JPPIPA 11(1) (2025)

Jurnal Penelitian Pendidikan IPA

*Journal of Research in Science Education*

http://jppipa.unram.ac.id/index.php/jppipa/index

# Profile of Critical Thinking Skills of Phase F Learning in Chemistry Subjects Acid-Base Material

Dini Catur Anisah[1], Harun Nasrudin[2*], Sukarmin[2]

[1] Science Education Department, Universitas Negeri Surabaya, Surabaya, Indonesia.
[2] Chemistry Department, Universitas Negeri Surabaya, Surabaya, Indonesia.

Received: October 18, 2024
Revised: November 28, 2024
Accepted: January 25, 2025
Published: January 31, 2025

Corresponding Author:
Harun Nasrudin
harunnasrudin@unesa.ac.id

DOI: 10.29303/jppipa.v11i1.9842



**Abstract:** The purpose of this study was to describe the profile of critical thinking skills of Phase F students at Al-Azhar Menganti High School in the chemistry subject of acid-base material. This research is a quantitative and qualitative descriptive research. Data collection techniques are questionnaires, tests, and interviews. The research was conducted at Al-Azhar Menganti High School with chemistry teachers and 37 students in class XII. The results showed that the profile of students' critical thinking skills was low in the category of less and very less with only 36.93% of students who were able to interpret; 17.12% analysis; 21.17% inference; 33.33% evaluation; and 36.04% explanation with the factors that caused the low critical thinking skills of students were inappropriate learning models and lack of learning tools that could facilitate in improving critical thinking skills.

**Keywords:** Critical thinking skills; Green chemistry; Problem based learning

## Introduction

The expansion of technology and information in the age of globalization necessitates pupils possessing 21st-century skills. Communication, cooperation, critical thinking, and creativity are among the skills required in the twenty-first century, as per to the Partnership for 21st Century Skills (P21) established in the United States of America (Khoerunisa & Habibah, 2020). Critical thinking is one of the abilities that students need to face the problems of the twenty-first century. One of the characteristics of good education is to prepare students to be able to solve problems and challenges in the real world (Prabasari et al., 2021). As per to the Merdeka Curriculum, one of the most important parts of the Pancasila learner profile to cultivate is critical thinking skills. In implementing the Merdeka Curriculum, students will be given strengthening character building based on the values of the Pancasila Student Profile, which are: faithful, devoted to God Almighty, and noble; independent; mutual cooperation; global diversity; critical reasoning; and creative (Kemendikbud, 2022). Critical thinking abilities must be developed so that students may process information more wisely and solve problems in accordance with current demands and the Merdeka Curriculum objectives.

Critical thinking skills must be taught to students because, in an age of complicated information, they must be able to sift, analyze, and evaluate information objectively in order to make sound judgments (Dewi et al., 2024). Critical thinking abilities not only assist learners in dealing with academic obstacles, but they also aid in the development of adaptation, reflection, and problem solving, thus they must be trained. Critical thinking skills are the ability to analyze and evaluate information in a systematic, reflective, and logical manner in order to understand problems, generate valid arguments, and make informed decisions based on relevant data and knowledge, allowing learners to effectively confront challenges and changing times (Susanti et al., 2020). Critical thinking skills involve questioning facts, concepts, or relationships between ideas, regardless of whether they are true or false. Critical thinking is also defined as thinking to create an

**How to Cite:**
Anisah, D. C., Nasrudin, H., & Sukarmin. (2025). Profile of Critical Thinking Skills of Phase F Learning in Chemistry Subjects Acid-Base Material. *Jurnal Penelitian Pendidikan IPA*, *11*(1), 17–27. https://doi.org/10.29303/jppipa.v11i1.9842

idea, concept, or notion from the outcomes of questions that query if the thought is true (Wasahua, 2021). Critical thinking abilities can be defined as the ability to rationally assess, evaluate, and understand information in order to make informed decisions based on relevant evidence and expertise. Critical thinking promotes self-control by interpreting, analyzing, evaluating, and explaining data, concepts, and relevant settings. Indicators of critical thinking skills include interpretation, analysis, evaluation, inference, explanation, and self-regulation (Facione, 2015).

Critical thinking abilities are essential for pupils because they allow them to better understand the subject matter and examine it. When faced with a problem, critical thinkers seek answers based on clear facts and evidence. However, the PISA and TIMSS findings show that critical thinking skills in Indonesia remain inadequate. The PISA 2022 results indicate Indonesia's scores for reading literacy 359, math 366, and science 383. Although Indonesia's ranking rose 5-6 ranks compared to 2018, scores nevertheless declined internationally because to the impact of the pandemic (OECD, 2023). Meanwhile, Indonesia's TIMSS 2015 math and science ranking was 44th out of 49 nations, with an average score of 397 (Mullis et al., 2015). Indonesia did not participate in either TIMSS 2019 or 2023 (Mullis et al., 2020). PISA and TIMSS use HOTS questions. Critical thinking is one of the Higher Order Thinking Skills (HOTS) (Sudirman et al., 2023). The findings of PISA and TIMSS show that students have low critical thinking skills. As per to Andraini et al. (2021) research, students in class XI MIPA at MAN 1 Bengkulu City's critical thinking skills in chemistry lessons are classified as less critical, moderately critical, and critical, with an interpretation indicator of 40% in the less critical category, an inference indicator of 67% in the critical category, and an exploration indicator of 63% in the moderately critical category. Thus, students' critical thinking skills must be enhanced so that they may think more critically, rationally, and systematically while dealing with difficulties, allowing them to make informed decisions based on pertinent facts, evidence, and information.

One of the efforts to enhance critical thinking abilities can be done by combining learning materials with the real experiences of students in the everyday environment, such as through practicum (Kurnia, 2023). Practicum is a learning activity that involves students directly to make observations/experiments both in the laboratory and the surrounding environment (Darmayanti et al., 2020). The independent curriculum includes learning outcomes based on practical activities or students' experiences performing studies and inquiry. When implementing the independent curriculum, the expected results of students after completing learning are designed in the form of learning outcomes, which contain the information, abilities, and attitudes that students must possess as a result of their learning experiences. The learning outcomes are divided into six phases in accordance with Kemendikbudristek Number 32 of 2024, with phase A for grades I-II SD, phase B for grades III-IV SD, phase C for grades V-VI SD, phase D for grades VII-IX SMP, phase E for grade X SMA, and phase F for grades XI-XII SMA. This study focuses on phase F of high school chemistry.

As per to Kemendikbudristek Number 32 of 2024, the learning outcomes for chemistry in high school are in phases E and F. In phase E, chemistry, physics, and biology are taught together. However, as phase F begins, these three subjects are split to allow for more in-depth investigation. This division allows students to dig deeper into chemistry concepts, both theoretically and practically. Chemistry is the study of matter, its transformations, and the energy required. As a practical discipline, chemistry allows students to do simple research or practicum using a variety of scientific approaches. Practicum activities teach students not only theoretical chemistry principles, but also how to think critically, communicate effectively, and collaborate in groups (Kemendikbudritek Nomor 32 Tahun 2024).

Based on the Learning Outcomes of chemistry phase F, materials that can be practiced include reaction rates, chemical equilibrium, acid bases, buffers, hydrolysis, thermochemistry, redox and electrochemistry, and hydrocarbons (Kemendikbudritek Nomor 32 Tahun 2024). This study focused on acid-base material because of its characteristics and relevance to everyday life, relatively easy to obtain materials, and safe to do in the school laboratory. The characteristics of acid-base materials focus on understanding the correlation between the pH of acidic, basic, and salt solutions and their application in everyday life. Acid-base materials are closely related to the concepts of moles and stoichiometry, involving complex chemical calculations to determine the concentration and strength of acids and bases. Acid-base materials also emphasize the development of scientific method skills through laboratory practice. Through a comprehensive understanding of the profile of critical thinking skills of high school students, it is expected to find effective learning strategies in improving the critical thinking skills of high school students in acid-base chemistry lessons. This research needs to be carried out to describe in depth the profile of critical thinking skills of phase F students on practicum-based acid-base material, as a strategic step in supporting the implementation of the Merdeka Curriculum and improving the quality of chemistry learning in Indonesia. This study aims to

describe the profile of critical thinking skills of Phase F students at Al-Azhar Menganti High School in acid-base chemistry subjects.

## Method

This study incorporates both qualitative and quantitative research. This study included chemistry teachers and Phase F high school students from Al-Azhar Menganti High School. The study's equipment included a learner research questionnaire, a teacher interview sheet, and a critical thinking skills test sheet. The student research questionnaire is a tool for gathering information on students' perceptions, experiences, and understanding of critical thinking abilities while learning acid-base chemistry. The questions in the questionnaire given to students refer to the following grid.

**Table 1.** Research Questionnaire Grid

| Aspect | Question Item |
|---|---|
| Acid-base | Perception and difficulty level of acid-base material |
| Learning strategy | The chemistry teacher's strategy at school and the strategy that most interests students |
| Critical thinking | What indicators have I ever practiced |
| PBL | Have you ever applied PBL and what stages have you done? |
| Green chemistry | Do you know green chemistry and what principles have been done? |
| Learning tools | Learning tools needed to make it easier to understand the material |

Teacher interview sheets are used to gather information from teachers about chemistry teaching and their perspectives on students' critical thinking skills. Chemistry teacher interview questions refer to the following grid.

**Table 2.** Interview Grid

| Aspect | Question Item |
|---|---|
| Learning process | Teacher experience in practicum chemistry learning |
| Learning model | Effective learning models and the application of green chemistry |
| Critical thinking | The importance of critical thinking skills |
| Learning tools | Learning tools needed to make it easier to understand the material |

The critical thinking skills test sheet is a tool for assessing critical thinking abilities using indicators such as interpretation, analysis, assessment, inference, and explanation. The critical thinking skills test grids are as follows.

**Table 3.** Critical Thinking Skills Test Grid

| Question Aspect | Indicator |
|---|---|
| Formulate a problem | Interpretation |
| Formulating a hypothesis | Inference |
| Making a data table | Interpretation |
| Explaining the relationship | Explanation |
| Analyzing Data | Analysis |
| Making conclusions | Inference |
| Evaluate | Evaluation |

The supervisor has validated the instrument. The research flow can be seen in the following figure.

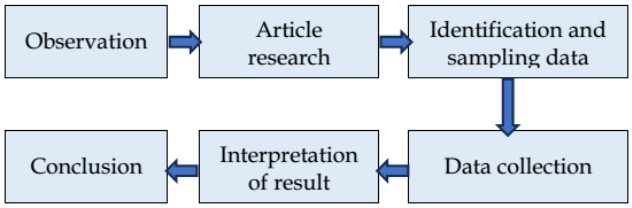


**Figure 1.** Research flow (Yuliarti et al., 2023)

Data was collected using questionnaires, tests, and interviews. Qualitative descriptive approaches were used to examine data from the research questionnaire and instructor interviews. The qualitative research method is a research approach that focuses on an in-depth understanding of a specific phenomenon or topic through descriptive data collecting, such as interviews and observations, to study individual experiences and perspectives in a broader context (Sahir, 2021). Critical thinking skills test data were analyzed descriptively quantitatively. Quantitative research method is a research approach that collects and analyzes data in the form of numbers and statistics to find patterns or relationships, so that the results can be measured and compared objectively (Sahir, 2021). The score of students' critical thinking skills can be calculated using the formula:

$$Critical\ thinking\ skills\ score = \frac{Score\ Obtained}{Maximum\ Score}\ x\ 100 \quad (1)$$

The score value is then averaged for each indicator of critical thinking skills, then can be interpreted in the following criteria table.

**Table 4.** Interpretation of Critical Thinking Skills Scores (Izzah et al., 2023)

| Presentation | Criteria |
|---|---|
| 81% - 100% | Very Good |
| 61% - 80% | Good |
| 41% - 60% | Fair |
| 21% - 40% | Less |
| 0% - 20% | Very Less |

## Result and Discussion

*Result*

The purpose of this study is to describe the critical thinking skills of SMA Al-Azhar Menganti students in the chemistry subject of acid-base materials. The study's findings include data from instructor interviews, student research questionnaires, and critical thinking skills tests. On October 29, 2024, the research was done at Al-Azhar Menganti High School in Gresik Regency. The research subjects for the teacher interview were chemistry teachers from Al-Azhar Menganti High School, while the pre-research questionnaire and critical thinking skills test were conducted on 37 XII grade students from Al-Azhar Menganti High School.

The data from the chemistry teacher interview at Al-Azhar Menganti Senior High School were collected using the teacher interview sheet instrument. A teacher interview sheet is a tool for gathering information from instructors about chemistry teaching, including their perspectives on students' critical thinking skills and appropriate learning approaches. Data from teacher interviews were examined using qualitative descriptive methods. As per to the teacher interview data, Al-Azhar Menganti High School follows the Merdeka Curriculum. Although there are basic practical assignments in acid-base material, most students continue to struggle with it due to challenges in linking concepts, theory, and practice. Critical thinking abilities are essential for teaching kids because they enable them to connect concepts, theories, and practices. Acid-base material requires practice using a learning paradigm that can connect concepts, theories, and practices, such as Problem Based Learning (PBL), which begins with real-world situations and trains critical and scientific thinking abilities. Simple practical exercises at Al-Azhar Menganti High School did not apply green chemistry principles. Teaching materials, such as printed worksheets and teaching modules, are more effective learning tools.

Data from pre-research questionnaires were analyzed using a pre-research questionnaire instrument. The pre-research questionnaire is a tool for gathering information about students' perceptions, experiences, and understanding of critical thinking abilities while learning acid-base chemistry. The results of the pre-research questionnaire were examined utilizing qualitative descriptive methodologies. As per to the data from the pre-research questionnaire, students consider acid-base material difficult and very difficult with a percentage of 43.2% due to abstract material with a percentage of 8.1%; material requiring a lot of memorization with a percentage of 10.8%; material containing too many formulas with a percentage of 40.5%; and a lack of learning resources with a percentage of 40.5%. Chemistry teacher strategies for learning chemistry material in the classroom include lectures (70.2%), questions and answers (43.2%), and practice questions (86.4%), while demonstrations, practicums, and group discussions are rarely used. On the other hand, 67.6% of students believe that the most successful learning approach for mastering chemical curriculum is practical. Students were provided opportunities to develop critical thinking abilities through scientific method exercises during their practicum experiences. In practicum activities, 51.4% of students had heard the term green chemistry, while 48.6% had not. When broken down into 12 principles of green chemistry, students who answered that they had applied the principle in practicum activities were 35.1% on principle 1; 18.9% on principle 2; 13.5% on principle 3; 21.6% on principle 4; 32.5% on principle 5; 21.6% on principle 6; 21.6% on principle 7; 18.9% on principle 8; and 13.5% on principle. 9; 16.2% on principle 10; 24.3% on principle 11; and 32.44% on principle 12. In chemistry class, students are asked if they require 86.5% reading materials, 70.3% worksheets, 56.8% electronic media, and 2.7% additional materials. Students prefer printed worksheets (81.1%) to electronic worksheets (18.9%).

Data on the outcomes of critical thinking skills assessed using a critical thinking test instrument. The critical thinking skills test sheet is a tool for assessing critical thinking skills based on indicators of interpretation, analysis, assessment, inference, and explanation. Data on the outcomes of critical thinking abilities were investigated using quantitative descriptive methodologies. The table below presents data on the results of students' critical thinking skills tests.

**Table 5.** Critical Thinking Skills Data

| Critical Thinking Skills | Presentation | Criteria |
|---|---|---|
| Interpretation | 35.93% | Less |
| Analysis | 17.12% | Very Less |
| Evaluation | 21.17% | Less |
| Inference | 33.33% | Less |
| Explanation | 36.04% | Less |

The critical thinking skills of students at Al-Azhar Menganti High School are still quite low, with only 36.93% of pupils being able to interpret in the less group. 17,12% are able to analyze in the very less category; 21,17% are able to form inferences in the less category; 33,33% are able to assess in the less category; and 36,04% are able to make explanations in the less category, indicating that critical thinking skills need to be strengthened further.

*Discussion*

The independent curriculum aims to achieve meaningful and effective learning by developing students' copyrights, tastes, and senses as lifelong learners with Pancasila character, which is then developed in accordance with the three main principles of independent curriculum design: (1) competency and character development; (2) flexibility; and (3) focusing on essential content. The profile of Pancasila students is defined as Indonesian students who are lifelong learners who are competent, have character, and conduct as per to Pancasila's beliefs (Wahyudin et al., 2024). Based on the urgency of information and abilities that need to be developed in Indonesian students, 6 (six) profile aspects were developed, all of which must be developed simultaneously in each individual Indonesian student. The Pancasila Student Profile includes six dimensions: Faithful, committed to God Almighty, and noble; Mutual cooperation; Critical Reasoning; Global diversity; Independence; and Creativity (Kemendikbud, 2022).

When the independent curriculum is implemented, the expected results for students after completing the learning process are designed in the form of learning outcomes, which include knowledge, skills, and attitudes that students should have as a result of their learning experiences. The learning outcomes are organized into six phases: phase A for primary school grades I-II; phase B for primary school grades III-IV; phase C for primary school grades V-VI; phase D for junior high school grades VII-IX; phase E for senior high school grade X; and phase F for senior high school grades XI-XII. In phase E of senior high school, chemistry, physics, and biology are taught as part of Natural Science studies. Then, in phase F, elective subjects were introduced, separating the chemistry, physics, and biology materials to allow for more in-depth study. In phase F, students can go deeper into chemistry lectures, which include theoretical and practical studies as well as the development of scientific skills. Chemistry is the theoretical and practical study of the interaction, structure, and properties of various materials, as well as their changes and the energy they generate. Chemistry is a practical subject in which students are taught to undertake simple scientific inquiry on real-world events, build analytical and communication abilities, and indirectly shape the profile of Pancasila students (Kemendikbudritek Nomor 32 Tahun 2024). One of the chemical components in phase F is acid-base.

The properties of acid-base materials in learning objectives chemistry phase F concentrate on comprehending the relationship between the pH of acidic, basic, and salt solutions and their practical application. Acid-base materials are closely related to the ideas of moles and stoichiometry, with complicated chemical calculations used to estimate acid and base concentrations and strengths. Acid-base materials also promote the development of scientific method abilities through laboratory practice (Kemendikbudritek Nomor 32 Tahun 2024). Practicum activities are critical given the nature and learning outcomes of acid-base materials. Practicum exercises can help students grasp acid-base material by integrating concepts, theory, and experience. On the other hand, practicum activities can stimulate and boost students' enthusiasm for chemistry, with 67.6% of students indicating that practicum is the most effective learning approach for mastering acid-base information. Simple practicum exercises exist at Al-Azhar Menganti High School, but they are rarely used, thus most students continue to struggle with linking concepts, theory, and practice. Students believe that acid-base material is difficult (43.2%) because it is abstract (8.1%), requires a lot of memorization (10.8%), contains too many formulas (40.5%), and lacks learning resources (40.5%). In line with research conducted (Awaliyah & Rusmini, 2023) that chemistry subjects are often considered difficult because they have many abstract and complex concepts.

Practical activities at SMA Al-Azhar Menganti are still infrequent due to a lack of laboratory equipment, and practicums can only be simple or based on video footage. Despite their importance, practical activities are rarely carried out. As per to Suryaningsih (2017), practicum activities can help students grasp concepts and theories by exposing them to essential tools, materials, or phenomena firsthand. As per to Al-Hafidz et al. (2024), practicum can develop critical thinking abilities by requiring students to comprehend, analyze, and evaluate material, as well as solve problems using real data and evidence. Acid-base practicum exercises not only give direct learning experiences and reinforce mastery of chemical topics, but they also help students build critical thinking abilities. This means that in order to acquire acid-base content, students must engage in practical activities that develop critical thinking abilities. As per to Sarafina et al. (2024) research, acid-base concepts are difficult to understand, necessitating the use of critical thinking skills, in which students are required to analyze and explain the phenomena or facts presented and draw conclusions based on the findings.

As per to professors at Al-Azhar Menganti High School, critical thinking abilities are essential for student development since they enable pupils to connect concepts, theories, and practices. Critical thinking skills, on the other hand, are extremely important to train because they teach students how to analyze and evaluate information systematically, reflectively, and logically in

order to understand problems, produce valid arguments, and make the right decisions based on relevant data and knowledge, allowing them to face challenges and changing times effectively (Susanti et al., 2020). In short, a critical thinker must be able to: interpret various kinds of information; analyze the relationship between statements, evaluate the credibility of statements, conclude, state results, and self-regulate their cognitive activities (Kolsto et al., 2024). In fact, the critical thinking skills of students at SMA Al-Azhar Menganti are still relatively low, according to the following data.

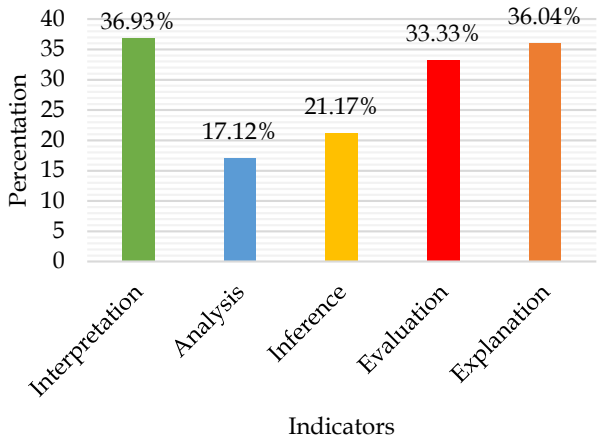


**Figure 2.** Critical thinking skills data

The critical thinking skills of students at Al-Azhar Menganti High School are still relatively low, with only 36.93% of students being able to interpret in the deficient category; 17.12% are able to analyze in the very deficient category; 21.17% are able to make inferences in the deficient category; 33.33% are able to evaluate in the deficient category; and 36.04% are able to make explanations in the deficient category, so that students' critical thinking skills need to be improved. Critical thinking skills are very important to train students to prepare students for the 21st century where future jobs are based on analyzing, producing, distributing, and consuming information so as to verify the truth and conclusions (Yusri et al., 2023). Furthermore Carmona (2023) explains that critical thinking is reflective thinking and provides the ability to evaluate several questions, and is able to defend arguments or statements. Critical thinking skills are very important skills because they can help learners understand and solve complex problems (Dissen, 2023).

The low critical thinking skills are caused when the learning process is still conventional which is teacher-centered and has not optimized learning activities that can improve students' critical thinking skills (Widyapuraya et al., 2023). Some of the characteristics that influence the critical thinking skills of Al-Azhar High School pupils include: Inappropriate learning models; a lack of learning tools to help improve critical thinking abilities. In line with research conducted (Chairatunnisa et al., 2023) the selection of the right model and the selection of learning tools as needed can encourage the improvement of critical thinking skills in accordance with curriculum objectives and prepare students in the 21st century. The first factor is an unsuitable learning model. As per to the Chemistry Teacher at Al-Azhar Menganti High School, acid-base material must be practiced using a learning model that connects concepts, theory, and practice, known as Problem Based Learning (PBL), which begins with real-world problems and trains critical and scientific thinking skills (Tefera et al., 2024). As per to Wahyudi et al. (2024) research, interactive and problem-based learning models or methodologies can help students improve their critical thinking skills, and research Quitadamo et al. (2008) conducted if the application of problem-based models can provide effective results in improving critical thinking skills and research conducted Styers et al. (2018) that the application of active learning strategies can be useful for improving critical thinking. The syntax of PBL is as follows.

**Table 6.** Sintaks Problem Based Learning (Arends, 2012)

| Phase | Description |
|---|---|
| Phase 1 | Provide problem orientation to learners |
| Phase 2 | Organize learners to research |
| Phase 3 | Assisting independent and group investigations |
| Phase 4 | Developing and presenting work |
| Phase 5 | Analyze and evaluate the problem-solving process |

Problem-Based Learning (PBL) is a learning methodology that introduces students to real-world situations to help them learn and promotes active learning through scientific procedures and group discussions, and problem solving (Manasikana et al., 2022). Problem solving is based on the knowledge that learners have and that knowledge can develop into new knowledge based on investigation (Asmussen et al., 2024). Furthermore, employing the Problem Based Learning (PBL) paradigm can make students more active (Kamala et al., 2022), assist students create new information based on concepts that are previously held (Usman, 2021), strengthen students' critical thinking skills (Zhang et al., 2024), and make it easier to understand concepts using crucial issues (Almagribi et al., 2024). The main features of PBL are: starting learning with a problem to activate learners' interest in learning; learner-centered; small group collaboration; teacher as facilitator; independent learning (Wijnia et al., 2024). The adoption of the Problem-Based Learning (PBL)

approach can help students enhance their critical thinking skills (Hasanah et al., 2023).

However, the chemistry teacher's classroom learning strategy in the category of always and often applied is lecture (70.2%), question and answer (43.2%), and practice questions (86.4%), while demonstrations, practicum, and group discussions are rarely used. In fact, according to research conducted (Zheng et al., 2023), problem-based learning in practicum is more effective when compared to lecture strategies. So practicum activities that can increase critical thinking skills and are of interest to students (67.7%) are rarely used. In addition to the need of practicing critical thinking skills, pupils should also be provided provisions for caring for the environment and working for sustainable development goals (SDGs), hence a green chemistry approach is required (Purwanti et al., 2023). Green chemistry is a method in chemistry that focuses on the application of green chemistry concepts in designing, utilizing, and producing chemicals to limit the use or manufacture of hazardous products and lessen negative effects on the environment and health. (Qulub et al., 2023). The green chemistry approach is applied with an independent curriculum with the aim of strengthening the character of students who care about the environment for sustainable development education (Jusniar et al., 2023). The application of green chemistry can provide benefits for human health, the environment, and economic sustainability which are closely related to the SDGs (Cahyani et al., 2024). Simple practicum exercises at Al-Azhar Menganti High School did not use green chemistry ideas. However, 51.4% of students understand the fundamentals of green chemistry, whilst 48.6% have never heard the term.

**Table 6.** Green Chemistry Principles (Anastas et al., 1998)

| Number | Principle |
|---|---|
| Principle 1 | Avoiding the generation of toxic chemical waste takes precedence over handling or cleaning up the chemical waste generated |
| Principle 2 | Atomic saving in designing synthesis methods. |
| Principle 3 | Producing chemicals that are harmless to the environment and harmless to human safety. |
| Principle 4 | Developing safer chemical products that, although toxic, function well. |
| Principle 5 | Use of safe and less harmful solvents and support materials. |
| Principle 6 | Design for efficient use of energy. |
| Principle 7 | Use renewable materials. |
| Principle 8 | Reduction of unnecessary by-products. |
| Principle 9 | Use catalysts to improve selectivity and minimize energy. |
| Principle 10 | Design chemical products from chemicals that can be degraded into harmless products. |
| Principle 11 | Simultaneous analysis to prevent pollution. |
| Principle 12 | Chemicals used in chemical processes are selected to be safer to avoid accidents. |

Based on the 12 principles of green chemistry, students who answered that they had applied these principles in practicum activities were 35.1% on principle 1; 18.9% on principle 2; 13.5% on principle 3; 21.6% on principle 4; 32.5% on principle 5; 21.6% on principle 6; 21.6% on principle 7; 18.9% on principle 8; 13.5% on principle 9; 16.2% on principle 10; 24.3% on principle 11, and 32.4% on principle 12. Green chemistry should be introduced to students in order to instill environmental stewardship and assist the Sustainable Development Goals.

The second factor is learning resources. Teachers, students, and learning technologies all contribute to effective learning (Wibowo & Hidayah, 2016). Learning tools are a collection of learning materials or support tools used by teachers and students to carry out the learning activity process. Learning tools can help facilitate the learning process and ensure that it runs smoothly (Asapari, 2020). Learning tools are important because they contain information, tools, or texts that are systematically arranged to train a competency in students in the learning process, containing the objectives of planning and implementing learning packaged in the form of textbooks, handouts, modules, LKPD, and others (Sugianto et al., 2023). In chemistry class, students are asked if they require 86.5% reading materials, 70.3% worksheets, 56.8% electronic media, and 2.7% additional materials. Students prefer printed worksheets (81.1%) to electronic worksheets (18.9%). As per to the Chemistry Teacher at Al-Azhar Menganti High School, the most effective learning tools are teaching materials or printed learning media such as printed worksheets and teaching modules.

It can be concluded that in the teaching and learning process acid-base materials are needed. First, to facilitate meaningful learner-centered learning and help teachers achieve specific learning objectives, it is necessary to use acid-base materials such as teaching modules (Salsabilla et al., 2023). Second, problem-based learning worksheets. As per to Hidayah et al. (2024) research, PBL-oriented worksheets can improve students' critical thinking skills based on the results of content and construct validity, which get mode 5 with a very valid category; practicality based on response questionnaires, with a percentage of 98.44% with a very practical category supported by the results of student activity observation sheets; and the effectiveness of the results in improving critical In addition to more effective worksheets for learning, printed forms make it easier for students to participate in learning and report learning outcomes. Third, electronic reading resources enable

students to learn anytime, anyplace. Learning by utilizing technology can make students learn more enthusiastically, creatively, and create a more pleasant learning atmosphere, one of which is using a technology-based learning module, namely e-modules (Saralee et al., 2024). As per to Ambarsih et al. (2023), electronic modules can be employed as a learning tool to develop students' critical thinking skills. Electronic modules can increase learning by delivering material that is more interactive, graphic, and easily accessible to students, while also keeping up with the rapid growth of information technology (Kristi & Andriani, 2023).

## Conclusion

Based on the data and discussion of research on the profile of critical thinking skills of Phase F high school students at Al-Azhar Menganti High School in the chemistry subject of acid-base material, it can be concluded that the critical thinking skills of students at Al-Azhar Menganti High School are still relatively low, with only 36.93% of students able to interpret in the less category; 17.12% are able to analyze in the very less category; 21.17% are able to Al-Azhar High School pupils' low critical thinking skills are caused by two factors: improper learning models and a lack of learning resources that can help them improve their critical thinking skills. Problem Based Learning (PBL) is a learning methodology that begins with real-world situations and trains critical and scientific thinking abilities using appropriate learning materials. Suggestions for educators related to improving the critical thinking skills of high school students, especially in chemistry, can use a problem-based learning model where learning begins with real problems and students solve problems through research or simple practicum in accordance with the principles of green chemistry so that they can train critical thinking skills and care for the environment, and use learning tools that can facilitate such as teaching modules, wor Suggestions for future study include developing chemical learning tools based on green chemistry using a problem-based learning methodology to boost high school students' critical thinking skills.

**Acknowledgments**
We would like to thank Surabaya State University, Al-Azhar Menganti High School teachers and students who have contributed to this research.

**Author Contributions**
D. C. A. researched at Al-Azhar Menganti High School and drafted the article; H.N. guided and reviewed the manuscript, and validated the instrument; S. guided and validated the instrument. All authors have read and approved the published version of the manuscript.

**Funding**
This research has no external funding.

**Conflicts of Interest**
This research experienced no conflicts during the process of writing. All participants worked well together.

## References

Al-Hafidz, N. N., Fia, A., Zhafarah, A., & Suryanda, A. (2024). Pembelajaran Biologi Berbasis Praktikum dan Kemampuan Berpikir Kritis Siswa: Sebuah Kajian Korelasi. *DIAJAR: Jurnal Pendidikan dan Pembelajaran*, *3*(1), 65-70. https://doi.org/10.54259/diajar.v3i1.2250

Almagribi, A. Z., Al-Qahtani, S. M., Assiri, A. M., & Mehdar, K. M. (2024). Perceptions of medical students at Najran University on the effectiveness of problem based learning and team-based learning. *BMC Medical Education*, *24*, 1-7. https://doi.org/10.1186/s12909-024-06148-w

Ambarsih, H. U., Sukarmin, & Marzuki, A. (2023). Analisis Kebutuhan Terhadap Pengembangan E-Modul Berbasis Flipped Classroom untuk Meningkatkan Kemampuan Berpikir Kritis pada Materi Gelombang Mekanik. *Seminar Nasional Pendidikan Fisika IX 2023 : Cybergogi dan Masa Depan Pendidikan Fisika di Indonesia*. Retrieved from https://prosiding.unipma.ac.id/index.php/SNPF/article/viewFile/4018/3270

Anastas, P. T., & Warner, J. C. (1998). *Green Chemistry : Theory and Practices.* New York: Oxford University Press.

Andraini, M. R., Rohiat, S., & Elvia, R. (2021). Analisis Kemampuan Berpikir Kritis Siswa pada Materi Reaksi Reduksi Oksidasi (Redoks) di MAN 1 Kota Bengkulu. *Alotrop: Jurnal Pendidikan dan Ilmu Kimia*, *5*(1), 35-41. https://doi.org/10.33369/atp.v5i1.16484

Arends, R. I. (2012). *Learning to Teach Ninth Edition.* New York: Mc Graw Hill.

Asapari, M. (2020). *Desain Perangkat Pembelajaran Bahasa Inggris Kontekstual : Model Pengembangan Borg & Gall (Teori, Konsep, Teknik, dan Implementasinya).* Mataram: Sanabil.

Asmussen, G., Rodemer, M., & Bernholt, S. (2024). Stepping stones to success: A qualitative investigation of the effectiveness of adaptive stepped supporting tools for problem-solving in organic chemistry to design an intelligent tutoring system. *International Journal of Science Education*, 1-23. https://doi.org/10.1080/09500693.2024.2361933

Awaliyah, S., & Rusmini. (2023). Profile of Students' Creative Thinking Skill on Colloid Materials Through Chemistry Flipbooks. *Jurnal Penelitian Pendidikan IPA*, *9*(12), 10750-10757. https://doi.org/10.29303/jppipa.v9i7.2954

Cahyani, M. D., Gusman, T. A., & Akbar, A. Y. (2024). Profile of Green Chemistry on Chemistry Education Students: Study on Developing Green Chemistry Practical Module to Support Sustainable Development Goals (SDGs). *Jurnal Penelitian Pendidikan IPA*, *10*(10), 7954-7959. https://doi.org/10.29303/jppipa.v10i10.7796

Carmona, A. G. (2023). Scientifc Thinking and Critical Thinking in Science Education Two Distinct but Symbiotically Related Intellectual Processes. *Science & Education*. https://doi.org/10.1007/s11191-023-00460-5

Chairatunnisa, A., Marlina, L., & Wiyono, K. (2023). Improvement of Critical Thinking Skills of Junior High School Students on Heat Transfer Material. *Jurnal Penelitian Pendidikan IPA*, *9*(11), 10377-10386. https://doi.org/10.29303/jppipa.v9i11.5681

Darmayanti, N. S., Wijaya, I. W., & Sanjayanti, N. A. (2020). Kepraktisan Panduan Praktikum IPA Sederhana Sekolah Dasar (SD) Berorientasikan Lingkungan Sekitar. *ORBITA : Jurnal Hasil Kajian, Inovasi, dan Aplikasi Pendidikan Fisika*, *6*(2), 310-314. https://doi.org/10.31764/orbita.v6i2.3365

Dewi, Y. C., Yusup, M., & Fathurohman, A. (2024). Junior High School Students' Critical Thinking Skills and Concept Mastery on Energy Topic. *Jurnal Penelitian Pendidikan IPA*, *10*(7), 4349-4356. https://doi.org/10.29303/jppipa.v10i7.7868

Dissen, A. (2023). A critical issue: assessing the critical thinking skills and dispositions of undergraduate health science students. *Discover Education*, *2*, 21. https://doi.org/10.1007/s44217-023-00044-z

Facione, P. (2015). Critical Thinking : What It is and Why It Counts. *Insight assessment, 1*(1), 1-23. Retrieved from https://shorturl.at/0p7HX

Hasanah, I. U., Ulfa, M., Yamtinah, S., Masykuri, M., Mulyani, B., & Shidiq, A. S. (2023). Comparative Study on Student's Critical Thinking Ability using POGIL, PBL, and TCL Models. *Jurnal Penelitian Pendidikan IPA*, *9*(11), 10264-10272. https://doi.org/10.29303/jppipa.v9i11.4628

Hidayah, S. N., Azizah, U., & Nasrudin, H. (2024). Development of Problem-Based-Learning (PBL)-Oriented Electronic Student Worksheets (e-Worksheet) to Improve Critical Thinking Skills of Class XI Senior High School Students on Factors that Influence Rate of Chemical Reactions Material. *International Journal of Current Science Research and Review*, *7*(6), 4284-4292. https://doi.org/10.47191/ijcsrr/V7-i6-80

Izzah, N. A., Suwaibatulilla, A., Khasfiyatin, S., Jayati, R. T., & Supeno. (2023). Profil Computational Thinking Skill Siswa SMP dalam Pembelajaran IPA. *Paedagogy : Jurnal Penelitian dan Pengembangan Pendidikan*, *10*(4), 1218-1225. https://doi.org/10.33394/jp.v10i4.9193

Jusniar, Syamsidah, & Auliah, A. (2023). Teacher's and Student's Perceptions of Green Chemistry and its Principles in Chemistry Learning in High Schools. *Jurnal Penelitian Pendidikan IPA*, *9*(10), 7924-7934. https://doi.org/10.29303/jppipa.v9i10.4756

Kamala, I., Idayanti, Z., & Ulfah, T. T. (2022). Increasing Student Participation in Science Learning Through Problem Based Learning Models. *Jurnal Penelitian Pendidikan IPA*, *8*(4), 2068-2076. http://dx.doi.org/10.29303/jppipa.v8i4.1850

Kemendikbud, B. (2022). *Dimensi, Elemen, dan Subelemen: Profil Pelajar Pancasila pada Kurikulum Merdeka.* Jakarta: Kemendikbud.

Kemendikbudristek. (2024). *Nomor 032/H/KR/2024 Tentang Capaian Pembelajaran pada Pendidikan Anak Usia Dini Jenjang Pendidikan Dasar, dan Jenjang Pendidikan Menengah pada Kurikulum Merdeka.* Jakarta: Kementrian Pendidikan, Kebudayaan, Riset, dan Teknologi.

Khoerunisa, E., & Habibah, E. (2020). Profil Keterampilan Abad 21 (21st Century Soft Skills) Pada Mahasiswa. *IKTISYAF: Jurnal Ilmu Dakwah dan Tasawuf*, *2*(2), 55-68. http://dx.doi.org/10.53401/iktsf.v2i2.20

Kolsto, S. D., Paulsen, V. H., & Mestad, I. (2024). Critical thinking in the making: students' critical thinking practices in a multifaceted SSI project. *Cultural Studies of Science Education*, *19*, 499-530. https://doi.org/10.1007/s11422-024-10217-3

Kristi, D., & Andriani, A. E. (2023). The Development of E-Books Based on Problem Based Learning to Improve Science Learning Outcomes. *Jurnal Penelitian Pendidikan IPA*, *9*(Special Issue), 828-835. https://doi.org/10.29303/jppipa.v9iSpecialIssue.6505

Kurnia, N. (2023). Potensi Pemanfaatan Pempek Palembang untuk Melatihkan Keterampilan Berpikir Kritis Mahasiswa. *Prosiding Seminar Nasional Kimia 2023 Universitas Islam Negeri Raden Fatah Palembang*, *2*(1), 19-24. Retrieved from https://proceedings.radenfatah.ac.id/index.php/snpk/article/view/1073

Manasikana, O. A., Af'ida, N., Mayasari, A., & Siswanto, M. B. (2022). *Model Pembelajaran Inovatif dan Rancangan Pembelajaran untuk Guru IPA.* Jombang: LPPM UNHASY Tebuireng Jombang.

Mullis, I. V., Martin, M. O., Foy, P., & Hooper, M. (2015). *TIMSS 2015 International Result in Mathematics*. United States: TIMSS & PIRLS International Study Center.

Mullis, I., Martin, M., Foy, P., Kelly, D. L., & Fishbein, B. (2020). *TIMSS 2019 International Result in Mathematics and Science*. United States: TIMSS & PIRLS International Study Center.

OECD. (2023). *PISA 2022 Results (Volume I) : The State of Learning and Equity in Education*. Paris: PISA, OECD Publishing.

Prabasari, J. S., Muzzazinah, & Wahyuningsih, D. (2021). Development of Electronic Modules (E-Modules) Based on Problem Based Learning on Additives and Addictive Substances to Improve Students' Critical Thinking Ability. *Jurnal Penelitian Pendidikan IPA*, *7*(Special Issue), 312-319. https://doi.org/10.29303/jppipa.v7iSpecialIssue.1233

Purwanti, Hernani, & Khoerunnisa, F. (2023). Profil Literasi Sains Peserta Didik SMK pada Penerapan Pembelajaran Projek Electroplating Berbasis Green Chemistry. *ORBITAL : Jurnal Pendidikan Kimia*, *7*(1), 1-10. https://doi.org/10.19109/ojpk.v7i1.16839

Quitadamo, I. J., Faiola, C. L., Johnson, J. E., & Kurtz, M. J. (2008). Community-based Inquiry Improves Critical Thinking in General Education Biology. *CBE: Life Sciences Education*, *7*, 327-337. https://doi.org/10.1187/cbe.07–11–0097

Qulub, T., Misrochah, N., & Rahmatulloh, R. (2023). Development of Green Chemistry Integrated Environmental Chemistry Practical Instructions. *SHEs: Social, Humanities, and Education Studies*, *6*(4), 187-194. https://doi.org/10.20961/shes.v6i4.81253

Sahir, S. H. (2021). *Metodologi Penelitian*. Yogyakarta: KBM Indonesia.

Salsabilla, I. I., Jannah, E., & Juanda. (2023). Analisis Modul Ajar Berbasis Kurikulum Merdeka. *Jurnal Literasi dan Pembelajaran Indonesia*, 3(1), 33-41. Retrieved from https://jurnalfkip.samawa-university.ac.id/JLPI/article/view/384

Sarafina, I., & Nasrudin, H. (2024). Development of Guided-Inquiry-Oriented Electronic Student Worksheet to Improve Critical Thinking Ability on Acid-Base Material. *Asian Journal of Science Education*, *6*(2), 42-52. https://doi.org/10.24815/ajse.v6i2.40192

Saralee, A., Fitria, Y., Sukma, E., & Hidayati, A. (2024). Development of E-Module IPAS Based on Problem Based Learning Assisted with Articulate Applications to Improve Students Think Criticall. *Jurnal Penelitian Pendidikan IPA*, *10*(4), 2032-2040. https://doi.org/10.29303/jppipa.v10i4.7014

Styers, M. L., Zandt, P. A., & Hayden, K. L. (2018). Active Learning in Flipped Life Science Courses Promotes Development of Critical Thinking Skills. *CBE : Life Sciences Educational*, *17*(39), 1-13. https://doi.org/10.1187/cbe.16-11-0332

Sudirman, Anggraeni, S., Marlina, N. P., Silalahi, E. K., Fitrian, A., Siregar, H. T., & Karim, S. (2023). *Implementasi Pembelajaran Abad 21 pada Berbagai Bidang Ilmu Pengetahuan*. Bandung: CV. Media Sains Indonesia.

Sugianto, Liunokas, A. B., Listari, N., Dewi, N. P., Rasyid, A., & Chaidir, D. M. (2023). Development of Human Reproductive System E-Module Teaching Materials using the Flip Pdf Corporate Application. *Jurnal Penelitian Pendidikan IPA*, *9*(12), 10965-10972. https://doi.org/10.29303/jppipa.v9i12.4573

Suryaningsih, Y. (2017). Pembelajaran Berbasis Praktikum Sebagai Sarana Siswa untuk Berlatih Menerapkan Keterampilan Proses Sains dalam Materi Biologi. *Jurnal Bio Educatio*, *2*(2), 49-57. https://dx.doi.org/10.31949/be.v2i2.759

Susanti, W., Saleh, L. F., Nurhabibah, Gultom, A. B., Saloom, G., Ndorang, T. A., & Lisnasari, S. F. (2020). *Pemikiran Kritis dan Kreatif*. Bandung: CV. Media Sains Indonesia.

Tefera, A. S., Melaku, E. E., Urgie, B. M., Hassen, E. M., Tamene, T. D., & Gebeyaw, E. D. (2024). Barriers to implementing problem-based learning at the school of medicine of Debre Berhan University, Ethiopia. *BMC Medical Education*, *24*, 501. https://doi.org/10.1186/s12909-024-05252-1

Usman. (2021). *Ragam Strategi Pembelajaran Berbasis Teknologi Informasi*. Parepare: IAIN Parepare Nusantara Press.

Wahyudi, A., & Purwanto, H. (2024). Menganalisis Aspek Peningkatan Kemampuan Berpikir Kritis Siswa dalam Pembelajaran IPA. *Edukasi Elita: Jurnal Inovasi Pendidikan*, *1*(4), 162-178. https://doi.org/10.62383/edukasi.v1i4.640

Wahyudin, D., Subkhan, E., Malik, A., Hakim, M. A., Sudiapermana, E., Alhapip, L., & Krisna, F. N. (2024). *Kajian Akademik Kurikulum Merdeka*. Jakarta: Pusat Kurikulum dan Pembelajaran, Badan Standar, Kurikulum, dan Asesmen Pendidikan.

Wasahua, S. (2021). Konsep Pengembangan Berpikir Kritis dan Berpikir Kreatif Peserta Didik di Sekolah Dasar. *Jurnal Horizon Pendidikan*, *16*(2), 72-82. https://doi.org/10.33477/hp.v16i2.2741

Wibowo, S. H., & Hidayah, R. (2016). Pengembangan Lembar Kegiatan Siswa Berorientasi Inkuiri Terbimbing untuk Melatihkan Keterampilan Proses Sains Siswa pada Materi Asam Basa. *Unesa Journal of Chemical Education, 5*. Retrieved from

https://ejournal.unesa.ac.id/index.php/journal-of-chemical-education/article/view/15792/14327

Widyapuraya, N. W., Suryana, A. L., Suyanta, & Wilujeng, I. (2023). Profile of Critical Thinking Skills of Junior High School Student. *Jurnal Penelitian Pendidikan IPA*, *9*(3), 1368-1374. https://doi.org/10.29303/jppipa.v9i3.1723

Wijnia, L., Noordzij, G., Arends, L. R., Rikers, R. M., & Loyens, S. M. (2024). The Efects of Problem-Based, Project-Based, and Case-Based Learning on Students' Motivation:a Meta-Analysis. *Educational Psychology Review*, *36*(29), 1-38. https://doi.org/10.1007/s10648-024-09864-3

Yuliarti, Y., Marlina, L., Siahaan, S. M., Fathurohman, A., & Sudirman. (2023). Profile of High School Students' Critical Thinking Skills about Renewable Energy Materials. *Jurnal Penelitian Pendidikan IPA*, 9(11), 10151-10160. https://doi.org/10.29303/jppipa.v9i11.5418

Yusri, H., Dirasta, G. R., Wilujeng, I., Suyanta, & Astuti, S. R. (2023). Critical Thinking Skills Profile Through EDUSAN as a Mobile Learning Application in Science Learning. *Jurnal Penelitian Pendidikan IPA*, *9*(7), 5383-5389. https://doi.org/10.29303/jppipa.v9i7.2954

Zhang, W., Wei, J., Guo, W., Wang, Z., & Chen, S. (2024). Comparing the efects of team-based and problem-based learning strategies in medical education: a systematic review. *BMC Medical Education*, *24*, 172. https://doi.org/10.1186/s12909-024-05107-9

Zheng, Q.-M., Li, Y.-Y., Yin, Q., Zhang, N., Wang, Y.-P., Li, G.-X., & Sun, Z.-G. (2023). The effectiveness of problem-based learning compared with lecture-based learning in surgical education: a systematic review and meta-analysis. *BMC Medical Education*, 23, 546. https://doi.org/10.1186/s12909-023-04531-7