



Critical Reasoning in Chemical Bonding: A Study of Students' Responses to Higher-Level Thinking Questions

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Critical Reasoning in Chemical Bonding: A Study of Students' Responses to Higher-Level Thinking Questions. Purpose: To analyze students' critical thinking skills in solving HOTS questions on chemical bonding and identify the dominant Ennis indicators. Method: This quantitative descriptive study involved 34 students at SMA Sriwijaya Negara Palembang (2025/2026) selected via purposive sampling. Data were collected through 8 HOTS essay items and interviews. Findings: Achievement in providing simple explanations reached 73.40%, concluding 68%, and providing further explanations 61%, all in the moderate category. The overall average score was 67.47% (moderate). Conclusion: Students' critical thinking skills in chemical bonding are categorized as moderate, with "providing simple explanations" as the most dominant indicator.

Keywords: Analysis, Critical Thinking, HOTS, Chemical Bonding.

Menalar Ikatan Kimia: Kajian Kemampuan Berpikir Kritis Peserta Didik dalam Menyelesaikan Soal Berpikir Tingkat Tinggi. Tujuan: Menganalisis kemampuan berpikir kritis siswa dalam menyelesaikan soal HOTS materi ikatan kimia dan mengidentifikasi indikator Ennis yang dominan. Metode: Penelitian deskriptif kuantitatif ini melibatkan 34 siswa SMA Sriwijaya Negara Palembang (2025/2026) melalui purposive sampling. Instrumen berupa 8 soal esai HOTS dan wawancara. Temuan: Capaian indikator memberikan penjelasan sederhana sebesar 73,40%, menyimpulkan 68%, dan penjelasan lebih lanjut 61% (kategori sedang). Rerata keseluruhan kemampuan berpikir kritis mencapai 67,47% (sedang). Kesimpulan: Kemampuan berpikir kritis siswa pada materi ikatan kimia berada pada kategori sedang, dengan dominansi pada indikator memberikan penjelasan sederhana.

Kata kunci: Analisis, Berpikir Kritis, HOTS, Ikatan Kimia.

■ INTRODUCTION

Learning is a systematic effort to facilitate students in constructing knowledge through interactions among educators, learners, and learning resources within a structured environment. In the context of 21st-century education, students are required to master essential competencies known as the 4C skills: critical thinking, creativity, communication, and collaboration. Among these skills, critical thinking plays a central role in enabling students to analyze information, evaluate arguments, and make reasoned decisions when facing complex problems (Ennis, 2011; Facione, 2015).

In line with these demands, the Indonesian Independent Curriculum emphasizes the development of Higher Order Thinking Skills (HOTS), particularly in science learning, including chemistry. HOTS-oriented learning encourages students to engage in analysis, evaluation, and reasoning processes rather than mere memorization, emphasizing students' ability to think critically and solve complex problems (Nugroho, 2018). One chemistry topic that strongly requires higher-order thinking is chemical bonding, as it involves abstract concepts, such as electron interactions, bond formation mechanisms, and the relationships between atomic structure, molecular shape, and chemical properties. Understanding chemical bonding therefore requires students to integrate multiple concepts and apply logical reasoning to solve problems (Taber, 2013).

Several previous studies indicate that students' critical thinking skills in chemistry are still relatively low. (Safitri, 2023) reported that approximately 80% of students had difficulty understanding HOTS-based questions due to limited exposure and practice, while 75% of students experienced specific difficulties in chemical bonding material. Similarly, (Juwanti, 2024) found that the indicator of providing simple explanations only reached 59% in atomic structure topics. International research also supports these findings, showing that students often struggle to demonstrate higher-order reasoning in chemistry problem-solving, particularly when dealing with abstract concepts such as bonding and molecular interactions (Zoller & Pushkin, 2007; Pirinelli et al., 2016). Furthermore, (Khotimah et al., 2022) reported that although basic clarification skills were relatively high, inference skills remained low, with an average score of 47.86.

This condition is closely related to conventional assessment practices that still emphasize low-level cognitive questions, resulting in limited opportunities for students to develop critical thinking skills. Although HOTS-based questions have begun to be implemented in some schools, their effectiveness in fostering critical thinking has not been comprehensively evaluated, particularly in relation to specific critical thinking indicators.

The research gap in this study lies in three main aspects. First, although many studies have examined students' critical thinking skills, only a limited number have focused specifically on chemical bonding material, which is known to be conceptually challenging. Second, studies that analyze critical thinking skills based on Ennis' critical thinking indicators in the context of HOTS-based chemistry problems are still scarce. Third, there is limited empirical evidence from schools that have already implemented HOTS-oriented assessments, particularly at the senior high school level in Indonesia. Therefore, further investigation is needed to obtain a more detailed profile of students' critical thinking skills within this specific context.

Based on these considerations, this study aims to analyze students' critical thinking skills based on Ennis' indicators in solving HOTS-based questions on chemical bonding material. In addition, this study seeks to identify the most dominant Ennis critical thinking indicators demonstrated by students during the problem-solving process. The findings of

this research are expected to provide valuable insights for chemistry teachers in designing learning strategies and assessments that are more effective in developing students' critical thinking skills.

■ **METHOD**

This study employed a quantitative descriptive research design aimed at describing and analyzing students' critical thinking skills in solving Higher Order Thinking Skills (HOTS) questions on chemical bonding material. This design was chosen because it allows researchers to present an objective description of students' abilities without manipulating variables, focusing instead on the distribution and characteristics of the observed data (Creswell, 2014).

The research was conducted during the odd semester of the 2025/2026 academic year at Sri Jaya Negara Senior High School, Palembang, Indonesia. The population of this study consisted of all eleventh-grade students who had learned chemical bonding material. The sample was selected using a purposive sampling technique, based on the recommendation of the chemistry teacher, with the consideration that the selected class had completed the chemical bonding topic and had been exposed to HOTS-based assessments. A total of 34 eleventh-grade students participated as research subjects.

The research procedure was carried out in several stages. The pre-research stage involved preparing research instruments, reviewing HOTS-based questions, and ensuring their suitability for measuring critical thinking skills. The implementation stage consisted of administering HOTS-based essay tests to students and collecting relevant documentation. Subsequently, the data processing stage included scoring students' answers and analyzing their critical thinking skills based on Ennis' indicators. The final stage focused on interpreting the results and drawing conclusions from the data obtained.

The main research instrument was a cognitive test consisting of eight HOTS-based essay questions at cognitive levels C4 (analyzing) and C5 (evaluating) according to the revised Bloom's taxonomy (Anderson & Krathwohl, 2001). The test items were adapted from instruments developed and validated in previous studies (Amalia, 2018; Oktafiyanti, 2021). Instrument validation in these studies included content validity through expert judgment in chemistry education, empirical validity testing using item validity analysis, and reliability testing using Cronbach's Alpha, which indicated a high level of reliability ($\alpha > 0.70$). In addition, item difficulty and discrimination index analyses showed that the questions were of moderate difficulty and had acceptable discriminating power. Therefore, the instrument was considered valid and reliable for measuring students' critical thinking skills in chemical bonding material. To support the quantitative data, a semi-structured interview guideline was also used to explore students' experiences in solving HOTS questions.

Data analysis was conducted using quantitative descriptive analysis. Students' answers were scored based on Ennis' critical thinking indicators, including providing simple explanations (elementary clarification), drawing conclusions (inference), and providing further explanations (advanced clarification). The scoring process referred to the PISA assessment framework, which emphasizes the quality of reasoning, clarity of explanation, and justification in problem-solving (OECD, 2006; OECD, 2009). The PISA framework was selected because it aligns with HOTS-oriented assessments and supports the evaluation of students' critical thinking performance beyond factual recall, which emphasizes reasoning quality and justification in line with HOTS assessment principles (Brookhart, 2010).

The percentage of students' critical thinking skills was calculated using the following formula:

$$NP = \frac{R}{SM} \times 100\%$$

Description:

NP: The desired or expected percentage value

R: The raw score obtained by the student

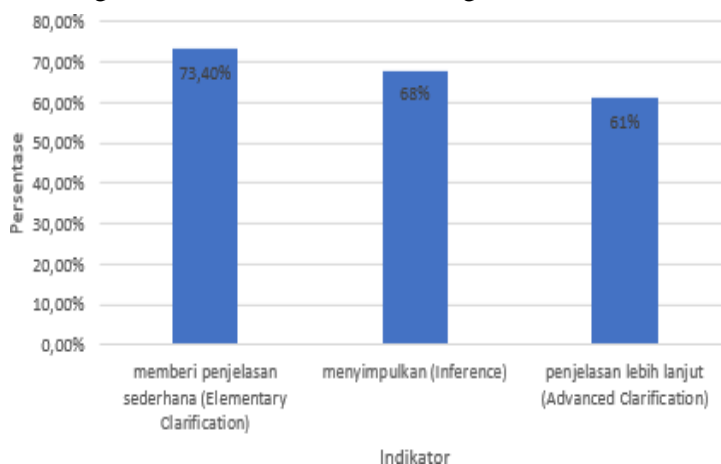
SM: The maximum ideal score for the test in question

The resulting percentage scores were then classified into levels of critical thinking skills to describe the overall profile of students' critical thinking abilities.

■ RESULT AND DISCUSSION

Students' critical thinking skills were measured using an eight-item HOTS-based essay test on chemical bonding material administered to 34 eleventh-grade students of Srijaya Negara Senior High School, Palembang. Students' responses were analyzed descriptively based on three Ennis critical thinking indicators, namely providing simple explanations (elementary clarification), drawing conclusions (inference), and providing further explanations (advanced clarification). The percentage of students' achievement for each indicator is presented in Figure 1.

Figure 1. Percentage of Students' Critical Thinking Skills Based on Ennis Indicators



Based on Figure 1, the average overall percentage of students' critical thinking skills reached 67.47%, which falls into the moderate category. This result indicates that students possess a sufficient level of critical thinking ability when solving HOTS-based chemical bonding problems, although their skills have not yet reached an optimal level. Among the three indicators, the highest achievement was found in the elementary clarification indicator with a percentage of 73.40%, followed by the inference indicator at 68%, while the advanced clarification indicator showed the lowest percentage at 61%.

The dominance of the elementary clarification indicator suggests that students were generally able to identify relevant information and provide basic explanations related to chemical bonding concepts. In several test items, students demonstrated the ability to explain the formation of ionic and covalent bonds by referring to differences in electronegativity and electron sharing. However, some explanations were still incomplete, particularly when students were required to explicitly integrate supporting concepts such as valence electrons, electron configuration, or the role of lone electron

pairs. This finding indicates that students' reasoning abilities were still limited to basic clarification and had not yet fully developed into deeper analytical explanations. Similar results were reported by (Handayani et al., 2022), who found that the elementary clarification indicator tended to show higher achievement compared to other critical thinking indicators.

The inference indicator obtained a percentage of 68%, indicating that students were moderately able to draw conclusions based on available information. Difficulties began to emerge when students were required to connect multiple concepts simultaneously, such as relating types of chemical bonds to the physical properties of substances or predicting molecular behavior based on bonding characteristics. Although most students were able to identify relevant facts, they often struggled to construct well-supported and logically structured conclusions. This result is consistent with the findings of (Pakpahan et al., 2020), who reported that students' inference skills were generally in the moderate category due to limited opportunities to practice deductive and inductive reasoning during learning activities.

The lowest achievement was observed in the advanced clarification indicator, with a percentage of 61%. This indicates that students experienced difficulties in providing deeper explanations, such as identifying assumptions, defining concepts accurately, and evaluating abstract statements related to chemical bonding. For example, many students found it challenging to analyze molecular polarity by simultaneously considering dipole moments and molecular geometry. This result aligns with (Sulistiani et al., 2016), who stated that advanced clarification skills are more difficult to achieve because they require higher levels of abstraction and conceptual integration.

In addition to the test results, interviews with the chemistry teacher provided further insight into the learning conditions that influenced students' critical thinking skills. Based on the interview, the teacher explained that chemistry instruction had begun to incorporate HOTS-based questions, particularly in assessment activities. However, the learning model implemented in daily classroom practice was still predominantly direct instruction combined with question-and-answer sessions and assignment-based tasks. Although group discussions were occasionally conducted, they were not consistently structured to train higher-order thinking processes such as analyzing assumptions, evaluating arguments, or constructing comprehensive explanations.

The teacher also noted that time limitations and curriculum demands constrained the implementation of learning models that explicitly emphasize critical thinking skills, such as problem-based learning or inquiry-based learning. Consequently, students were more frequently trained to understand concepts at a procedural and factual level rather than engaging deeply in analytical and evaluative reasoning. These instructional conditions help explain why students' critical thinking skills were categorized as moderate, with stronger performance in elementary clarification indicators and weaker performance in advanced clarification indicators.

Overall, the findings of this study indicate that students' critical thinking skills tend to decrease as the level of cognitive demand increases. This pattern is consistent with previous studies showing that elementary clarification skills are generally easier to develop than inference and advanced clarification skills (Khotimah et al., 2022). From a pedagogical perspective, these results imply the need for chemistry learning strategies that place greater emphasis on training students' higher-order reasoning skills. This finding is consistent with previous studies which emphasize that problem-based and

HOTS-oriented learning approaches are effective in improving students' higher-order thinking skills (Widodo & Kadarwati, 2013).

■ CONCLUSION

The critical thinking skills of students at SMA Srijaya Negara Palembang in solving Higher Order Thinking Skills (HOTS)-oriented problems on chemical bonding material are generally in the moderate category. This indicates that students have an adequate foundation in higher-order thinking skills, but still need optimization in deeper analysis aspects. Of the various indicators tested, the ability to provide simple explanations is the most dominant aspect that appears, which reflects that students are superior in organizing basic information compared to making inferences or providing further, abstract explanations. This finding contributes to the development strategy for chemistry learning, where strengthening critical thinking skills is not only sufficient to the stage of conceptual understanding, but must be integrated with exercises that hone the sharpness in analyzing unstated variables. As a suggestion, educators are expected to start getting used to the use of more varied HOTS evaluation instruments and implementing problem-based learning models to emphasize the gap between basic clarification skills and students' deduction abilities.

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