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Exploring the Impact of Teaching Strategies on Students' Critical Thinking Skills in Chemistry

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ABSTRAK

Rendahnya keterampilan berpikir kritis siswa dalam pembelajaran kimia masih menjadi tantangan di jenjang SMA. Kondisi ini disebabkan oleh kurangnya penerapan model pembelajaran yang dapat mendorong siswa berpikir secara analitis dan reflektif. Penelitian ini bertujuan menganalisis hasil analisis keterampilan berpikir kritis siswa melalui penerapan model pembelajaran penemuan pada mata pelajaran kimia di kelas XI SMA. Penelitian ini menggunakan metode penelitian kualitatif dengan pendekatan deskriptif analisis. Subjek penelitian mencakup guru kimia dan siswa. Pengumpulan data dilakukan melalui observasi, wawancara, dan analisis dokumen. Teknik analisis data menggunakan triangulasi, member check, audit trail, serta pengecekan kredibilitas untuk memastikan validitas temuan. Hasil penelitian menunjukkan adanya perbedaan tingkat keterampilan berpikir kritis siswa selama proses pembelajaran dengan model penemuan. Beberapa indikator berpikir kritis, seperti kemampuan menganalisis informasi dan memberikan argumen yang logis, belum diterapkan secara optimal oleh siswa. Perbedaan interaksi di kelas turut memengaruhi hasil belajar siswa. Guru 1 menerapkan interaksi multiarah yang mendorong diskusi aktif, sementara Guru 2 cenderung menggunakan interaksi searah yang membatasi partisipasi siswa. Keterampilan mengajar guru memainkan peran penting dalam memfasilitasi pengembangan keterampilan berpikir kritis siswa. Simpulan dari penelitian ini menunjukkan bahwa model pembelajaran penemuan dapat meningkatkan keterampilan berpikir kritis siswa jika didukung oleh interaksi yang efektif dan kemampuan mengajar guru yang memadai.

ABSTRACT

The low level of students' critical thinking skills in learning chemistry is still a challenge at the high school level. This condition is caused by the lack of application of learning models that can encourage students to think analytically and reflectively. This study aims to analyze the results of the analysis of students' critical thinking skills through the application of discovery learning models in chemistry subjects in class XI SMA. This research used qualitative research method with descriptive analysis approach. The research subjects included chemistry teachers and students. Data collection was done through observation, interview, and document analysis. Data analysis techniques used triangulation, member check, audit trail, and credibility checking to ensure the validity of the findings. The results showed differences in the level of students' critical thinking skills during the learning process with the discovery model. Some critical thinking indicators, such as the ability to analyze information and provide logical arguments, have not been applied optimally by students. Differences in classroom interactions also affected students' learning outcomes. Teacher 1 applies multi-directional interactions that encourage active discussions, while Teacher 2 tends to use unidirectional interactions that limit students' participation. Teachers' teaching skills play an important role in facilitating the development of students' critical thinking skills. The conclusion of this study shows that the discovery learning model can improve students' critical thinking skills if supported by effective interactions and adequate teacher teaching skills.

1. INTRODUCTION

The 21st century challenges faced by students have been facilitated by the current Merdeka Curriculum, where several competencies that need to be improved include 1) communication skills, 2) the

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ability to think clearly and critically, 3) the ability to consider the moral aspect of a problem, 4) the ability to being a responsible citizen, 5) the ability to try to understand and be tolerant of different views, 6. the ability to live in a globalized society, 7) having a broad interest in life, 8) having a readiness to work, 9) having intelligence according to talent/interests, 10) have a sense of responsibility towards the environment. Referring to the above, one of the future competencies that is prioritized is equipping students with critical thinking skills, as a competency that supports their life activities in the future. This is because with the increasingly rapid development of technology, students are required to have high-level thinking skills (critical, creative, problem solving and decision making) to solve problems in life. Students who have critical thinking skills will not just believe the facts around them without providing proof so that the facts can truly be trusted. Apart from that, critical thinking has become one of the tools used in everyday life to solve several problems because it involves the ability to reason, interpret and evaluate information to make it possible to make valid and reliable decisions (Jones & Smith, 2023; Nugroho et al., 2020).

In the thinking process, the events of analyzing, criticizing, and reaching conclusions based on inference or careful consideration take place (Ayirahma & Muchlis, 2023; Gazali & Dasna, 2023). By thinking critically, people understand arguments based on differences in values, understand the existence of inferences and are able to interpret them, are able to recognize errors, are able to use language in arguments, are aware of and control emotions and are responsive to different views. However, in reality, even though learning with the Independent Curriculum has been implemented, there are still many learning outcomes that have not been achieved optimally (Anderson, 2021; Ariesta & Awalludin, 2021). This is in accordance with the results of observations and pretest and posttest results in chemistry subjects for students' critical thinking skills at SMA Negeri 1 Pupuan that the chemistry learning process still focuses on the teacher as an informant who plays a dominant role in every learning activity. Based on the results of interviews with chemistry teachers and the results of questionnaires with several Pupuan 1 Public High School students, the Minimum Completeness Criteria (KKM) in chemistry subjects is more than 74, which is one of the most difficult subjects for students. This is supported by the number of students who have not reached the KKM, namely more than 50%, where students generally have difficulty understanding the concept of hydrolysis, types of salt and hydrolysis reactions as well as the pH value of salt solutions. Apart from that, the use of a monotonous chemistry learning model makes many students less active and has an impact on students' thinking abilities which can be seen through decreasing exam results (Brown, 2021; Lin et al., 2020).

Another thing is that students' ability to ask questions is still low, this can be seen when teachers give students the opportunity to ask questions, students rarely ask questions, in fact no one asks. The low critical thinking ability of students in chemistry subjects is a complex problem that is influenced by various interrelated factors. This phenomenon not only impacts students' academic performance, but also their ability to apply chemistry knowledge in their daily lives and future careers. One of the roots of the problem lies in the teaching methods that are still dominant in many schools (Limna et al., 2022; Maielfi et al., 2024; Trimurtini et al., 2021; Wulan et al., 2022). Traditional approaches that focus on memorization and one-way transfer of knowledge from teacher to student tend to produce shallow understanding. Students may be able to remember formulas and definitions, but often have difficulty when asked to analyze, evaluate, or create new solutions based on the concepts they have learned. The lack of experimental and practical activities also reduces students' opportunities to develop observation skills, data analysis, and drawing conclusions, all important components of critical thinking.

Previous research shows that discovery learning models can improve students' concept understanding and critical thinking skills. According to research conducted by other researchers, the application of discovery learning model in chemistry learning can increase students' involvement in the learning process and develop their analytical skills. This model allows students to explore chemical phenomena independently, build hypotheses, conduct experiments, and draw conclusions based on the evidence found. Thus, the discovery learning model is in line with active learning principles that can improve students' conceptual understanding of salt hydrolysis. Based on these problems, innovation is needed in learning strategies that can improve students' critical thinking skills on salt hydrolysis material. One solution offered is the development of a discovery learning model that is more structured and in accordance with the characteristics of chemical materials (Nuraeni et al., 2019; Rabea, 2021). The novelty in this research lies in the application of discovery learning with a direct experiment-based approach, which not only emphasizes cognitive aspects but also involves deeper learning experiences through laboratory activities and reflective discussions. Thus, with this approach, students not only gain theoretical understanding of salt hydrolysis but also have the opportunity to develop analytical and evaluative skills in solving chemical problems.

The urgency of this research lies in the importance of improving the quality of chemistry learning in schools, especially in overcoming students' low critical thinking skills. With the increasing global

demands for 21st century competencies, students need to be equipped with high-level thinking skills in order to compete in the academic and professional world. This research is expected to contribute to the development of more effective learning methods, as well as provide recommendations for teachers in designing student-centered learning strategies. Based on this background, this study aims to: (1) analyze the effectiveness of the application of the discovery learning model in improving students' critical thinking skills on salt hydrolysis material; (2) identify obstacles and challenges in implementing the discovery learning model in chemistry learning; and (3) formulate a discovery learning-based teaching strategy that can be applied more widely in chemistry learning. Thus, this research is expected to provide applicable solutions in improving the quality of chemistry learning in schools.

2. METHOD

This research uses a qualitative design, which is research whose focus rests on the general principles that underlie the manifestation of a phenomenon in human life, or also patterns that are analyzed from socio-cultural indications through community culture to obtain a representation of ongoing examples (Pohan & Rambe, 2022; Sukib & Eli Yanti, 2019). Qualitative research according to other researchers is a research process that focuses on human or community problems. Researchers create whole complex pictures, analyze words, report informants' opinions in detail, and conduct research in a natural environment. The definition of qualitative research according to other researchers is a qualitative observation structure used to research on natural object conditions (as opposed to experiments). In this method the researcher acts as the main tool. Accumulation of facts is done through triangulation (combined). Qualitative research was chosen because it provides flexibility to explore in-depth understanding of the implementation of the discovery learning model in chemistry learning at SMA Negeri 1 Pupuan. The descriptive-analytic approach was used to analyze the data in depth, with the aim of better understanding and explaining the observed phenomena. This approach will help in revealing various aspects related to the effectiveness of the learning model under study.

The subjects of this study consisted of chemistry teachers and 11th grade students of SMA Negeri 1 Pupuan who participated in learning using the discovery learning model. Specifically, this study involved two teachers and 29 science students of class 3 and 36 science students of class 1 as the main participants. The selection of subjects was carried out using purposive sampling technique, namely the selection of informants based on certain criteria relevant to the research objectives. Data collection in this study was conducted through interviews, observations, and document analysis. In-depth interviews were conducted with teachers to find out their perceptions and experiences in applying the learning model. Observations were conducted during the learning process to observe student activeness, classroom interaction, and the effectiveness of the applied model. In addition, document analysis was conducted on learning tools such as lesson plans, student worksheets, and learning evaluation results (Ihsan et al., 2019; Lee et al., 2019). The instruments used have been validated by experts using an instrument validity grid that includes aspects of relevance, clarity, and applicability in the research context. The data obtained were analyzed using thematic analysis techniques through the stages of data reduction, data presentation, and conclusion drawing. Data reduction was carried out by sorting, selecting, and grouping data relevant to the research objectives. The reduced data were then presented in the form of descriptive narratives to facilitate interpretation. Furthermore, inductive inference was drawn based on patterns of findings that emerged from the results of data analysis.

3. RESULT AND DISCUSSION

Result

Critical Thinking Skills are Built by Students Who Are Taught Using the Discovery Learning Model. This research is a type of research that uses qualitative methods with a case study approach, carried out at SMAN 1 Pupuan with research subjects in class XI MIPA. Based on the results of interviews, observations and giving questionnaires to students, the learning process with teacher 1 using the discovery learning model was good. It can be seen from several aspects of the indicators that students' critical thinking skills have been able to be implemented. This can be seen when the teacher asks questions to students at the beginning of learning. The students are very enthusiastic in giving answers. After that, the teacher again gave students questions. Science class 3 students analyzed the questions given. Then they answer according to what they understand based on the results of the teacher's explanation. Next, students are given LKPD by the teacher, students are expected to synthesize and solve problems. In the LKPD given by the teacher, students are expected to synthesize salt hydrolysis and examples in everyday life.

At this stage, students are given the opportunity to convey the results of the discussion and then conclude regarding the matters that have been discussed. This shows that in the learning process carried out by teacher I in general science class 3, it was found that several indicators of critical thinking abilities in the discovery learning model had been implemented. The indicators that can be applied are: analytical skills, synthesizing skills, concluding abilities and problem solving abilities. Meanwhile, the ability to evaluate or assess is obtained from the test results given by the teacher at the end of the learning process. Based on the test results given by the teacher, 68.9% or 20 out of 29 students scored above the KKTP. It can be concluded that 68.9% of students were successful in the discovery learning process given by teacher 1. The results of the analysis of the critical thinking skills of the first teacher are presented in Table 1.

Table 1. Results of Analysis of Critical Thinking Ability in Teachers 1

Indicator	Learning Process
Analyzing skills	Students ask questions about the images displayed. Question what is expected is: 1. Are the properties of the three salts the same? 2. Do the three salts taste the same, namely salty? 3. Are the ingredients of the salt the same?
Synthesizing skills	Teachers differentiate content by providing material according to the learning style of each student, including: 1. Material in the form of PDF files and textbooks on salt hydrolysis (for students with a visual learning style). 2. Material in video form (for students with an auditory learning style) which contains an explanation of the types of salt hydrolysis. 3. Experimental tools to determine the type of salt hydrolysis (for students with a kinesthetic learning style).
Skills to recognize and solve problems	1. The teacher gives each small group a LKPD to discuss in their group (the LKPD is attached). 2. Each group and its members work together to solve problems in the LKPD. 3. The teacher differentiates the process by providing assistance to small groups in solving the problems given on the LKPD. (The teacher will provide more assistance to groups whose understanding is still at a basic level and provide flexibility in exploring the material to groups who already have an advanced level of understanding).
Inferencing skills	1. Students present the results of the discussion contained in the LKPD in front of the class by discussing first who will present the results of the discussion. 2. The teacher asks the groups that are not making presentations to respond to the answers from the groups that are presenting and tells each group that is making presentations to consider the views/thoughts of other people by responding to other students' answers with respect and empathy. 3. The teacher asks students to conclude the material discussed.
Evaluating or judging skills	Wayan is known as a child who likes meat. During the Galungan holiday, he ate so much meat that he couldn't defecate. Because he couldn't stand it, he took medicine containing English salt (MgSO4.7H2O) to wash his stomach. Determine: a. Acids and bases form MgSO4 salts, and write the hydrolysis reaction! b. The following salts are based on their constituent acids and bases, and determine which salts belong to one group. $(NH_4)_2SO_4$ NaOCl $NaHCO_3$ CH_3COONH_4 One form of evaluation of learning outcomes given by the teacher 1

Based on observations of the use of discovery learning by chemistry teachers at SMA Negeri 1 Pupuan, several important conclusions can be drawn. First, teachers implement experimental-oriented learning activities that actively engage students in chemistry experiments. Through group discussions and result presentations, students develop their understanding based on direct experience. Second, interactions in the classroom encourage critical thinking, as teachers pose questions that guide students to plan, evaluate, and conclude experimental results. Teachers also provide in-depth feedback, which helps students

interpret data more critically. Third, student participation is highly active, as they work in groups to plan experiments, record findings, and present their results to the class, demonstrating strong engagement in discovery learning. However, despite its benefits, teachers face significant obstacles, particularly in providing suitable experimental materials. This challenge underscores the need for adequate infrastructure and thorough preparation to optimize the effectiveness of discovery learning.

Thus, the use of discovery learning by chemistry teachers at SMA Negeri 1 Pupuan has proven effective in increasing student engagement, developing critical thinking skills, and providing in-depth direct experience in understanding chemical concepts. Efforts to continually improve preparation and support for this approach can strengthen overall student learning outcomes. Based on the results of interviews, observations and giving questionnaires to students, it was found that the learning process with teacher 2 using the discovery learning model had not been implemented optimally. It can be seen from several aspects of the indicators that students' critical thinking abilities have not been applied during the learning process. This can be seen when at the beginning of learning the teacher does not provide apperception to students. The teacher immediately explains the concept of acids and bases. Teachers also do not provide opportunities for students to explain the acids and bases that they often encounter in everyday life. Synthesis skills in students' critical thinking abilities in the learning carried out by teacher 2 are still not visible.

The next thing is that students are given LKPD and discuss it with their group. However, students are only asked to answer the LKPD without being directed or given any understanding first. This causes students to be less able to solve the problems they encounter. In the final stage the teacher directly asks students to do the assignment without concluding or asking students to conclude the material being taught. For the evaluation and assessment aspect at the end of the learning process, it was found that many students' test results in Science 1 class still did not meet the KKTP. As many as 52.7% or 17 people out of 36 students were able to fulfill the requirements. The results of the analysis of the second teacher's critical thinking skills are presented in Table 2.

Table 2. Results of Analysis of Critical Thinking Ability in Teacher 2

Indicator	Learning Process
Analyzing skills	1. The teacher conveys an apperception about the previous material. 2. The teacher provides trigger questions, an overview of the benefits of studying the material to be studied.
Synthesizing skills	1. The teacher groups students and provides LKPD 2. The teacher displays pictures of 3 pieces of salt that are famous in everyday life
Skills to recognize and solve problems	1. The teacher gives each small group a LKPD to discuss in their group (the LKPD is attached). 2. Each group and its members work together to solve problems in the LKPD 3. The teacher accompanies students in working on the LKPD given and provides solutions if students cannot solve the problem
Inferencing skills	The teacher asks students to conclude the material discussed
Evaluating or judging skills	The posttest question shown is an example given by the teacher in the teaching module.

In the table of results of the analysis of students' critical thinking abilities based on the teaching module, teacher 2 has implemented indicators of critical thinking abilities. However, during the learning process the opposite is true. The teacher does not fully implement what is written in the teaching module. This is what causes several indicators of critical thinking skills to not be implemented well. It can be concluded that the learning process carried out by teacher 2 using the discovery learning model is still not carried out optimally. There are several indicators that are still not visible during the learning process, including: 1) synthesizing skills, 2) problem recognition and solving skills, and 3) concluding skills. The implementation of the discovery learning model by Teacher 2 at SMA Negeri 1 Pupuan reveals several key aspects of the conventional learning approach. The focus of learning primarily rests on direct theory teaching, where the teacher plays a central role in explaining and presenting material to students. Consequently, learning activities revolve around teacher-led instruction, with minimal emphasis on exploration or independent discovery. Additionally, the interaction between teachers and students tends to be more directed, as the teacher assumes the primary responsibility for delivering information and answering questions. In this setting, students generally receive information passively, with limited engagement in activities that foster critical thinking. Student participation in this approach also varies, with

some students actively engaging in discussions or responding to questions, while others remain passive and less involved. Furthermore, the lack of emphasis on practical experimental activities or in-depth group discussions restricts the development of students' practical skills and critical thinking abilities. As a result, students may face challenges in applying theoretical concepts to real-world situations, limiting their overall learning experience.

Student interaction in chemistry learning using the discovery learning model. During the learning process using the discovery learning model, students reported that they felt more involved and had a sense of ownership of the learning process. They are invited to explore various solutions and solve problems independently or in small groups. The interactions carried out in the learning process in science class 3 are multidirectional interactions between teachers and students. When the teacher asks questions, then students respond and respond to each other with other students. After that, the teacher provides reinforcement for the opinions expressed by the students. Meanwhile, the interactions that occur during the learning process in science class 1 with teacher 2 are described as follows. Based on excerpts from the conversation between teacher 1 and students in science class 3, the interaction that occurred was a multi-directional interaction. Multidirectional interactions between teachers and students can form dynamic and collaborative learning. In modern education, interaction patterns in the classroom have undergone significant transformation.

Multidirectional or multidirectional interactions can be seen from communication carried out by teachers and students, but also between students and students. In the discovery learning model applied by teacher 1, students are required to be active in giving their opinions. This also happens because the teacher always gives questions and also examples that are closely related to everyday life, for example the teacher shows table salt, chemical fertilizers, and also batteries. Multidirectional communication in the learning process carried out in Science 3 class is an approach that involves active interaction between teachers and students as well as students and other students. When the learning process takes place, it is not just a matter of transferring knowledge but a collaborative process where all parties play an active role in it. Teachers no longer stand as the only source of information, but transform into facilitators who guide discussions and encourage students' critical thinking.

Discussion

Based on the research results, the learning process with teacher 1 using the discovery learning model was good. It can be seen from several aspects of the indicators that students' critical thinking skills have been able to be implemented. This can be seen when the teacher asks questions to students at the beginning of learning. The students are very enthusiastic in giving answers. After that, the teacher again gave students questions. Science class 3 students analyzed the questions given. Then they answer according to what they understand based on the results of the teacher's explanation. Next, students are given LKPD by the teacher, students are expected to synthesize and solve problems. In the LKPD given by the teacher, students are expected to synthesize salt hydrolysis and examples in everyday life. At this stage, students are given the opportunity to convey the results of the discussion and then conclude regarding the matters that have been discussed. This shows that in the learning process carried out by teacher I in general science class 3, it was found that several indicators of critical thinking abilities in the discovery learning model had been implemented. The indicators that can be applied are: analytical skills, synthesizing skills, concluding abilities and problem solving abilities. Meanwhile, the ability to evaluate or assess is obtained from the test results given by the teacher at the end of the learning process. Based on the test results given by the teacher, 68.9% or 20 out of 29 students scored above the KKTP. It can be concluded that 68.9% of students were successful in the discovery learning process given by teacher 1.

Based on the interactions carried out in the learning process in Science 1 class, it is a two-way interaction between teachers and students. This can be seen when the teacher only explains without giving initial questions or apperception to students. learning is more conventional because the teacher explains and conveys the material more. Students' opportunities to synthesize ideas or concepts according to the material are not optimal. This is actually inversely proportional to the teaching module created by teacher 2. In the teaching module, the syntax of the discovery learning model has been described which can analyze students' critical thinking abilities, but at the time the learning process was still not carried out optimally. This causes the interactions that occur to be two-way only. A two-way interaction pattern is an interaction pattern that is only centered on the teacher (Amalia et al., 2021; Khoirul Akbar et al., 2023). The pattern of two-way interaction in the learning process in Science 1 class is only that the teacher asks questions and then the students answer. There was no response from other students regarding the response from their friends. What should happen is that the teacher gives other students the opportunity to give their opinions. In the discovery learning model that is applied, students should also be active in discovering or exploring the material or concepts being taught themselves. The teacher as a facilitator in directing and guiding.

However, in the Science 3 class with 2 teachers, learning is still focused on the teacher. The teacher conveys more material and also answers questions from the LKPD provided. Students answer the teacher's questions. After that there was no interaction between one student and another student.

Regarding critical thinking in the context of chemistry learning at SMA Negeri 1 Pupuan, this research reveals that the discovery learning model makes a significant contribution in developing students' critical thinking abilities (Anderson, 2021; Trimurtini et al., 2021). Critical thinking in chemistry involves students' ability to not only understand chemical concepts theoretically, but also be able to apply this knowledge in relevant situations. In the context of discovery learning, students are encouraged to be active in exploring concepts, conducting experiments, and drawing conclusions based on the empirical evidence they obtain. This helps them develop deep analytical skills, such as the ability to identify patterns in experimental data, relate theories to phenomena they observe, and evaluate the accuracy of their experimental results.

The critical thinking abilities of students who are taught using the discovery learning model in science 1 and science 3 classes are very clearly visible. This can be seen from the students' ability to respond to the teacher's questions, students' ability to conclude learning and students are still not able to solve the problems given optimally. For science 3 students with teacher 1, the learning process using the discovery model takes place in accordance with the teaching module created. The steps in the discovery learning model have been implemented so that students' ability to think critically is very good. All indicators of critical thinking abilities have emerged, namely the ability to analyze, synthesize, solve problems, conclude up to the evaluation stage or the opportunity to reflect on the learning process. Meanwhile, the discovery learning process in science class 1, teacher 2, is still not optimal. Learning does not comply with the steps of the discovery learning model. The teacher provides more material or the concept of acids and bases. During the learning process, teachers ask very few questions to stimulate students' thinking abilities (Munandar, 2021; Novitasari, 2023).

In the context of chemistry learning, critical thinking is a very important skill for students to develop a deep and applicable understanding of chemical concepts. According to research from other researchers states that, critical thinking is not just recognizing facts or remembering information, but involves the ability to analyze, evaluate, and make conclusions based on existing evidence. In chemistry learning at SMA Negeri 1 Pupuan, the concept of critical thinking is widely applied to ensure that students not only understand basic theories, but are also able to apply them in the context of experiments and real life situations. Regarding critical thinking in the context of chemistry learning at SMA Negeri 1 Pupuan, this research reveals that the discovery learning model makes a significant contribution in developing students' critical thinking abilities. Critical thinking in chemistry involves students' ability to not only understand chemical concepts theoretically, but also be able to apply this knowledge in relevant situations (Nguyen et al., 2022; Sathianwatchai & Niramitchainont, 2022). In the context of discovery learning, students are encouraged to be active in exploring concepts, conducting experiments, and drawing conclusions based on the empirical evidence they obtain. This helps them develop deep analytical skills, such as the ability to identify patterns in experimental data, relate theories to phenomena they observe, and evaluate the accuracy of their experimental results (N.P.F.V. Dewi et al., 2023; Wulandari et al., 2023).

The application of the discovery learning model also helps students to develop critical thinking skills through direct experience in solving complex problems. In an atmosphere that supports exploration and discussion, students learn to question assumptions, test hypotheses, and critically evaluate evidence. This not only leads to a deeper understanding of chemistry concepts, but also prepares them to face complex intellectual challenges in real life. In discovery-based chemistry learning, students are not only recipients of information but also active knowledge constructors who can apply their understanding more widely. During the learning process using the discovery learning model, students reported that they felt more involved and had a sense of ownership of the learning process. They are invited to explore various solutions and solve problems independently or in small groups (Clark, 2020; Dhysa & Soenandar, 2020). This not only improves their practical skills in applying chemical theories, but also develops their confidence in exploring more complex concepts.

The use of technology is also an integral part of the student learning experience in this discovery learning model. Students use simulation software or applications to support their experiments, which broadens the scope of their learning beyond the traditional classroom environment. Some students described how using this technology helped them to visualize abstract concepts or understand chemical phenomena that were difficult to explain with theory alone. Apart from that, interaction between students is also strengthened in the discovery learning model. They learn to work together in teams, share ideas, and solve problems together. This creates a collaborative learning environment where students feel supported and able to actively contribute to group learning (Akcay et al., 2019; Nurani, 2022). For example, in group-

based experiments or projects, students experience how working together can produce better solutions than individual efforts.

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The implications of this research cover various aspects. For teachers, this study shows the importance of designing discovery learning-based lessons systematically, including providing initial questions that stimulate critical thinking and encourage discussion among students. For schools, this research can be the basis for conducting training for teachers to improve their skills in implementing the discovery learning model more effectively. Meanwhile, for students, this learning model can help them develop critical thinking skills that are useful in further studies and in everyday life. For policy makers, the results of this study can serve as a basis for developing a curriculum that emphasizes discovery-based learning to improve the quality of education in Indonesia. Although this study provides valuable insights, there are some limitations that need to be considered. This study was only conducted in one school with two classes, so the results cannot be widely generalized. In addition, external factors such as students' academic background, teachers' teaching style and learning environment may affect the results. The limited duration of the study is also an obstacle in measuring the long-term effects of the discovery learning model on students' critical thinking development. Therefore, future research is suggested to involve a wider scope with several schools and different grade levels, use mixed-methods (quantitative and qualitative) to get a more in-depth analysis, further examine the factors that can hinder the effectiveness of discovery learning and strategies to overcome them, and explore the role of technology in supporting the implementation of discovery learning to improve student interaction and understanding in chemistry learning.

4. CONCLUSION

Based on the research results, it was found that the discovery learning model significantly increased students' understanding and application of critical thinking skills. Students who engage in this learning tend to be better able to analyze information, evaluate arguments, and make decisions based on evidence they find themselves or through practical experiments they conduct in the context of chemistry. The conclusions from this research are as follows first, in the learning process in science 1 and science 3 classes, differences in students' critical thinking skills can be seen. Several indicators of students' critical thinking skills have not been implemented optimally. Second, the interactions carried out by teacher 1 and teacher 2 are different, with teacher 1 there is multidirectional interaction while with teacher 2 there is two-way interaction. This is also influenced by the teacher's teaching skills. Discovery learning requires students to be active in the learning process, develop hypotheses, look for evidence, and draw conclusions. The learning process in the discovery model focuses more on understanding concepts and the discovery process itself.

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