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A Systematic Literature Review on Critical Thinking Skills in Physics Education

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Abstract

Critical thinking skills are skills that were developed in the 21st century. Critical thinking skills are student-centered learning. Critical thinking skills can be developed from elementary school to college. Through a literature review, this study aims to provide information related to learning models and instruments used that can improve critical thinking skills in physics learning. Data collection is based on the source of the Scopus database. This type of document originated from journal articles with the keywords <<critical thinking>>, <<critical thinking skills>>, <<physics>>, and <<physics learning>> from 2015 to 2025. The procedure used in this literature review was adapted from PRISMA. The published documents are based on predetermined content analysis criteria including learning model, physics material topics, research subjects, education level and analysis. Learning with the guided inquiry model and problem-based learning are learning models that are often used to improve critical thinking skills with various indicators. Static fluids are a topic that is often discussed in research. This research broadly contributes to improving students' thinking skills through recommended learning models. The research findings provide information that student-centered learning models can improve students' thinking skills.

Introduction

In the 21st century, the world has undergone significant changes in various aspects of life, especially in the fields of technology, information, and communication. These changes require individuals to develop more complex and adaptive abilities especially when it comes to critical thinking. Critical thinking is defined as the ability to analyze, evaluate, and formulate arguments logically and systematically (Facione, 2015). This ability is the main key in facing the challenges of the 21st century. According to the Partnership for 21st Century Skills (2015), individuals are not only required to master technical knowledge skills, but must also be able to sort through valid information, evaluate sources, and make informed decisions. Critical thinking also encourages individuals to think creatively, innovatively, and selectively in dealing with multidimensional problems (Brookfield, 2012).

Critical thinking skills have always been the main goal of education (Bailin, 2002). Ennis (2011) states that critical

thinking is logical and reflective thinking that is driven by what is certain to believe and do. To improve critical thinking skills, it cannot be developed independently, but students must be taught. Improving critical thinking skills takes a long time. Therefore, a teacher must be committed to developing critical thinking skills in the learning process (Rudd, 2011). In some ways, this research is different from previous studies that discussed understanding concepts and critical thinking skills. First, this study is focused on all articles published from 2015 to 2025; all of them have been SCOPUS accredited. Second, this research is devoted to researching a number of articles with critical thinking skills as their main focus. Third, various parameters are used as the basis for content analysis.

Previous literature review research examined five main topics related to critical thinking skills on google scholar and Scopus articles in the 2011-2021 span (Ubaidillah et al., 2023). The discussion in this review has similarities with Ubaidillah et al. (2023), namely reviewing critical thinking skills that focus on learning models that can improve critical thinking skills, indicators used in improving critical thinking skills, physics materials taught, and education levels. This review research is very important because it can provide up-to-date information regarding learning models including the use of technology that can improve critical thinking skills in physics learning from elementary to tertiary levels. These results are a reference and a strong basis for planning the development of a more effective, innovative, and creative curriculum in physics learning that can encourage the role of teachers, researchers and education practitioners in improving critical thinking skills.

Method

The research method used a literature review with a modified procedure from a systematic review and meta-analysis (PRISMA) adapted from (Ubaidillah et al., 2023). This procedure consists of identification, screening, eligibility and input. The research procedure is shown in Figure 1.

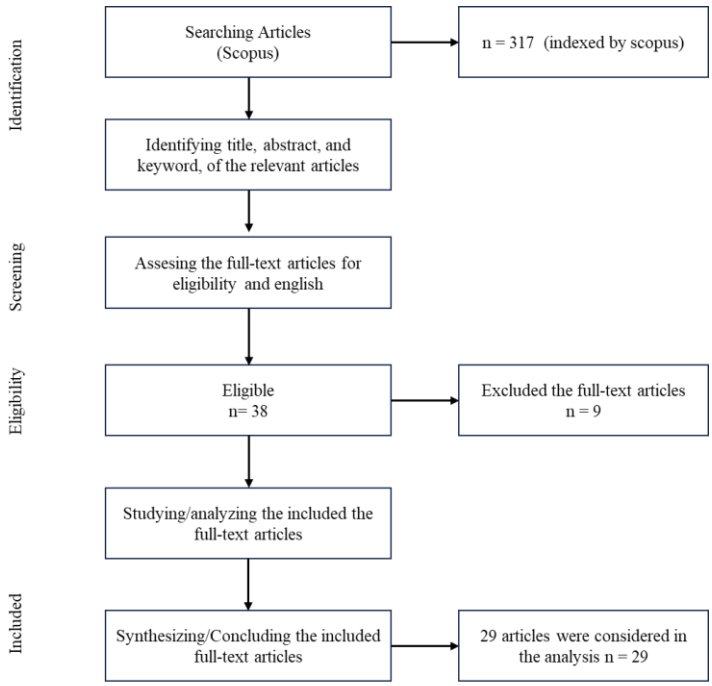

Figure 1. Research Procedure

The data of this study uses searches from Scopus journals that are indexed with databases. The selected articles are those published between 2015-2025. The keywords of the articles used as data sources were <<critical thinking>>, <<critical thinking skills>>, <<physics>>, and <<physics learning>>. The articles used came from articles published in journals, conference papers and in English. The subject areas used are social science and physics and astronomy, Articles from book chapters, book reviews, editorials, and commentaries are excluded from analysis. Based on the indexed search data on Scopus, 317 articles were indexed by Scopus. 38 articles were found to be eligible, but 9 are excluded from the analysis. The 9 articles excluded this analysis were articles used qualitative methods, and did not inform the physics material being thought. There are 29 articles analyzed in this systematic literature review. Data analysis was carried out based on learning model criteria, indicators of critical thinking skills, type of instrument, level of education used as a research place, and physics material topics.

Results

From the articles that have been analyzed using the systematic literature review method, 5 criteria will be analyzed, namely learning models that can improve critical thinking skills, indicators of critical thinking skills, types of instruments used, the level of education where the research is conducted, and physics subjects

Learning Models That Can Improve Critical Thinking Skills

According to Marie and Emmanuelle (2011), thinking skills are not innate possessed by students, but thinking skills can be learned and require learning. To train students' critical thinking skills, it is necessary to make efforts in the learning process, one of which is by choosing the right and more student-centered approach or learning model. The learning model applied to improve critical thinking skills is shown in Table 1. Learning models that can improve critical thinking skills in Table 1 are classified into 7 based on the characteristics of students' learning experiences, learning context, problem solving, outcome orientation, and technology involved in improving critical thinking skills. The classification of learning models is shown in Table 2. The results of a literature review from various studies show that inquiry-based learning and problem-based learning are learning models that are often used to improve critical thinking skills.

Table 1. Learning Models That Can Improve Critical Thinking Skills

No	Author	Model of Teaching	Frequency
1.	Maknun, 2020; Phonna et al., 2020; Zain & Jumadi, 2018; Wartono et al., 2018	Guided Inquiry	4
2.	Moreno & Díaz, 2021; Marcinauskas et al., 2024; Suhirman & Prayogi, 2023; Salazar et al., 2023	Problem Based Leaning	4
3.	Handhika et al., 2018; Khoiri et al., 2023	Project Based Learning	3
4.	Damayanti & Kuswanto, 2021	Physics comic of Android-based	1

No	Author	Model of Teaching	Frequency
		marbles games	
5.	Rizki et al., 2024	Cooperative Learning with Augmented Reality	1
6.	Danday, 2021	Microteaching Lesson Study (Active & Passive MLS)	1
7.	Asrizal et al., 2022	Physics Electronic Teaching Material-integrated STEM (PETMS)	1
8.	Hunaidah et al., 2018	CinQASE Model (Collaborative Critical Thinking)	1
9.	Moreno & Díaz, 2021	STEAM + Problem Based Learning	1
10.	Siddiqui, 2022	Categorized and Correlated Multiple Choice Questions	1
11.	Sahidah Lisdiani et al., 2019	Hot Lab Activity	1
12.	Tiruneh et al., 2016	Systematic learning based on First Principles of Instruction	1
13.	Arymbekov et al., 2024	Augmented Reality	1
14.	Ardianti et al., 2020	Blended Learning-STEM	1
15.	Rahmayani et al., 2024	E-book- Augmented Reality (AR)	1
16.	Asrizal et al., 2024	STEM-Smart Physics E-Module	1
17.	Putra et al., 2023	Engineering Design Process	1
18.	Suprapto et al., 2024	Project-Oriented Problem-Based Learning	1
19.	Rahim et al., 2019	Learning Tool-Project Based Learning	1
20.	Rahayu & Kuswanto, 2021	Game Comic-Discovery Learning	1
21.	Maghfiroh & Kuswanto, 2022	Benthik Android Physics Comic	1

Table 2. Classification Learning Model

No	Classification	Model of Teaching
1.	Inquiry Based-Learning	• Guided Inquiry • Game Comic-Discovery Learning
2.	High Order Thinking and Cognitive Strategies	• Higher and Correlated Multiple Choice Question • Systematic Learning Based on First Principles of Instruction • CinQase Model (Collaborative Critical Thinking)
3.	STEM Education	• Physics Electronic Teaching Material Integrated STEM (PETMS) • STEM-Smart-Physic E-Module • Blended Learning STEM

4.	Technology-Enhanced Learning	• Cooperative Learning with Augmented Reality • E-Book-Augmented Reality • Augmented Reality • Hot Lab Activity
5.	Project Based Learning	• Project Based Learning • Learning Tools- Project Based Learning
6.	Ethnoscience and direct instruction	• Physics comic of Android-based marbles games • Benthik Android Physics Comic
7.	Reflective and creative learning	• Microteaching Lesson Study (Active & Passive MLS) • Engineering Design Process
8.	Problem Based Learning	• Problem-Based Learning • STEAM+Problem-Based Learning • Project-Oriented Problem-Based Learning

Aspects of Indicators and Types of Critical Thinking Skill Instruments

The results of the article review can be seen in table 3. It shows that the critical thinking skills referred to by the researcher vary widely. The critical thinking skill indicators of Binkley et al. (2012) and Ennis (1995) are indicators often used in research. In addition, the critical thinking skill indicators Facione (2015) and Hanumi (2007) are also often used by researchers in articles that have been reviewed. Broadly speaking, the indicators used in this study are evenly distributed in several articles.

Table 3. Aspects of Critical Thinking Indicator used in Research

No	Reference	Indicator of Critical Thinking	Frequency
1.	Binkley et al., 2012	Explain, Analyze, Interpreting, Synthesizing, inference and evaluation	6
2.	Ennis (1995)	Focus, reason, inference, situation, clarity and overview	6
3.	Facione (2015)	Interpretation, Analysis, Inference, Evaluation, Explanation and Self-regulation	5
3.	Hanumi (2007)	Elementary clarification, basic support, inference, advanced clarification, advanced clarification, strategies and tactics.	4
4.	Linda & Richard (2010)	Critical thinking based on purpose and question, selection of information, concepts, assumption, implication and consequences, points of View, Inference and Interpretation	3
5.	Facione (1990)	Analysis, Evaluation, Inference, and Decision Making	3
6.	No mention of source	Only mentions critical thinking variables without indicators	2

Correlated Multiple Choice Questions" (CCMCQs) to evaluate students' comprehensive knowledge of physics (Siddiqui, 2022), Questionnaire de Competencias Genéricas Individuales (CCGI) as an instrument to measure critical thinking (Moreno & Díaz, 2021), Direct Assessment of Collaborative Critical Thinking (DACCT) with valid and reliable indicators: questioning, analyzing, synthesizing, and evaluating (Hunaidah et al., 2018), a critical thinking skills test consisting of 8 essay questions (Suhirman & Prayogi, 2023), Critical thinking skills test based on the Binkley framework, which includes indicators such as analysis, evaluation, interpretation, synthesis, and inference (Sahidah Lisdiani et al., 2019), Domain-specific test (CTEM): Measuring critical thinking skills on topics of electricity and magnetism and General-domain test (HCTA): Measuring critical thinking skills on daily life problems (Tiruneh et al., 2016) and Pretest-posttest test in the form of multiple-choice questions, to measure aspects of critical thinking skills (Zain & Jumadi, 2018).

Classification Based on Level of Education

The level of education that is the object of critical thinking skills research is from junior high school to higher education. The senior high school level occupies the first position with 17 studies, then followed by the higher education level with 10 studies, and for junior high school it consists of only 2 studies. The classification of critical thinking skills research based on education level is shown in Table 4.

Table 4. Classification Based on Level of Education

No	Level	Frequency
1.	Higher Education	10
2.	Senior High School	17
3.	Junior High School	2

Classification Based on Physics Subject Matter

Classification related to materials that are physics topics in improving critical thinking skills are also studied in this study. Static fluid is a material that is often discussed in research related to improving critical thinking skills. After that, it was followed by momentum and impulse materials, Mechanics and Parabolic Motion, and renewable energy. Dynamics, Heat, Electricity, Waves, Optics, Magnetic Field, Newton's Laws, and Kinematics are also topics that are quite discussed in this study. Meanwhile, the materials of Electromagnetic Radiation, Basics Physics, Electric Circuit, Dynamic Fluids, Nuclear Physics and Mechanics, Thermodynamics, and Electromagnetic are slightly discussed in this study.

Table 5. Classification Based on Physics Subject Matter

No	Subject Matter	Frequency
1.	Static Fluids	4
2.	Momentum and Impulse	3
3.	Renewable energy	3
4.	Mechanics and Parabolic Motion	3

No	Subject Matter	Frequency
5.	Dynamics, Heat, Electricity, Waves, Optics	2
6.	Magnetic Field	2
7.	Newton's Laws	2
8.	Kinematics	2
9.	Electromagnetic Radiation	1
10.	Electric Circuit	1
11.	Basics Physics	1
12.	Elasticity	1
13.	Dynamic Fluids	1
14.	Nuclear Physics	1
15.	Mechanics, Thermodynamics, and Electromagnetic	1

Discussion

A number of physics learning skills need to be developed in 21st century education. One of the physics skills that is important for students in the 21st century is that critical thinking skills are included in higher-level thinking skills (Ikuenobe, 2001). Critical thinking skills need to be continued in the learning process (Kealey et al., 2005). The main focus is on the golden generation who will live their future lives from elementary school to university level. The results of Chartrand (2010) research show that 70% of high school graduates lack competence in critical thinking skills and even after 4 years of college, students only have 28% of critical thinking skills. The factor causing the lack of development of students' critical thinking skills is teachers who do not have adequate competence in designing learning (Aybek, 2007). Therefore, various ways are currently being carried out to improve students' critical thinking skills such as the use of learning models, the use of media and technology used in physics learning.

Information obtained from Table 1. It shows that various learning models that can improve critical thinking skills can be divided into several learning models. Categorization is based on the characteristics inherent in the learning model. The classification of learning models consists of inquiry-based learning, high order thinking and cognitive strategies, STEM education, Technology-enhanced learning, project-based learning, ethnoscience and direct instruction, reflective and creative learning, and problem-based learning. The characteristics of inquiry-based learning-oriented learning models include guided inquiry and game comic-discovery learning. The characteristics of the learning model oriented to high order thinking and cognitive strategies include higher and correlated multiple choice question, systematic learning based on first principles of instruction, and the CinQASE model (collaborative critical thinking). The characteristics of the learning model oriented to STEM education include physics electronic teaching material integrated STEM (PETMS), STEM-smart-physics e-module, and blended learning STEM. The characteristics of the technology-enhanced learning model include cooperative with learning with augmented reality, e-book-augmented reality, augmented reality, and Hot Lab activity. The characteristics of the project-based learning model include project-based learning and project-based learning tools. The characteristics of the learning model that are oriented to ethnoscience and direct instruction include benthic

android, physic comic and Physics comic of Android-based marbles games. The characteristics of the reflective and creative learning model include microteaching lesson study (active & passive MLS) and engineering design process. Finally, the learning model with a problem-based learning environment has its characteristics, namely problem-based learning, STEAM+problem-based learning and project-oriented problem-based learning.

The implementation of the guided inquiry learning model has the ability to improve students' critical thinking skills. This is because this model provides opportunities for students to independently build concepts through problem presentation, hypothesis formulation, data collection, analysis, and conclusions (Maknun, 2020). According to Sutikno (2014), guided inquiry is a learning model in which teachers provide guidance and direction to students in the process of finding concepts or solutions through a series of systematic steps. Sutikno (2014) emphasized that terming inquiry consists of seven stages, namely orientation, formulating problems, proposing hypotheses, collecting data, drawing conclusions, and applying concepts. In the context of physics learning, the implementation of guided inquiry can be carried out through a randomized pretest-posttest control group design (Maknun, 2020). According to Zain & Jumadi (2018), the Guided Inquiry approach based on Blended Learning is more effective in improving critical thinking skills than the Guided Inquiry approach without blended learning. This research makes an important contribution to the development of learning methods that combine technology with scientific approaches. Teachers are encouraged to utilize e-learning such as the WhatsApp application to support the implementation of Guided Inquiry. The application of the practicum-based guided inquiry method significantly improved students' critical thinking skills compared to verification-based practicum. This learning provides students with the opportunity to design, develop, and carry out experiments independently, thereby encouraging the development of critical thinking skills (Phonna et al., 2020). In addition, the inquiry-discovery learning model through empirical and theoretical review results in higher critical thinking skills compared to conventional learning. Therefore, the inquiry-discovery learning model is recommended for learning other physics materials to improve students' critical thinking skills. (Wartono et al., 2018).

The implementation of High Order Thinking and Cognitive Strategies Integration also has several advantages. The use of CCMCQs can be applied in physics teaching to help students develop better understanding of concepts, critical thinking skills, and quantitative abilities (Siddiqui, 2022). The application of the CinQASE learning model has been proven to be effective in improving the collaborative critical thinking skills of physics education students (Hunaidah et al., 2018).

Android-based physics comic media through traditional Benthik games can be an effective learning strategy to improve concept understanding and critical thinking skills in physics learning (Maghfiroh & Kuswanto, 2022). The use of local knowledge-based physics comics and Android-based marble games has been shown to be effective in improving students' verbal representation and critical thinking skills in physics learning. This media is not only engaging for students but also provides a meaningful and contextual learning experience (Damayanti & Kuswanto, 2021). Android-based comic media games integrated with discovery learning (MIKIMOM) have proven to be effective in improving students' critical thinking skills and mathematical representations in physics teaching. This media can be used as an alternative in choosing teaching media to improve students' critical thinking skills and mathematical representation (Rahayu & Kuswanto, 2021).

STEM-based blended learning models can effectively improve students' critical thinking skills. This is because learning is student-centered, more interactive, and involves STEM-based projects (Ardianti et al., 2020). Technology-Enhanced Learning as a learning model that utilizes technology is also a priority in the learning process to improve critical thinking skills. This Cooperative and augmented reality-based learning model is effective in improving students' critical thinking skills and learning motivation (Rizki et al., 2024). The implementation of HOT Lab can be an innovative solution in physics learning to develop students' critical thinking skills (Sahidah Lisdiani et al., 2019). The use of AR e-books in physics learning not only improves students' conceptual understanding, but also other important skills such as critical thinking and multiple representation. This research provides insights for educators to adopt the latest technologies in their teaching practices (Rahmayani et al., 2024).

The STEAM + PBL approach can gradually support the development of critical thinking, although it takes a longer duration of intervention to see significant development (Moreno & Díaz, 2021). Instructional principles-based systematic learning design can improve domain-specific critical thinking skills. However, the transfer of such abilities to general-domain issues has not been significant without explicit intervention on critical thinking skills (Tiruneh et al., 2018). The PBL method that uses a virtual simulation of a mobile application-based PhET provides an interactive and motivating digital learning environment, so that it is effective in developing students' critical thinking skills (Suhirman & Prayogi, 2023). This model can be a physics learning strategy to develop students' critical thinking skills (Rahim et al., 2019). This study concludes that the critical thinking skills of physics students are mostly in the low category. The POPBL learning model has promising prospects for application in physics learning because it can improve critical thinking skills and provide a richer learning experience (Suprapto et al., 2024). The critical thinking skills of female students are higher than those of men, with statistically significant differences.

Active MLS-based teaching strategies in the educational curriculum of prospective teachers can provide significant advantages in the development of their critical thinking skills. This study suggests the need for the implementation of Active MLS to improve the teaching competence of prospective teachers and their critical thinking skills (Danday, 2021). The use of the PjBL model through traditional games is also effective in improving critical, creative, and collaborative thinking skills. This learning provides a fun and meaningful learning experience, which encourages students to actively participate in the learning process (Khoiri et al., 2023).

Critical thinking skills are the ability to convey ideas, analyze facts, make comparisons, draw conclusions, and solve problems ((Dewi et al., 2017; Polat & Aydın, 2020; Jalinus et al., 2021). Critical thinking is at the fifth level of the cognitive domain of bloom. Critical thinking intersects with the Bloom taxonomy theory which discusses the concept of thinking with a level of thinking divided into two. First, Lower Order Thinking Skills (LOTS) which contains levels of knowledge, understanding, and application. Second, the ability to think at a higher level or Higher Order Thinking Skills (HOTS) which contains the level of analyzing, evaluating, and creating (Susilowati, 2020). This ability will provide opportunities for students to use the information they have to provide solutions to a problem (Sadhu & Laksono, 2018; Rahmawati et al., 2019). Ennis (1995) revealed that people who think critically ideally have several criteria or basic elements abbreviated as FRISCO (Focus, Reason, Inference,

Situation, Clarity, and Overview). According to Facione, (2015), critical thinking skills consist of five indicators, namely interpretation, analysis, evaluation, inference, and self-regulation. Meanwhile, according to Hanumi (2007), there are 12 indicators of critical thinking that are summarized in five critical thinking groups, namely providing simple explanations, building basic skills, concluding, making further explanations and strategies and tactics. The critical thinking skill indicators used in the article are taken from Facione (2015) which consists of interpretation, analysis, inference, evaluation, explanation and self-regulation (Salazar et al., 2023). Critical thinking research based on table 3 is dominated by high school level. Several treatments have been carried out that can improve students' thinking skills in high school. Research on critical thinking skills has been conducted in several high schools (Suprapto et al., 2024; Damayanti & Kuswanto, 2021; Rahayu & Kuswanto, 2021; Maghfiroh & Kuswanto, 2022; Rizki et al., 2024; Ambarwati & Suyatna, 2018). The research on critical thinking skills at the high school level is divided into two, namely the experimental class and the control class (Arymbekov et al., 2024). Critical thinking skills research was also carried out in several universities such as this study involved 460 first-year students of the engineering program at Kaunas University of Technology. (Marcinauskas et al., 2024); development of critical thinking skills for prospective physics teachers through active and passive Microteaching Lesson Study (MLS) methods (Danday, 2021); first-year students of physics study programs at two public universities in Ethiopia (Tiruneh et al., 2017); the development of critical thinking through the learning of electrical circuits in engineering students in Mexico (Moreno & Díaz, 2021); and first-year students of the engineering program at Kaunas University of Technology, Lithuania (Marcinauskas et al., 2024). The results showed that there was an improvement in critical thinking skills after being given treatment.

The topics of physics material in this study are very varied and in accordance with the characteristics of the learning model carried out. Some studies combine several materials in their research such as dynamics, heat and thermodynamics (Danday, 2021); classical mechanics, mechanical oscillations and waves, thermodynamics and molecular physics (Marcinauskas et al., 2024). Static fluid material is a material that is often discussed in this study, because this material is very close to students' lives. The inquiry-discovery learning model through empirical and theoretical review can improve students' cognitive achievement on static fluid materials, which can empower students to solve real problems in daily life and minimize student misunderstandings (Wartono et al., 2018).

Several previous studies have shown that mechanics and parabolic motion also often occur in the poor, which results in low students' thinking skills (Siddiqui, 2022). Other studies have also often misunderstood electrical circuit materials (Moreno & Díaz, 2021); Newton's law (Phonna et al., 2020); heat transfer (Sahidah Lisdiani et al., 2019); electricity and magnetism (Tiruneh et al., 2017); nuclear physics (Arymbekov et al., 2024); and optics (Zain & Jumadi, 2018). Understanding concept is the basis for improving students' critical thinking skills (Yulianty, 2019).

Recommendations

This review has provided information on efforts to improve critical thinking skills in physics learning at the junior high, high school and student levels and various countries. This paper focuses on the disclosure of the use of

learning models, instruments used in improving critical thinking skills, education levels, and physics materials that are the topics of research. Various ways that can be done in improving critical thinking skills are by involving students in problem solving through real learning, through laboratories and the use of technology that can stimulate students' cognition. Critical thinking skills can be practiced from all levels. The results of the study provide information to teachers about the application of learning models that can improve students' critical thinking skills. The next researcher is expected to conduct a literature study related to the success of improving critical thinking skills that focuses on the influence of local wisdom or local potential that can improve students' thinking skills.

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