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Research Article

Efforts to Improve Critical Thinking Through the Discovery Learning Model on Benzene Material at De Britto College Senior High School

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Abstract
Critical thinking is one of the essential 21st-century skills that must be fostered in chemistry learning. However, observations indicate that students still struggle to connect the concept of benzene with a deep understanding, resulting in suboptimal development of critical thinking skills. This best practice aims to describe the implementation of the discovery learning model in enhancing the critical thinking skills of twelfth-grade MIPA 2 students at Kolese De Britto Senior High School, Yogyakarta, on the topic of benzene. The study was conducted with 29 male students aged 17–18 years. The discovery learning model was implemented through six instructional stages: stimulation, problem identification, data collection, data processing, verification, and generalization. The research instruments consisted of (1) a critical thinking test covering interpretation, analysis, evaluation, and inference with five essay questions; (2) a student activity observation sheet with ten engagement criteria; (3) open-ended interviews with six guiding questions to explore learning experiences; and (4) documentation in the form of field notes and students' group work. Instrument validity was established through expert judgment, while the reliability of the test was analyzed using Cronbach's Alpha coefficient of 0.82 (high category). The results revealed a significant improvement in students' critical thinking skills. The average test score increased from 58.3 (pre-implementation) to 74.6 (initial cycle), and further to 86.2 (final practice). The N-gain analysis yielded 0.67, categorized as medium-to-high. Observations also indicated enhanced student participation in discussions, the ability to pose questions, and independent conclusion-making. In conclusion, this best practice demonstrates that the discovery learning model is effective in improving students' critical thinking skills in learning benzene. The limitation of this study lies in the relatively small number of participants and the restricted context of a single school. Therefore, further research with a larger population and different chemistry topics is recommended to strengthen the generalizability of the findings.

Keywords: Benzene, Critical Thinking, Discovery Learning, HOTS

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1. INTRODUCTION

21st-century education requires students not only to master knowledge but also to develop higher-order thinking skills (HOTS), one of which is critical thinking (Kotsis, 2025; Rachid et al., 2025). In chemistry learning, this ability is very important because students face conceptual and abstract material that demands analytical, evaluative, and logical reasoning. Indonesia's 2013 Curriculum emphasizes the development of HOTS as a primary learning objective.

However, classroom practice shows several challenges. Learning materials and assignments are often not aligned with students' conditions, while the learning process still focuses on memorization and mastery of cognitive knowledge (C1–C3). Students' dominant activities include listening, taking notes, and completing exercises, limiting opportunities to discover concepts. Activities such as expressing opinions, asking questions, and sharing information rarely occur. Consequently, students tend to be passive, have low problem-solving ability, and have underdeveloped critical thinking skills. In addition, teachers rarely use learning media that support HOTS, making the classroom atmosphere rigid and less enjoyable.

Based on classroom observations, it was found that a) students are reluctant to participate in teacher-centered lessons, and b) besides lecturing, teachers often assign tasks. Many students reported boredom with purely theoretical assignments that could simply be copied from textbooks. As demonstrated by Agung et al. (2023), students' critical thinking improved through the Discovery Learning (DL) model. Similarly, Rachmi (2020) stated that the DL model is suitable as a best practice for HOTS-oriented learning because it enhances students' abilities in knowledge transfer, critical thinking, and problem-solving.

One challenging topic in 12th-grade chemistry is the structure and nomenclature of benzene compounds. This topic requires students to understand resonance concepts, rules for naming aromatic compounds, and to distinguish among various derivatives, demanding deep understanding and systematic thinking. Initial observations in Class XII MIPA-2 revealed that most students still struggled to fully comprehend these concepts and tended to memorize without analyzing or relating them to a broader context. Low analytical ability in benzene and its derivatives is indicated by a) scores below the minimum mastery criteria (KKM), b) low student interest as observed in teacher journals, such as sleeping or leaving class, c) suboptimal lesson planning due to limited teacher expertise and lack of sensitivity to classroom issues, d) teachers not fully exploring creativity in developing learning media that could stimulate student interest, and e) underutilization of information technology in learning.

Therefore, students must be equipped with higher-order thinking skills. One HOTS-oriented learning model recommended in the 2013 Curriculum is DL. DL encourages students to discover concepts through direct learning experiences. This model aligns with strengthening critical thinking within HOTS-oriented learning frameworks. DL emphasizes understanding key structures or ideas within a discipline through active student engagement in the learning process.

In DL, students are required to actively seek learning experiences, analyze and solve problems, and investigate independently. These challenges highlight the need for an approach that fosters student engagement, encourages exploration, and facilitates critical thinking.

Djamarah (2013:19) states that DL is learning by searching and discovering independently. In this teaching-learning system, the teacher presents material not in a final form, but students are given opportunities to explore and discover using problem-solving techniques. Moreover, DL involves organizing the studied material into a final form while requiring students to play an active role in classroom learning (Mulyono, 2014:63). According to Bruner (Siregar, 2010:30), DL is a learning process for discovering something new in teaching and learning activities. According to Aunurrahman (in Dari & Ahmad, 2020), selecting and applying an appropriate learning model should foster enjoyment, increase motivation, enhance critical thinking, and facilitate student understanding to achieve better learning outcomes. Learning using the DL model is intended to encourage students to actively discover concepts (Rosdiana et al., 2017). In education, quality can be assessed by fulfilling expectations from students, parents, society, government, businesses, and other institutions that are directly or indirectly related to the school (Lustyantie et al., 2015).

Through the application of DL on the topic of benzene structure and nomenclature, students are expected not only to understand the material conceptually but also to develop their critical thinking skills through actively observing, questioning, experimenting, reasoning, and concluding.

After implementing chemistry learning using DL, it was found that both the learning process and students' outcomes improved compared to previous lessons. When DL was applied in other Class XII MIPA sections, the learning process and outcomes were equally positive. This successful implementation of DL can be concluded as a best practice for HOTS-oriented learning using the DL model.

1.1. Literature Review

1.1.1. Discovery Learning

DL is an instructional approach that emphasizes the active role of students in discovering concepts, principles, or rules through mental processes such as observing, classifying, measuring, predicting, explaining, and concluding. This model is grounded in constructivist theory, where students are considered active individuals who construct knowledge through direct experiences and interactions with their learning environment (Bruner, 1966).

Joyce et al. (2009) highlighted that DL encourages students to become active problem solvers and construct concepts independently. During the process, students are exposed to learning situations that require exploration and experimentation, thereby engaging in higher-order thinking processes such as analysis, synthesis, and evaluation.

Similarly, Syah (2013) described DL as a learning process in which students do not simply receive complete information from the teacher but instead organize their own learning experiences and discover scientific principles based on their investigations and reasoning. Bruner, as cited in Hosnan (2014), emphasized that knowledge acquired through discovery is more meaningful and memorable, as the act of discovery itself strengthens cognitive structures.

Thus, DL positions students at the center of the learning process (student-centered), while teachers serve as facilitators who provide resources, guidance, and conducive learning situations to help students discover concepts or principles independently. This approach aligns with the goals of 21st-century education, which stresses the development of critical thinking, problem-solving, and lifelong learning skills.

According to Hosnan (2014), DL involves six stages: (1) stimulation, where the teacher presents a phenomenon or problem; (2) problem statement, where students formulate questions based on the stimulus; (3) data collection, where students gather relevant information; (4) data processing, where students analyze and identify patterns; (5) verification, where hypotheses are tested against data; and (6) generalization, where students draw conclusions or formulate new concepts.

In the context of teaching the structure and nomenclature of benzene in grade XII chemistry, DL can be applied by introducing examples of aromatic compounds and guiding students to identify patterns in their structures and naming. The process may begin with stimuli such as molecular representations of benzene and its derivatives, followed by problem formulation, data collection, hypothesis testing, and the construction of systematic nomenclature rules. This approach not only supports conceptual understanding but also fosters critical thinking, collaboration, and independent learning in alignment with the *Profil Pelajar Pancasila*.

1.1.2. Higher-Order Thinking Skills (HOTS)

Higher-order thinking skills (HOTS) refer to cognitive abilities beyond basic levels, such as remembering and understanding. The concept originates from Anderson and Krathwohl's (2001) revision of Bloom's Taxonomy, which categorizes cognitive processes into six levels: remembering, understanding, applying, analyzing, evaluating, and creating. The last three levels—analyzing, evaluating, and creating—are regarded as HOTS because they require complex and in-depth cognitive engagement.

HOTS focuses not only on knowledge acquisition but also on how students apply their knowledge to solve problems, make decisions, and create new solutions in diverse contexts (Brookhart, 2010). Therefore, HOTS is essential in 21st-century education, which requires students to become critical, creative, and adaptive thinkers.

According to King et al. (2011), HOTS is characterized by several features: (1) being reflective and logical, involving conscious and systematic reasoning; (2) being problem-oriented, where students apply prior knowledge and experience to new situations; (3) involving reasoning and decision-making, requiring the evaluation of information before drawing conclusions; and (4) fostering the creation of new ideas or products, thus stimulating creativity and innovation.

The development of HOTS cannot be achieved through one-way teaching or lecture-based methods. Instead, it flourishes when students are actively engaged, confronted with authentic and complex problems, given opportunities to think independently and collaboratively, and guided by teachers in formulating solutions or generalizations. Zohar and Dori (2003) argued that science education is particularly suitable for cultivating HOTS, as it requires deep conceptual understanding along with analytical and evaluative reasoning.

DL is closely related to HOTS development because it involves active exploration and inquiry rather than passive knowledge reception (Bruner, 1966; Hosnan, 2014). Through DL, students analyze data, test hypotheses, interpret information, and draw independent conclusions. Majid (2013) emphasized that DL's stages—problem identification, data collection and analysis, hypothesis testing, and generalization—directly engage students in higher-order thinking processes, making it an effective strategy for developing HOTS in the classroom.

1.1.3. Critical Thinking

Critical thinking is a high-level cognitive competency that is vital in education, especially in the 21st century. Ennis (1993) defined critical thinking as a rational and reflective process focused on deciding what to believe or do, involving interpretation, analysis, evaluation, and inference based on evidence and logic. Paul and Elder (2008) described critical thinking as the art of analyzing and evaluating thought with the aim of improving it. This means that critical thinking is not merely about thinking deeply but also about structuring, testing, and refining arguments systematically.

Facione (2011) identified six core cognitive skills of critical thinking: (1) interpretation—understanding and clarifying meaning from information; (2) analysis—identifying relationships among information; (3) evaluation—assessing the credibility of sources and strength of arguments; (4) inference—drawing logical conclusions from evidence; (5) explanation—communicating findings and reasoning; and (6) self-regulation—reflecting on and correcting one's own thinking processes. Critical thinking also requires dispositions such as open-mindedness, healthy skepticism, and the pursuit of truth through objective reasoning (Ennis, 1993; Paul & Elder, 2008).

In science education, including chemistry, critical thinking is essential because students encounter complex phenomena that require understanding, analyzing, and concluding based on data (Agustin et al., 2024; Wahyudiati & Qurniati, 2025). Zoller and Pushkin (2007) noted that science is not merely a collection of facts but a process of reasoning and inquiry. Consequently, science instruction should foster students' critical thinking abilities.

Topics such as the structure and nomenclature of benzene demand a deep conceptual understanding of molecular structure, resonance, and systematic naming rules. Critical thinking skills enable students to identify patterns, analyze structural isomers, and draw logical conclusions from representations such as diagrams, tables, or molecular models.

The relationship between critical thinking and DL is strong, as DL encourages students to investigate phenomena, pose questions, collect and analyze data, and derive conclusions (Hosnan, 2014). All these processes are integral to critical thinking. DL also provides an environment for students to think logically and systematically, evaluate information, and formulate arguments or generalizations based on evidence. In other words, DL creates a learning ecosystem that naturally facilitates the development of critical thinking skills.

2. METHODS

This study is a best practice aimed at describing the implementation of the DL model in chemistry instruction oriented toward Higher Order Thinking Skills (HOTS). The research focused on the topic of the structure and nomenclature of benzene in Grade XII MIPA-2 of SMA Kolese De Britto Yogyakarta. The design employed a descriptive approach with both qualitative and simple quantitative analyses to evaluate the improvement of students' critical thinking skills.

2.1. Research Design

This study is a best practice aimed at describing the implementation of the DL model in chemistry instruction oriented toward HOTS. The research focused on the topic of the structure and nomenclature of benzene in Grade XII MIPA-2 of SMA Kolese De Britto Yogyakarta. The design employed a descriptive approach with both qualitative and simple quantitative analyses to evaluate the improvement of students' critical thinking skills.

2.2. Participants

This best practice involved 29 male students of Grade XII MIPA-2 at SMA Kolese De Britto Yogyakarta in the 2024/2025 academic year. The school is homogeneous, with students aged between 17 and 18 years. This demographic characteristic is important to understand the context of implementation and the variation in students' critical thinking abilities. The practice was carried out by the chemistry teacher as part of efforts to promote learning oriented toward higher-order thinking skills.

2.3. Research Instruments

Several instruments were employed to evaluate the effectiveness of this best practice:

Critical Thinking Test: consisting of 10 open-ended questions based on HOTS indicators (analysis, evaluation, inference). Each response was scored using a rubric (0–3 scale). The total score reflected the overall students' critical thinking ability. Indicators were developed with reference to critical thinking models and adapted to the topic of benzene for content relevance.

Observation Sheet: containing 8 indicators of student activities (e.g., asking questions, expressing opinions, collaborating, analyzing, and drawing conclusions). Observations were carried out during lessons and rated on a 1–4 scale by two observers to ensure reliability.

Reflective Questionnaire: consisting of 12 statements using a 5-point Likert scale (1 = strongly disagree to 5 = strongly agree) to measure motivation, engagement, and perceptions of the learning model.

Semi-Structured Interviews: comprising 5 guiding questions focusing on students' experiences with discovery-based learning and their perceptions of critical thinking development.

Documentation: photos, videos, and students' work products were collected as evidence of engagement. Analysis focused on the quality of argumentation, conceptual understanding, and alignment with critical thinking indicators.

Student Worksheets**:** used to support data collection and processing stages.

2.3.1. Validity and Reliability of Instruments

The research instruments were developed based on the critical thinking indicators proposed by Facione (2011), which include interpretation, analysis, evaluation, and inference. Content validity was ensured through the alignment of each item with these indicators. The reliability of the test was analyzed using Cronbach's Alpha, yielding a coefficient of 0.82, which falls within the high category.

2.4. Procedures

The procedure followed the syntax of discovery learning, beginning with stimulation through the presentation of real-world phenomena and products containing benzene to activate students' curiosity. Learners then identified problems by formulating key questions related to the structure and nomenclature of benzene. This was followed by data collection conducted through literature review, group discussions, and the examination of relevant products. The collected information was subsequently processed through structural analysis, the use of molecular models, and the application of IUPAC nomenclature rules. Verification occurred as students engaged in group presentations and concept clarification sessions to validate their findings. Finally, the learning process culminated in generalization, where students synthesized their understanding by drawing comprehensive conclusions regarding the structure and nomenclature of benzene.

Table 1. DL Activity Plan

Learning Stage	Learning Activities
Introduction (Preparation/Orientation)	Open the class with greetings and a prayer to begin learning Check student attendance as a discipline habit Prepare students physically and psychologically to begin the lesson
Aperception	Connect the upcoming topic/activities with prior lessons: structure, nomenclature, properties, identification, and uses of: haloalkanes, alkanols, alkoxy alkanes, alkanals, alkanones, alkanoic acids, and alkyl alkanoates Review the prerequisite material by asking questions Pose questions related to the upcoming lesson
Motivation	Provide an overview of the benefits of learning the topic for daily life If this topic/project is completed thoroughly, students are expected to explain the structure and isomers of benzene and its derivatives, as well as IUPAC rules for naming benzene and its derivatives State the learning objectives for the session Ask questions
Providing Guidance	Inform the material to be discussed during the session Divide students into groups of five Explain the mechanism for learning experiences according to the lesson steps
Phase I: Stimulation	Invite students to read information about benzene compounds and their applications in daily life Students observe several products containing benzene and its derivatives
Phase II: Problem Statement	Students identify as many problems as possible related to the structure of benzene in household products, by finding answers to: What substance is contained in scented disinfectant (carbol)? What is the structure of benzene? What are examples of commonly used aromatic compounds (e.g., TNT, benzoic acid, aspirin)?
Phase III: Data Collection	Distribute Worksheet 1: Structure and Nomenclature of Benzene to each group Instruct students to read the worksheet instructions and allow time for clarification questions Facilitate observation of images or product packaging prepared by the teacher Students record observation results in the worksheet
Phase IV: Data Processing	Facilitate group brainstorming to answer questions in Part 1 of the worksheet Facilitate students to write group brainstorming results on the chart paper in front of the class After inter-group discussions and agreement on benzene structure, facilitate students to proceed to Part 2 of the worksheet Still in groups, facilitate students to answer further questions; students may consult books or websites to gather information on benzene nomenclature Facilitate each group to discuss and record results in the worksheet
Phase V: Verification	Discuss the brainstorming results, confirm and agree on conclusions, and have students revise their answers in the worksheet
Phase VI: Generalization	Students finalize and refine their answers in the worksheet

Table 2. Lesson Plan for Benzene Using the DL Model

DL Stage	Teacher Activities	Student Activities	BC Indicators
Stimulation	Present chemical phenomena related to benzene	Observe phenomena and note questions	Understand the concept of benzene
Problem Identification	Guide students to formulate problems	Formulate research questions	Formulate simple chemical problems
Data Collection	Provide worksheets and literature sources	Seek information from books and discussions	Collect data on benzene concepts
Data Processing	Facilitate the analysis of information	Analyze data and create graphs/diagrams	Analyze the structure and properties of benzene
Verification	Direct the discussion of the analysis results	Compare results with theory	Evaluate analysis results
Generalization	Facilitate conclusion drawing	Conclude benzene concepts	Formulate principles and applications of benzene

2.4.1. Mapping of Core Competencies

The practice was conducted in several stages as follows. The lesson plan was prepared in accordance with the Basic Competencies (BC) of the 2013 Curriculum. Table 2 presents a summary of BC, indicators, and the DL stages.

2.4.2. Formulation of Competency Achievement Indicators

Table 3. Basic Competencies and Indicators of Competency Achievement

Basic Competencies (BC)	Indicators of Competency Achievement
KD 3.3. Analyze the structure and nomenclature of aromatic compounds (benzene and derivatives) based on IUPAC rules.	Identify the structure of benzene and its derivatives; Write the structures of benzene and its derivatives
KD. 4.3. Present the analysis results of the structure and nomenclature of aromatic compounds (benzene and derivatives) systematically in oral, written, or other media forms.	Collect information regarding the uses of benzene derivatives

2.5. Data Analysis

The data were analyzed using both quantitative and qualitative approaches. Quantitatively, students' critical thinking test scores were examined by calculating the mean and normalized gain (N-gain). The N-gain was computed using the formula proposed by Hake (1998):

$$\text{N- gain} = \frac{(\text{Spost} - \text{Spre})}{(\text{Smax} - \text{Spre})}$$

where S_{post} represents the average post-test score, S_{pre} the average pre-test score, and S_{max} the maximum possible score. The resulting *N*-gain values were then categorized following Hake's (1998) classification, in which an N-gain greater than 0.7 indicates a high level of improvement, a value between 0.3 and 0.7 reflects a medium level of improvement, and a value of 0.3 or lower signifies low improvement.

The qualitative data in this study were analyzed through several complementary approaches. Observation results were examined based on the frequency of student engagement, while interview data were processed using the stages of data reduction, presentation, and conclusion drawing as outlined by Miles and Huberman (1994). Quantitative data, including critical thinking tests and questionnaires, were analyzed descriptively to assess averages and percentages of student achievement, whereas qualitative data from observations, interviews, and reflections were used to describe changes in students' activity levels, motivation, and critical thinking skills. The critical thinking test results indicated notable improvement, with an average score of 74.6 before the implementation of discovery learning (DL) and an average score of 86.2 afterward, aligning with previous research demonstrating the effectiveness of discovery-based learning in enhancing critical thinking (Zhang & Chen, 2021). Improvements in students' understanding and thinking skills were assessed through critical thinking test scores, supported by observations and student responses that reflected their engagement during the learning process. The success of this best practice was characterized by at least 80% of students achieving a minimum score of 80 on the critical thinking test, increased active participation and enthusiasm throughout learning activities, and positive student reflections regarding the applied learning model. The learning media utilized included student worksheets, images or product packaging containing benzene and its derivatives, assessment sheets, and chart paper, while the instruments used consisted of rulers, markers, a whiteboard, and a laptop with a projector. This best practice activity was conducted from January 31 to February 10, 2025, at SMA Kolese De Britto Yogyakarta.

3. RESULTS

3.1. Student Critical Thinking

The critical thinking test was administered after the learning process using the DL model. The test was developed based on indicators of critical thinking skills such as analyzing molecular structures, evaluating statements, and drawing scientific conclusions.

Table 4. Critical Thinking Test Scores

Score Category	Number of Students	Percentage
≥ 80	25 students	86.20%
< 80	4 students	13.80%
Total	29 students	100%

The test results show that the majority of students (86.2%) achieved a minimum score of 80. The average score increased significantly from 58.3 (pre-implementation) to 74.6 (initial cycle), and reached 86.2 at the end of the implementation. The N-gain analysis of 0.67 indicates an improvement in the medium–high category.

These results can be further illustrated in the form of a bar chart or a pie chart for visual representation.

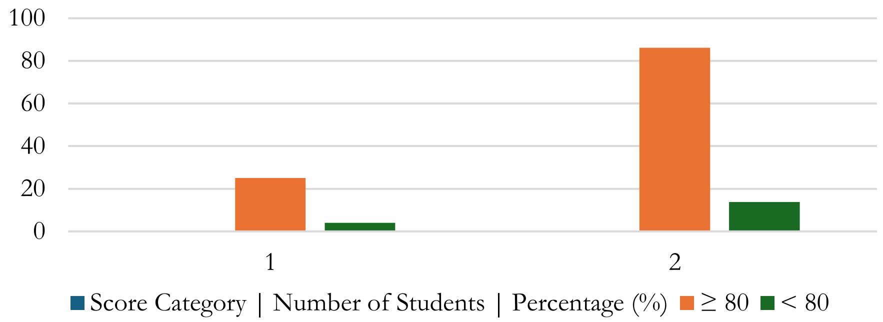

Figure 1. Critical Thinking Test

3.2. Student Engagement

Student engagement during the learning process was examined through teacher observation sheets and supported by student reflection questionnaires. The teacher's observations revealed that 87% of students actively participated in group discussions, 90% were able to express their opinions and ask questions, and 80% demonstrated the ability to independently draw conclusions from their discoveries. Similarly, the student reflections showed strong positive responses: 88% of students reported that the learning activities encouraged them to think more deeply, 85% felt that the material was easier to understand through self-discovery, and 90% expressed greater enthusiasm and engagement compared to regular learning. Overall, the combined observation and reflection data illustrate a clear increase in active participation and heightened student enthusiasm throughout the learning process.

3.3. Evaluation of Best Practice Success

The implementation of the DL model in teaching the structure and nomenclature of benzene to Grade XII MIPA-2 students demonstrated a significant improvement in critical thinking skills. This was evident from the observation results, group discussion activities, student worksheets (LKPD), and evaluation answers reflecting critical thinking indicators such as analyzing, evaluating, and concluding.

Table 5. Evaluation of Best Practice Success

Indicator	Description
≥ 80% of students achieved a minimum score of 80 on the critical thinking test	Achieved (86.20%)
Increased active participation and student enthusiasm in learning	Achieved (based on observations and reflections)

3.4. Improvement of Learning Activities

During the learning process, students were more active in observing, asking questions, and expressing opinions. Group discussions took place dynamically, with each member contributing to solving problems related to the structure and nomenclature of benzene compounds. This activity indicates that students were beginning to build their own knowledge through deeper thinking processes.

3.5. Engagement in the Discovery Process

Through the worksheets (LKPD) designed based on DL, students were able to independently discover patterns of aromatic compound structures and their naming rules. This process encouraged students not only to memorize but also to understand and apply concepts independently. Their ability to construct logical arguments during group presentations also improved.

The final evaluation in the form of HOTS questions showed that most students were able to answer with appropriate analysis. They could explain the benzene structure, identify functional groups in its derivatives, and provide names according to IUPAC rules. A small number still experienced difficulties, particularly in distinguishing substituent positions (ortho, meta, para), but this became a point of reflection for further learning.

3.6. Teacher's Reflection

As the teacher, it was realized that implementing DL requires thorough planning and effective time management. However, the outcomes were highly positive. Students not only gained a better understanding of the concepts but also demonstrated scientific attitudes and enthusiasm in participating in the learning process.

Overall, the implementation of DL successfully improved students' critical thinking skills. The results of tests, observations, questionnaires, and reflections indicated improvements in both cognitive and affective aspects. This model proved effective in creating an active, challenging, and supportive learning environment for achieving HOTS-oriented learning, particularly in complex material such as the structure and nomenclature of benzene.

4. DISCUSSION

The application of the DL model to benzene material demonstrated improved critical thinking skills in grade XII MIPA 2 students. This result was evident in the higher posttest scores compared to the pretest, as well as in the students' active engagement throughout the learning process. Hidayat et al. (2020) emphasized that discovery-based learning significantly supports the development of higher-order thinking skills.

According to Amri and Ahmadi (2010), discovery-based learning is one method that can be used to train critical thinking skills, allowing students to identify problems, analyze them, formulate hypotheses, collect data, test them, and determine possible solutions. The activities carried out align with the learning stages in discovery learning, where opportunities for activities can be developed at each stage of learning using the DL model. One of the learning activities is identifying problems and finding possible solutions. The DL model, according to Suprijono (2013), emphasizes higher-order thinking and helps students develop dialectical thinking through logical induction. With this method, students learn to discover concepts through observation, experimentation, and manipulation. This process encourages students to think from facts to concepts, strengthening their understanding of the learning material.

Furthermore, exploratory activities in DL have been shown to strengthen conceptual understanding, as demonstrated by Afriana (2019). Rahayu's (2019) research also emphasized the importance of developing HOTS in chemistry learning so that students can analyze and evaluate concepts in depth. This aligns with the findings of Utami et al. (2020), which demonstrated an improvement in students' critical thinking skills in ionic bonding through guided discovery learning.

Setiawan et al. (2021) emphasize that chemical bonding confirms that DL is effective not only for basic concepts but also for more complex topics, strengthening students' problem-solving abilities. From a cognitive perspective, DL success in enhancing HOTS is supported by the revised Bloom's Taxonomy, which emphasizes the development of analysis, evaluation, and creation skills (Anderson & Krathwohl, 2001). The implementation of this strategy enabled students to identify the structure of benzene, interpret its properties, and analyze its applications, thereby fostering critical and creative thinking skills.

In addition to cognitive aspects, collaborative student interaction also contributes to successful learning. Slavin (2018) emphasized the importance of collaboration among students in the learning process, which aligns with the cooperative learning practices implemented in this class (Suprijono, 2016). Through group discussions, students can test hypotheses, clarify ideas, and deepen their understanding of concepts.

Overall, the results of this study confirm that the DL model is effective in improving critical thinking skills in benzene. This finding aligns with research by Afriana (2019), Hidayat et al. (2020), Rahayu (2019), Utami et al. (2020), and Setiawan et al. (2021), which consistently demonstrate that a discovery-based approach can develop students' HOTS. Thus, this study makes an important contribution to modern chemistry learning practices oriented toward 21st-century skills.

The implementation of the DL model demonstrated a notable improvement in the critical thinking skills of grade XII MIPA-2 students, particularly in mastering the structure and nomenclature of benzene. This progress was evident across several indicators of critical thinking, including analyzing, evaluating, and creating. The learning process using the DL model was active and engaging, allowing students to participate more actively in responding to questions and encouraging continuous involvement throughout the lesson. Before the DL model was applied, students generally possessed only basic conceptual understanding and tended to answer questions similar to those previously discussed. Their ability to link molecular structures with nomenclature and to apply logical reasoning when explaining the properties of benzene compounds was still limited. The classroom atmosphere also tended to be tense, with students mostly working individually and learning dominated by the teacher's deductive lecture approach, in which understanding was largely shaped by what the teacher presented.

After the DL model was introduced, significant positive changes were observed. During the stimulation and problem identification phases, students became more actively involved in formulating and explaining initial hypotheses related to benzene structures. In the data collection and processing phases, they developed the habit of working collaboratively, modeling benzene structures, and analyzing contextual problems using HOTS-based reasoning. Students' critical thinking skills showed remarkable improvement during the proof-making and conclusion-drawing stage, where they began constructing scientific arguments supported by relevant data, such as explaining the stability of the benzene ring or determining the nomenclature of derivative compounds based on structural analysis. Reflection questionnaire responses indicated that most students felt more motivated because the DL model provided greater opportunities and a deeper understanding. They felt more engaged in the learning process and found it easier to grasp complex concepts such as electron delocalization and aromatic reactivity. Increased enthusiasm and participation during discussions further demonstrated enhanced critical thinking abilities.

Despite these positive developments, some students faced challenges, particularly in adapting to a learning process that demands independence and collaborative work. Continuous guidance and reinforcement are therefore essential for sustainable implementation. A number of students were also unfamiliar with the DL approach and felt more confident with traditional lecture-based instruction, especially when preparing for assessments. To address this, the teacher explained the purpose, procedures, and benefits of HOTS-oriented learning, helping students understand that meaningful learning goes beyond memorizing theories and concepts and instead requires active engagement and analytical thinking.

Overall, the results confirm that the DL model is effective in enhancing students' critical thinking skills, especially in complex chemistry topics such as benzene structure and nomenclature. This approach offers a strong pedagogical alternative for designing HOTS-oriented chemistry lessons that are more contextual, active, and meaningful. In the context of benzene nomenclature learning, the DL model encourages students to construct understanding through observation and discussion, processes that inherently demand critical thinking. Additionally, the implementation of the DL model improved students' problem-solving skills. Prior to its use, classroom activities relied heavily on teacher and student textbooks, which often presented problems unrelated to students' real-life contexts and limited exposure to diverse text types. With DL, students learned not only from written materials but also from nature and were provided opportunities to seek data and information from various sources, enriching their learning experience and deepening their understanding.

5. CONCLUSION

Based on the results of this study, it can be concluded that the implementation of the DL model in the benzene material for class XII MIPA 2 at SMA Kolese De Britto has proven effective in improving students' critical thinking skills. This improvement is reflected in the higher post-test scores compared to the pre-test, as well as in the active participation of students during the learning process. In addition, students also demonstrated higher learning motivation, as indicated by their active involvement in discussions, data collection, and presentation of learning outcomes. Thus, DL can be recommended as one of the effective learning models to foster critical, creative thinking skills, as well as promote students' learning independence. DL is effective in developing students' HOTS, both in basic material and in more complex chemical concepts.

Nevertheless, this best practice has several limitations. First, the relatively small number of participants (29 students from one class) makes the findings less generalizable. Second, since the research design was in the form of best practice, no comparison with a control group was conducted, so the effects of DL can only be interpreted descriptively. Third, the relatively homogeneous context of the school in terms of students' backgrounds is another limitation that should be considered.

For future research, it is recommended that DL be applied to other complex chemistry topics such as hydrocarbon isomers, redox reactions, or chemical equilibrium. Furthermore, it is necessary to test its implementation on a larger and more diverse student population, using a quasi-experimental research design to provide stronger empirical evidence of the effectiveness of this model.

5.1. Research Implications

The findings of this study offer several important implications. For chemistry teachers, discovery learning (DL) can serve as an effective strategy for strengthening students' critical thinking skills, especially when dealing with abstract and complex topics. For students, this learning model not only enhances conceptual understanding but also provides structured opportunities to develop higher-order thinking skills. At the school level, the successful implementation of innovative learning models requires strong institutional support through teacher training, adequate learning resources, and curriculum policies that encourage such pedagogical innovation. In terms of curriculum development, the results underscore the need to integrate discovery-based, problem-solving, and STEM-oriented approaches within chemistry education to meet 21st-century competency standards, with DL offering an evidence-based strategy to foster higher-order thinking skills (HOTS). Furthermore, these findings open avenues for future research to explore hybrid instructional models, such as combining DL with Problem-Based Learning (PBL) to further optimize students' HOTS development.

5.2. Research Suggestions

This study is limited by its restricted content focus on benzene and its small sample size involving only one class. Therefore, future research is encouraged to expand the scope by applying DL to other chemistry topics, such as equilibrium, thermochemistry, or electrolysis, to provide a more comprehensive understanding of its effectiveness. Further studies should also examine additional learning variables, including creativity, scientific literacy, and collaborative skills, to gain broader insights into students' cognitive and affective development. A wider research design involving more schools, classes, and participants is recommended to increase the generalizability of the findings. Integrating DL with digital technology, virtual laboratories, or PBL in blended or hybrid learning environments may also yield deeper insights into its relevance for contemporary chemistry education. In addition, longitudinal research is needed to evaluate the long-term sustainability of DL in improving students' mastery of HOTS.

5.3. Recommendations

Teachers are encouraged to move beyond reliance on student textbooks and teacher manuals by innovatively contextualizing instruction—particularly in topics such as benzene nomenclature and its derivatives—to align with students' backgrounds and school environments, thereby making learning more meaningful. Students, in turn, should cultivate higher-order thinking rather than merely memorizing theories, as this approach supports a deeper and more durable understanding of the material. Schools, especially principals, are advised to promote HOTS-oriented instruction among teachers by providing supportive institutional policies, adequate facilities, and opportunities for disseminating best practices, all of which can broaden teachers' perspectives and enhance the implementation of HOTS-based chemistry education.

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