Profile of Critical Thinking Skills of Chemistry Education Students in Solving Problems Related to the Concept of Mole

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Abstract. Critical thinking skills are needed in solving problems because identifying problems requires an analytical thinking process based on clear data and reasons. The purpose of this study was to describe the critical thinking skills of chemistry education students class of 2020 in solving problems related to the mole concept. The type of research used in this study is descriptive quantitative. Subjects who participated voluntarily in this study were 38 people out of 49 chemistry education students class of 2020. Data collection techniques using measurement and direct communication. The research instrument used was adopted from the stoichiometry e-book developed by Rahmat Rasmawan in 2022 which has been validated by 10 validators with a score of 85 which means it is validated and can be used. The data analysis technique used was descriptive analysis. The results showed that critical thinking skills in the skilled category was 40%, while in the less and unskilled were 55% and 5% respectively. In each indicator, which are making assumptions is in the highly skilled criteria with 66%, making inductive thinking conclusions are in the skilled criteria with 84%, and interpreting information is in the unskilled criteria with 61%. The critical thinking skills of students in the 2020 chemistry education class are still in the unskilled category, this is due to the inhibiting factors, namely the online learning system and inappropriate learning methods.

Keywords: Critical Thinking, Problem-Solving, Quantitative, Problem-Based Learning, Online Learning

Introduction

The 21st century is a period full of challenges where the development of the industrial revolution is growing very rapidly. Global changes in various aspects of life and rapid world development are challenges for the nation in preparing future generations (Rachmantika & Wardono, 2019). One of the developments that occurred in the 21st century was the improvement of science and technology (IPTEK). Developments that occur in science and technology result in an increase in the field of science. One of the difficulties in development in the 21st century is the challenge of solving problems.

These challenges are also in line with the kerangka kualifikasi nasional Indonesia which states that undergraduate graduates must be able to adapt to current conditions and use science, technology, or art in the field of problem-solving. Then graduates must be able to formulate procedural solutions to problems and understand general theoretical concepts and specific theoretical concepts from various scientific fields. In addition, they can able to assist individuals and groups in choosing alternative
solutions and making appropriate decisions based on information and data analysis. From these expectations and challenges, a person, especially a student, must be able to solve future problems and be able to provide solutions from the results of the data analysis carried out. To help face the challenges in solving these problems, skills are needed that can solve these difficulties.

Critical thinking skills are one of the things that help in problem-solving. Álvarez-Huerta et al. (2022) argued that critical thinking is an important complement to cognitive processes to deal with complex problems. Matthee & Turpin (2019) argued that a person needs an analytical mindset based on critical thinking to solve a problem. One must be a critical thinker in addressing various problems. Critical thinking allows a person to make decisions and take action more quickly by organizing, adjusting, reconstructing, or improving their thinking (Maulana, 2017). A person goes through a rational process before finding a reasonable solution. The rational critical thinking process aims to decide whether to believe or do something. Therefore, critical thinking skills need to be developed to help solve problems that come later.

Critical thinking skills require higher-order cognitive processes (Barta et al., 2022). To achieve critical thinking skills, it is developed through the educational process. In the 21st century, critical thinking has long been an important terminology in the educational process and has a very specific definition (Belecina & Ocampo, 2018). The educational process is one of the mainstays to improving critical thinking skills. Critical thinking is a core academic skill that teaches students to question or reflect on their knowledge of the information presented (Seki et al., 2022). Wiliawanto et al. (2019) suggested that critical thinking is the most important part of learning objectives. The Chemistry Education Study Program of FKIP Tanjungpura University is one of the universities in pontianak that aims to prepare prospective chemistry teachers at the junior and senior high school levels. Students in the chemistry education study program must be able to meet the graduate learning outcomes, one of which is that students can use logical, systematic, critical, and innovative thinking in the context of improving or applying science and/or technology based on their field of expertise. Then students must be able to apply this way of thinking to solve problems in their field by determining the right decision based on the results of information and data analysis. Therefore, critical thinking skills need to be improved in the learning process.

Critical thinking skills are one of the materials contained in chemistry learning. The material of the mole concept is the relationship between moles, molar mass, and molar volume. In this study, the mole concept material is used as the basis for measuring critical thinking skills in solving problems related to the mole concept. This is because the mole concept material is often considered easy by students because the mole concept material that students know is only calculating the mole content in a compound. But in reality, when the concept of a mole is associated with a form of problem-solving in everyday life, it is found that many students fail to solve the mole concept problem. This is because the concept of moles is often considered easy by students because what students know is only to calculate the mole content of a compound in the material.

The basis for choosing the mole concept material is also supported by the results of an interview with one of the students. According to the results of the interview, students understand the concept of a mole and how to calculate the mole content in a compound. But when the concept of a mole is implemented in the form of problems in everyday life, it is found that many students fail to solve the mole concept problem. This is because the concept of moles is often considered easy by students because what students know is only to calculate the mole content of a compound in the material.

Some research results show that students' critical thinking skills need attention. Among them is research conducted by Oktariani et al. (2020) which analyzes the critical thinking skills of prospective chemistry teachers at the Islamic University of Riau and shows that the ability of chemistry education students is still at sufficient criteria, especially on indicators
of providing explanations or making assumptions, building conclusions, and developing strategies or solutions. Then supported by research by Suryani et al. (2020) which suggests that students' critical thinking skills are still at low criteria, and the indicators used are also the same as previous research, namely providing explanations or making assumptions, building conclusions, and developing strategies or solutions. However, of the many studies that analyze students' critical thinking skills, there is still no one who analyzes students' critical thinking skills in solving problems related to the concept of moles. Therefore, researchers are interested in analyzing how the critical thinking skills of chemistry education students of FKIP UNTAN class of 2020 in solving problems related to the concept of mole.

Methods

This research uses a descriptive method with a quantitative approach. The subjects of this study were chemistry education students class of 2020 consisting of 2 classes and totaling 38 people out of a total of 49 people who participated voluntarily. This research subject was taken because it was considered to have received material related to the concept of mole and already had some skills in critical thinking if faced with a problem. The data collection technique used is a measurement technique, namely by giving a test of problem-solving questions adopted from the stoichiometry e-book developed by Rahmat Rasmawan in 2022 which has been validated. The purpose of using this tool is to determine the extent of students' ability to think critically when faced with a problem.

Table 1. The relationship between Critical Thinking Indicators and Problem Indicators

<table>
<thead>
<tr>
<th>No</th>
<th>Critical Thinking Indicators</th>
<th>Problem Indicators</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Making Assumptions</td>
<td>Students can predict the storage volume capacity needed to accommodate CO₂ with different temperatures and pressures.</td>
</tr>
<tr>
<td>2</td>
<td>Making Inductive Thinking Conclusions</td>
<td>Students can conclude the minimum mass of succimer needed to bind lead in the blood of poisoned patients.</td>
</tr>
<tr>
<td>3</td>
<td>Interpreting Information</td>
<td>Students can suggest the volume of seawater needed for a solution to pay off the compensation suffered by Jerman in World War 1.</td>
</tr>
</tbody>
</table>

The data analysis is done by scoring the answers using a scoring rubric that has been adjusted to the critical thinking indicators. The critical thinking indicators used are adopted from Rasmawan (2017) which consist of making assumptions, making inductive thinking conclusions, and interpreting information. After obtaining the overall score, the average score is calculated to determine the criteria of critical thinking skills by totaling the scores and then taking the average. Then the results of the average scoring are grouped into the critical thinking skills category.
After grouping into categories, interviews were conducted with 10 students who were taken based on the high, skilled, less, and unskilled categories seen from the answers given by students and the results of data analysis. Then the results of the analysis and interview results are described using a quantitative approach.

**Result and Discussion**

The results of critical thinking skills of chemistry education students class of 2020 are in the skilled category with a percentage of 40%, the less skilled category has a percentage of 55% and the unskilled category has a percentage of 5%. The results are presented in Figure 1.

*Figure 1. Results of Students’ Critical Thinking Skills*

Figure 1 shows the results of the critical thinking skills of the chemistry education students class of 2020 as a whole. Based on the results of critical thinking skills, it is found that the average of students are still in the low category. This is by the results of interviews which state that students are not familiar with the concept of moles that are implemented in problems in everyday life. Someone will use their critical thinking if faced with problem-solving. Therefore, critical thinking skills are needed in solving problems that will be faced. The results of this study are also in line with the results of research by Rasmawan (2017) which suggests that the critical thinking skills of chemistry education students are still relatively low, namely in the less skilled category.

<table>
<thead>
<tr>
<th>Score</th>
<th>Category</th>
</tr>
</thead>
<tbody>
<tr>
<td>≥ 3.50</td>
<td>Highly skilled</td>
</tr>
<tr>
<td>2.50 – 3.49</td>
<td>Skilled</td>
</tr>
<tr>
<td>1.50 – 2.49</td>
<td>Less skilled</td>
</tr>
<tr>
<td>0.00 – 1.49</td>
<td>Unskilled</td>
</tr>
</tbody>
</table>

Table 2. Category for Critical Thinking Skills
The results of critical thinking skills are obtained from the results of tests that have been carried out by giving question sheets to students directly in the joint lecture building B. Students are given 90 minutes to work on the questions that have been given. The questions used in measuring critical thinking skills are in the form of essay questions, namely problem-solving questions with each item adjusted to the indicators measured. Problem number 1 is a problem used to measure indicators of making assumptions. Problem number 2 is used to measure indicators of making inductive thinking conclusions and number 3 is a problem used to measure the interpreting information. The skills of chemistry education students class of 2020 in solving problems related to the concept of moles on each indicator are presented in form Table 3.

**Table 3. Percentage of Students' Critical Thinking Skills in Each Indicator**

<table>
<thead>
<tr>
<th>No</th>
<th>Indicator</th>
<th>Highly Skilled</th>
<th>Skilled</th>
<th>Less Skilled</th>
<th>Unskilled</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Making Assumptions</td>
<td>66</td>
<td>31</td>
<td>3</td>
<td>-</td>
</tr>
<tr>
<td>2</td>
<td>Making Inductive Thinking Conclusions</td>
<td>-</td>
<td>84</td>
<td>13</td>
<td>3</td>
</tr>
<tr>
<td>3</td>
<td>Interpretation of Information</td>
<td>-</td>
<td>-</td>
<td>39</td>
<td>61</td>
</tr>
</tbody>
</table>

Table 3 shows that the skills of each indicator have different percentages. For the highly skilled category which has the largest percentage is the indicator of making assumptions at 66%, while for the skilled category, the largest percentage is in the indicator of making inductive thinking conclusions at 84%. The less skilled category which has the largest percentage is the indicator interpreting information of 39% and the unskilled category of the indicator interpreting information has the largest percentage of 61%.

From the results of student answers, it can be seen the level of the questions given. The level of the questions given can be seen from the results of the average score of student answers presented in Figure 2.

![Figure 2. Average Score of Student Answers.](image-url)
From Figure 2, it can be seen that questions with indicators of making assumptions are the easiest level questions, this is because the results of the average score show a high number of 3.6 with a very skilled category. Then questions with indicators of making inductive thinking conclusions are included in questions with a medium level, namely with a score of 2.8 in the skillful category. However, on questions with interpreting information indicators, the score obtained is only 0.8 in the unskilled category. This indicates that the level of the problem with the information interpretation indicator is the most complicated problem to solve.

**Making Assumptions**

In the indicator of making assumptions, students are asked to be able to make assumptions based on consideration of factual background factors and provide clear and logical justification. This indicator measures how students' skills in providing assumptions based on background and clear justification when faced with problem-solving. The percentage results of the indicator of making assumptions are presented in Figure 3.

![Image of Figure 3](image.png)

**Figure 3. Percentage Results of Making Assumptions**

Figure 3 shows that in the highly skilled category, 66% of students answered the question with the calculation results showing the storage and release volumes based on clear facts about the background and acceptable justifications. The background and justification given in students' answers are in the question asked about the volume of CO$_2$ with different temperatures and pressures, students provide justification with the assumption that CO$_2$ is an ideal gas. This is in line with the theory which suggests that CO$_2$ can include ideal gas with acceptable differences. Therefore, to calculate the volume in question, the calculation process uses the ideal gas formula, namely $PV = nRT$ with $R$ as the ideal gas constant. Student answers in the highly skilled category can be seen in Figure 4.
Then for the skillful category, the student's answer is 31% with the answer that the calculation results show the storage and release volume based on a clear factual background but the justification for the calculation results is not clear. The answers of students in the skillful category can be seen in Figure 5.

In Figure 5, it can be seen that students justify that the volume of release and storage has a relationship and they use the Boyle-Gay Lussac law. Whereas in the question there is no relationship between the volume of release and the volume of storage associated with Boyle-Gay Lussac's law. This is in line with the research of Pratiwi, et al.: Profile of Critical Thinking Skills of Chemistry Education Students.
Romadona et al. (2020) which suggests that there are misconceptions between the application of the use of ideal gas calculations and the calculation of Boyle-Gay Lussac's law.

![Figure 6. Student Answers in the Less Skilled Category](image)

In Figure 6 are the answers of students in the less skilled category with a percentage of 3% with answers to calculation results based on general factual background and do not justify. Students' answers in the less skilled category only provide the required volume of answers without justifying what they answer.

**Making Inductive Thinking Conclusions**

In the indicator of making inductive thinking conclusions, students are expected to be able to induce existing data to provide relevant knowledge. Because in making reasonable and rational conclusions, relevant information is needed related to the problem at hand (Sundari & Sarkity, 2021). Students are also expected to be able to connect conclusions and data to obtain clear and logical information. Rijal & Sere (2017) revealed that inductive thinking is drawing conclusions from specific statements to general statements. Therefore, this indicator measures how students' skills make conclusions by linking data clearly in solving a problem. The percentage results of the inductive thinking conclusion indicator are presented in Figure 7.

![Figure 7. Percentage Results of Making Inductive Thinking Conclusions](image)
Figure 7 shows that in the skillful category of 84% where students perform induction by using relevant information, data, or knowledge but the relationship is still not clear so that it can cause bias. In this category, the students' answers can be seen in Figure 8.

**Figure 8. Student Answer in the Skilled Category**

In Figure 8, the student answers by inducing data from calculating the total mass of lead in the blood then finding moles of lead and then connecting moles of lead with moles of succimer. However, in the calculation the student related it to the number of particles instead of relating it to the mass of succimer needed to bind the lead. The calculation does not need to be associated with the number of particles, therefore the results cause irrelevant.

Then the category of less skillful students' answers amounted to 13% where the student only do induction but the data used is not related to the conclusions formulated. In this category, students' answers can be seen in Figure 9.

**Figure 9. Student Answer in the Less Skilled Category**
In Figure 9, students answered by inducing data from moles of lead which is related to the percent lead content. The data used in this answer has no relationship with the conclusion formulated because to find the minimum mass of the succimer there is no need to find the percent lead content.

![Image](masso_succimer_yang_dibubuhkan.png)

**Figure 10.** Student Answer in the Unskilled Category

Figure 10 is an unskilled student answer with a percentage of 3% where students do induction without being supported by the underlying reasons, namely writing directly the mole mass of succimer without any completion process.

**Interpreting Information**

The information interpretation indicator is used to measure students' ability to interpret information. Interpretation skills are skills to be able to express and understand the significant meaning or meaning of a problem (Solikhin & Fauziah, 2021). Therefore, in this indicator, students are asked to be able to interpret information with the assessment criteria, namely utilizing the measurement results obtained to provide clear information and their relationship with a number so that the proof can be rejected or accepted. The percentage results of the information interpretation indicator are presented in Figure 11.

![Image](interpretation_information_percentage_results.png)

**Figure 11.** Interpretation of Information Percentage Results

Figure 11 shows that in the highly skilled and skilled categories, none of the students were able to interpreting information by using relevant information, data, or knowledge and could link conclusions logically. Whereas in the less skillfed category, 39% of student answers were where students interpreted information but used information, data, or knowledge that had nothing to do with the conclusions formulated. In the less skilled category, students' answers can be seen in Figure 12.

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In Figure 12, students answer by interpreting the information data but the interpretation does not have a relationship to the conclusion asked, namely only calculating the moles of gold and then connecting to the wrong volume formula in finding the required conclusion volume.

Then in Figure 13 is the answer of student’s in the unskilled category with a percentage of 61% where students interpret information but without being accompanied by the underlying reasons.

From the results of the data analysis, it can be seen that the average student’s skills are still in the less skilled category. These skills are caused by several obstacles experienced by students mentioned in the results of interviews, they mentioned that in learning students are constrained by the online learning system. This is in line with the opinion of Handayani & Jumadi (2021) who states that students have difficulty understanding the material in online learning. Then students also do not ask the teacher directly if there is a material that cannot be understood. Whereas according to Mukarramah et al. (2021) suggest that the opportunity given by the teacher to ask questions during learning can help improve students’ thinking skills. By asking questions, students can criticize various problems that occur around their environment. In addition, in online learning, students also only listen to lecturers without taking notes on what the lecturer discusses. Even though recording material during learning is a way to help students remember the material discussed for a longer time than just listening. This can affect critical thinking skills because if students are not based on the knowledge they get, they will not be able to criticize the problems that will be given related to the material. Then in online learning, students are also constrained by several factors that cause ineffective learning, one of which is difficult internet access. Internet connection is the main component of online learning (Hamdani & Priatna, 2020). Students and lecturers will not...
be able to interact directly without an internet connection. Syah (2020) argues that an uneven internet network can complicate online learning.

Then not only online learning is an obstacle, but learning methods are also one of the drivers and determinants in the development of critical thinking skills. The success of learning methods is very influential in learning outcomes. From the results of interviews, students experience problems with learning methods. The learning method used is the lecture method, namely the lecturer explains and students only listen to the explanation of the lecturer. Then sometimes in the learning process, the lecturer only provides material without any further explanation related to the material that has been given. This makes students feel bored with the learning process because the learning methods used do not hone critical thinking skills. This is supported by the opinion of Suwarno (2015) which states that mostly in learning, the teacher acts as the center of information while students just sit and listen to the material given by the teacher. This learning method is difficult to develop students’ thinking skills because they only sit and listen without any activities that stimulate their higher-order thinking. One method that can be used to assist in the development of critical thinking skills in solving problems is the problem-based learning (PBL) method. PBL is a learning method that requires students to solve a problem to gain knowledge in learning the learning material (Pratiwiningrum et al., 2022). Putri et al. (2016) argued that the PBL learning method gives students freedom in determining the solution to the problem at hand so that a variety of new answers and opinions are produced by students. Similarly, Syaribuddin et al. (2016) argued that in the PBL learning method, students identify problems given by the teacher, and organize strategies for solving problems to find solutions and conclusions. From the learning process that has been carried out, students can improve their critical thinking skills. In addition to PBL-based learning methods, methods that can help improve critical thinking skills are PBL-STEAM learning methods. Putri et al. (2020) suggested that the learning process with the PBL-STEM method has the potential to spur students’ critical thinking skills and motivate them to learn the material. Learning using the STEM-PBL method can develop students’ critical thinking skills (Adiwiguna et al., 2019). Fadhilah et al. (2022) suggested that the use of the STEM-PBL method had a good impact on students’ critical thinking skills. Febrianto et al. (2021) also mentioned that applying the STEAM-PBL method in learning can develop critical thinking skills in solving problems. Therefore, PBL and PBL-STEAM learning methods can help improve students’ critical thinking skills.

**Conclusion**

From the research conducted, it was concluded that the critical thinking skills of chemistry education students class of 2020 in solving problems related to the concept of moles were still in the less skilled category with a percentage of 55%. This is because students are still not familiar with problems in the form of problem solving so that their critical thinking skills are still low. The supporting factors that hinder students' critical thinking skills are the online learning system and inappropriate learning methods.
References


