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# Development of a critical thinking skills instrument through problem-based learning for senior high school students

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**ABSTRACT**

This study aims to develop an assessment instrument, comprising essay questions and scoring rubrics, to measure high school students' critical thinking skills through Problem-Based Learning (PBL). The instrument was developed by adapting the Research and Development (R&D) design using the ADDIE model, which consists of five stages: Analysis, Design, Development, Implementation, and Evaluation. Expert validation results indicated that the instrument was suitable for use, with minor editorial revisions recommended to improve clarity and objectivity. A trial conducted with 67 students showed that all assessment items were valid (r-calculated > r-table) and the instrument demonstrated high reliability (Cronbach's Alpha = 0.745). The scoring rubric consists of six main indicators referring to the critical thinking framework by Robert Ennis (1993): focus, supporting reasons, reasoning, organisation, language use, and relevance. This instrument is considered effective in supporting authentic assessment and can be used by teachers to evaluate students' critical thinking skills more systematically, in line with the Merdeka Curriculum and 21st-century competency demands.

## INTRODUCTION

Critical thinking is the ability to think reflectively and rationally with the purpose of making sound decisions regarding beliefs and actions (Nisa et al., 2025). In the learning process, students are expected to analyse, organise, and formulate information systematically so that they can distinguish between valid and invalid information and make appropriate decisions based on available data. Critical thinking also encompasses the ability to evaluate arguments, draw logical conclusions, and solve problems effectively (Fajri et al., 2024). These skills are vital for students to filter through the vast amount of information that can be easily accessed. Critical thinking skills are essential to develop because they directly contribute to students' learning outcomes (Ismayanti et al., 2022). Beyond academic achievement, these skills serve as a decisive foundation for students to face complex real-world challenges (Kollo et al., 2024). Therefore, the development of critical thinking skills should begin at an early age through structured and contextual learning in schools (Nadhiroh & Anshori, 2023). In this way, students will become accustomed to collecting, processing, and evaluating information in a logical and objective manner. The critical thinking skills can be improved by using contextual learning for students.

Critical thinking is one of the four essential 21st-century skills, commonly referred to as the 4C skills: Critical Thinking, Communication, Collaboration, and Creativity. These four skills are considered crucial for shaping individuals who are adaptive, creative, and capable of working effectively in an ever-changing global environment. In this context, critical thinking helps students filter information, solve complex problems, and make meaningful decisions, while communication and collaboration enable them to express ideas clearly and work interactively with others. Creativity is equally essential, as it encourages students to generate innovative solutions to various challenges (Fajari et al., 2021).

External factors such as family, social environment, and the role of teachers also influence the development of students' critical thinking skills (Akhyar et al., 2024). A supportive family environment and cognitively challenging play activities can help children develop sharper thinking abilities. In addition, open communication with educators and active participation in learning activities serve as significant foundations for fostering critical thinking and other interrelated 4C skills. Therefore, the critical thinking skills of students can be developed depending on the learning model and the environment used by the teacher.

Unfortunately, the condition in Indonesia shows that students' critical thinking skills remain relatively low. International assessment data indicate that Indonesia ranked 64th out of 65 countries in 2012 and remained in 64th place out of 72 countries in 2015 in terms of higher-order thinking skills (Aurelia, 2023). This reflects that 21st-century thinking skills have not yet been fully integrated into the curriculum and educational practices in Indonesia comprehensively and effectively. The 2013 Curriculum, revised in 2017, has actually emphasised the urgency of strengthening critical thinking skills as part of learning competencies (Fajari et al., 2020). In today's era of globalisation and technological advancement, individuals are required to access knowledge, identify problems, and create innovative solutions. Schools are no longer merely responsible for transferring knowledge but also for educating a generation that is tolerant of differing opinions and capable of thinking logically, creatively, and critically (Arisoy, 2021; Asiah, 2021).

Learning based on direct experience, such as experiments, scientific investigations, and contextual approaches, is essential to encourage students to ask questions, observe, analyse data, and draw conclusions, thereby strengthening scientific understanding and fostering higher-order thinking skills (Sa'adah & Anwar, 2023). These strategies also develop communication, collaboration, and creativity, supporting the holistic growth of 4C skills. Problem-Based Learning (PBL) is a relevant model that presents contextual problems as learning stimuli and emphasises real-world issues, local relevance, and sustainability principles through structured activities (Janssen et al., 2022; Lee, 2025). PBL trains students to solve complex problems, apply knowledge in real-life contexts, identify issues, gather information, analyse data, engage in discussions, and formulate solutions independently or collaboratively, which enhances critical thinking, problem-solving abilities, engagement, curiosity, and intrinsic motivation (Valerio et al., 2025). Therefore, the PBL is a suitable learning model to develop students' critical thinking skills.

However, to optimally foster critical thinking skills, a valid, reliable, and learner-appropriate assessment instrument is required. Unfortunately, most available measurement tools remain too general and are not specifically designed to meet the needs of senior high school students. Several scholars who have focused on measuring critical thinking skills include Robert Ennis and Peter Facione. According to Ennis (1993), critical thinking is reflective and rational thinking aimed at deciding what to believe or do. Meanwhile, Facione (2016) defines critical thinking as a purposeful, self-regulatory judgment process intended to produce reasonable and objective decisions. This research adopts Robert Ennis's theory of critical thinking and employs a problem-based learning (PBL) approach. Robert Ennis's critical thinking theory and instrument are more appropriate to use in this research because Ennis's indicators are operational, easy to adapt into contextual essay questions, aligned with PBL, capable of assessing both cognitive aspects and critical dispositions, and have been proven valid and reliable in educational research.

Therefore, this study aims to develop a valid and reliable critical thinking skills instrument for high school students, which can be used by teachers to identify students' levels of critical thinking ability. The author expects that this research will contribute by producing a critical

thinking assessment instrument that can be used in schools, enabling teachers to map and improve students' critical thinking skills using the rubric developed in this study.

## METHOD

This research is a type of Research and Development (R&D) study aimed at developing a product in the form of a critical thinking skills instrument through problem-based learning (PBL) for senior high school students. R&D research not only produces a product but also tests its feasibility and effectiveness (Borg & Gall, 1983). The development model used in this study is the ADDIE model, which stands for Analysis, Design, Development, Implementation, and Evaluation. The ADDIE model is general and straightforward, with a systematically structured application (Rahmandhani & Utami, 2022). It is a development framework that emphasises the fundamental aspects of educational product design, aligning with technology, learners' needs, and content (Safitri & Aziz, 2022). Furthermore, the ADDIE model provides opportunities for continuous evaluation and revision at each stage of the development process.

The instrument was developed based on the theory and indicators of critical thinking proposed by Ennis (1993), which include the aspects of focus, supporting reasons, reasoning, organisation, language conventions, and relevance (see Table 1). The instrument blueprint was then developed into five essay test items with a cognitive level of analysis (C4) on the topic of atomic structure. The essay questions were designed as High Order Thinking Skills (HOTS) items, containing contextual problem stimuli that are linked to the scientific concepts being studied. The instrument was developed through Problem-Based Learning (PBL). The syntax of the Problem-Based Learning model consists of: 1) orienting students to the problem; 2) organising students for learning; 3) guiding individual or group investigations; 4) developing and presenting the work results; and 5) analysing and evaluating the problem-solving process.

The subjects in this study consisted of two groups. The first group was a team of experts, including material experts and instrument experts, who were responsible for conducting content and construct validation of the test items and assessment rubrics. The second group comprised the trial participants, namely 67 twelfth-grade students from one Senior High School in Surabaya, selected through purposive sampling to ensure representation across classes and diversity in academic ability levels.

The data collection techniques included expert validation sheets, critical thinking essay questions, and assessment rubrics used to evaluate students' answers based on predetermined indicators. These instruments were validated by expert lecturers according to the criteria presented in Table 2. Data analysis was conducted using both qualitative and quantitative approaches. Content validity was analysed using Aiken's V formula to determine the level of agreement among experts for each item (Azwar, 2015). Empirical validity was obtained through item-total correlation analysis with the aid of SPSS software. Meanwhile, the instrument's reliability was analysed using the Cronbach's Alpha coefficient to determine the internal consistency of the instrument (Sugiyono, 2017).

**Table 1. Critical thinking skills instrument blueprint**

| No | Indicators | Description |
|---|---|---|
| 1 | Focusing | Writing answers that directly address the core of the question. |
| 2 | Reasoning | Providing reasons based on relevant scientific facts or chemical concepts. |
| 3 | Conclusing | Drawing conclusions that are consistent with the evidence or explanation provided. |
| 4 | Organising | Organising answers in a logical sequence: introduction, explanation, and conclusion. |
| 5 | Relevance | Giving examples or analogies that support the explanation. |
| 6 | Language | Writing in clear, unambiguous, and communicative sentences. |

Source: Ennis (1993).

**Table 2. Instrument feasibility criteria**

| No | Aspect | Criteria |
|---|---|---|
| 1 | Material | The test items are developed according to the established blueprint. |
| 2 | Material | The measured indicators are selected based on their relevance and real-world application. |
| 3 | Material | The content of the test items corresponds to the students' level of thinking ability. |
| 4 | Material | The item formulations require elaborated (open-ended) responses. |
| 5 | Material | The language used follows proper and correct Indonesian grammar conventions. |
| 6 | Material | The instructions for completing the instrument are clear. |
| 7 | Construction | The scoring scale is aligned with the measurement objectives. |
| 8 | Language | The assessment rubric corresponds to the indicators. |

Source: Kubiszyn, Tom and Borich (2013).

The results from the validation and trial stages were used as the basis for revising and refining the instrument to ensure its feasibility for assessing high school students' critical thinking skills authentically and contextually. The higher the reliability coefficient, the more dependable (reliable) the instrument is, and the smaller the likelihood of measurement error.

## RESULT

The development process of the critical thinking skills instrument through Problem-Based Learning (PBL) was carried out using the ADDIE development model, which consists of five stages: Analysis, Design, Development, Implementation, and Evaluation. In the analysis stage, the need for an assessment instrument relevant to the characteristics of Problem-Based Learning at the senior high school level was identified. This analysis included a review of the curriculum, basic competencies related to higher-order thinking skills, and an examination of critical thinking indicators adapted from Ennis's theory. In addition, an analysis of students' characteristics and learning conditions was conducted, revealing that critical thinking aspects had not been optimally assessed in current practices.

The design stage focused on developing a blueprint or instrument grid that included indicators, question formats, and contextual problems aligned with the Problem-Based Learning approach. This blueprint served as the foundation for constructing test items that represent active thinking processes in organising, analysing, and evaluating information through various means such as observation, experience, reflection, reasoning, and communication (Demir, 2024).

In the development stage, the test items were constructed based on the blueprint and then validated by a panel of experts, including lecturers in chemistry education and educational evaluation specialists. The results of expert validation indicated that most of the items met the criteria for content validity. The validation method employed expert judgment, which concluded that the test items were valid and suitable for use, with minor editorial revisions for clarity. Table 3 exhibits the validated test items and assessment rubrics.

The implementation stage was carried out by applying the instrument in an actual problem-based learning context in the classroom. A total of 67 twelfth-grade students were assigned to solve problems contained in the test items designed to elicit critical thinking skills. The test results were then analysed to evaluate item quality and the consistency of the measurements. Data analysis was conducted using SPSS to obtain the validity and reliability values of the instrument (see Table 5 & 6).

The evaluation stage included a comprehensive assessment of the instrument development results. The quantitative validity test showed that all indicators were valid, as indicated by the calculated r values being greater than the table value (0.240). This indicates that each assessment item effectively measures aspects of critical thinking skills. In addition, the instrument demonstrated a high level of internal consistency based on the reliability test results.

The Cronbach's Alpha value of 0.745 obtained from the trial indicated that the instrument had high reliability, exceeding the minimum threshold of 0.60 (Nunnally, 1978). Thus, the critical thinking assessment rubric developed in this study is not only valid in terms of content and construct but also reliable and feasible to be used to support both formative and summative assessments in chemistry learning at the high school level.

**Table 3. Question items**

| No | Question | Cognitive Level |
|---|---|---|
| 1 | When we turn on the television or radio, we are actually utilising electromagnetic waves. The discovery that atoms have nuclei and electrons arranged around them forms the foundation of this technological development. From Dalton's simple theory to the modern quantum mechanical model, human understanding of the atom has continuously evolved. Critically explain the relationship between the phenomenon described above and the development of atomic models, along with your reasoning. | C4 |
| 2 | Packaged drinking water often lists mineral contents such as sodium (Na), calcium (Ca), and magnesium (Mg). All of these substances are composed of the same subatomic particles protons, neutrons, and electrons—yet they exhibit very different chemical properties. Critically explain how the number of subatomic particles, especially protons, determines the identity of an element, and relate the role of electrons to the differences in chemical properties among the elements found in these minerals. | C4 |
| 3 | In the medical field, the radioactive isotope carbon-14 is used to determine the age of fossils, while iodine-131 is used for thyroid cancer therapy. Both isotopes have the same number of protons as their parent elements but differ in the number of neutrons. Critically analyse why isotopes have nearly identical chemical properties but different physical properties, and relate this to the concept of the subatomic particles that make them up. | C4 |
| 4 | In the periodic table, there are terms such as isobars and isotones. For example, argon-40 and calcium-40 are isobars, while carbon-14 and nitrogen-15 are isotones. In daily life, understanding these concepts is particularly important in the fields of nuclear research and medicine. Critically analyse the differences among isotopes, isobars, and isotones, and explain why these classifications are important for understanding atomic properties and their applications. | C4 |
| 5 | Neon lamps and fireworks produce characteristic colors of light due to the movement of electrons within atoms. These colors are determined by the unique electron configurations of each element. Critically explain how the electron configuration of an atom can influence its chemical properties while also producing colorful light in everyday phenomena, and provide examples of specific elements to support your explanation. | C4 |

**Table 4. Rubric scoring for critical thingking**

| Indicator | Description | Score 1 | Score 2 | Score 3 | Score 4 |
|---|---|---|---|---|---|
| Focusing | Writing answers that directly address the core of the question. | Off-topic or misses the main point. | Partially answers the question. | Generally focused, with minor irrelevance. | The answer is focused and accurate. |
| Reasoning | Providing reasons based on relevant scientific facts or chemical concepts. | Irrelevant or no reasoning. | Reasoning vague or off-concept. | Reasoning mostly correct but incomplete. | Reasoning is correct and relevant. |
| Conclusing | Drawing conclusions that are consistent with the evidence or explanation provided. | No or unclear conclusion. | Weak conclusion. | Conclusion logical but not concise. | Conclusion is logical and concise. |
| Organising | Organising answers in a logical sequence: introduction, | Unclear and uncommunicative sentences. | Unclear or disorganised sentences. | Sentences fairly clear, slightly ambiguous. | Sentences are clear and coherent. |

| Indicator | Description | Score 1 | Score 2 | Score 3 | Score 4 |
|---|---|---|---|---|---|
| | explanation, and conclusion. | | | | |
| Relevance | Giving examples or analogies that support the explanation. | No examples or analogies. | Inaccurate example. | Example relevant but weak. | Examples are relevant and supportive. |
| Language | Writing in clear, unambiguous, and communicative sentences. | Poor or random structure. | Poor structure. | Structure fairly organised but incomplete. | Structure is organised and complete. |

Source: Ennis (1993)

**Table 5. The result of validity test**

| N | Indicators | r-value | r-table |
|---|---|---|---|
| 67 | 1 | 0.562 | 0.240 |
| | 2 | 0.586 | 0.240 |
| | 3 | 0.612 | 0.240 |
| | 4 | 0.688 | 0.240 |
| | 5 | 0.654 | 0.240 |
| | 6 | 0.535 | 0.240 |

**Table 6. The result of reliability test**

| N | N of items | Cronbach's Alpha | Minimum Value |
|---|---|---|---|
| 67 | 6 | 0.745 | 0.600 |

## DISCUSSION

The results of this study support the importance of authentic assessment in 21st-century learning, particularly in evaluating students' critical thinking skills. Critical thinking is a conscious and deliberate process of evaluating arguments to make reasonable decisions (Watson et al., 2024). This emphasises that an assessment instrument should not only measure students' final outcomes but also reflect their reasoning processes in a reflective and in-depth manner. Critical thinking is an active way of organising, analysing, and evaluating information through observation, reflection, reasoning, and communication (Demir, 2024). In this context, the context-based essay questions developed in this study encourage students not only to provide factual answers but also to use data, scientific concepts, and reasoning to support their arguments.

The rubric for assessing the critical thinking skills requires students to support claims with evidence, draw logical conclusions, and consider alternative viewpoints reflected in sub-indicators such as reasoning, supporting evidence, and coherence (see Table 4). Critical thinking emphasises disciplined intellectual processes and skills in analysing, synthesising, and evaluating information from various perspectives (Seale, 2025). In this rubric, sub-indicators such as the ability to provide logical reasons, connect arguments to conclusions, and present scientific justification align with their framework of critical thinking indicators. It is valuable to assess the process of thinking, including interpretation, analysis, inference, and justification (Facione et al., 2016).

Beyond the cognitive domain, critical thinking also includes dispositional and attitudinal dimensions, as reflective and rational thinking directed toward deciding what to believe or do, reflecting openness and systematic thinking. Therefore, the use of appropriate scientific terminology, linguistic clarity, and real-world contextualisation in the rubric also assesses students' scientific disposition (Ennis, 1993). The rubric allows students to explore understanding not only conceptually but also in real-life contexts through the "connection" indicator. Critical thinking serves as a tool for solving complex problems, communicating information logically, and making evidence-based decisions (Rosdiana et al, 2025). In this sense, the critical thinking rubric encourages students to think broadly, not limited to right-or-wrong answers, but to investigate issues, analyse impacts, and present arguments with ethical and social considerations. Critical

thinking must be viewed within the context of social change and critical pedagogy (Cui, and Zhao, 2024).

By integrating theoretical perspectives from various experts and supported by high validity and reliability test results, this critical thinking assessment rubric can be effectively applied in chemistry learning and other subjects that require the evaluation of critical thinking skills. This aligns with the spirit of the Merdeka Curriculum, which promotes diagnostic, formative, and summative assessments that foster the *Profil Pelajar Pancasila* (The Five-Pillars Student Profile) and 21st-century competencies.

In this study, the author provides both theoretical and practical contributions. Theoretically, the research enriches the body of knowledge on critical thinking assessment by refining and applying Ennis's framework within a Problem-Based Learning context, offering validated indicators that can be adapted for future educational research. Practically, the study produces a usable critical thinking assessment instrument and rubric that teachers can apply to diagnose, map, and enhance students' critical thinking skills in classroom settings, thereby supporting more targeted instruction and improving the overall quality of learning.

## CONCLUSION

The development of the critical thinking assessment instrument for Grade XII students at one senior high school in Surabaya successfully produced a valid and reliable tool grounded in Ennis's (1993) critical thinking framework, offering comprehensive indicators that capture students' analytical, reasoning, and communication skills. The expert validation and field testing confirmed that the instrument and rubric can effectively guide teachers in evaluating and enhancing students' critical thinking within chemistry learning, particularly when integrated with Problem-Based Learning (PBL) to support higher-order thinking as emphasised in the Merdeka Curriculum. However, this study is limited by its sample size, single-school context, and focus on one subject area, which may affect the generalisability of the findings. Future research is recommended to expand the implementation across diverse schools, subjects, and grade levels, as well as to explore digital-based assessment formats to further strengthen the instrument's applicability in various learning environments.

### Author contributions

The authors made significant contributions to the study's conception and design. The authors was in charge of data analysis, interpretation, and discussion of results. The final manuscript was read and approved by the authors.

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### Conflict of interest

The authors declare that there is no potential conflict of interest.

### Data availability statement

All data are available from the authors.

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