I can be resolved in cycle II.

3. There is an increase in students' chemistry identity after the application of the *5E learning cycle* assisted by interactive digital simulator media from pre-cycle to cycle II, which is 40.4%.

RECOMMENDATIONS

For future researchers, they can allocate a longer implementation time because to grow/improve students' chemistry identity requires a long period of time. It is hoped that this research can provide an initial picture of the current condition of students, so that teachers can try to implement learning that can improve their chemistry identity.

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