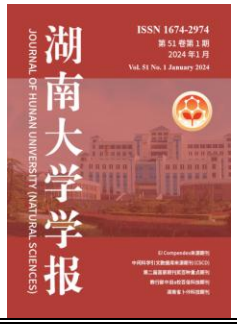

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Students' Critical Thinking Abilities Based on Cognitive Style in STEM-Integrated Problem-Based Learning

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Abstract: This research aims to determine students' cognitive styles in STEM-integrated problem-based learning and differences in students' critical thinking abilities based on field-independent and field-dependent cognitive styles. The novelty of this research lies in integrating STEM in problem-based learning as a context for analyzing students' critical thinking abilities based on their cognitive style. This research is descriptive and qualitative. The research subjects were selected using a purposive sampling technique, consisting of SMA Negeri 8 Semarang class X students. The results of this research are as follows: (1) There are 15 field-independent cognitive style students with the following characteristics: high curiosity, liking individual assignments, independent and structured learning, and a highly competitive spirit. There are 21 field-dependent cognitive style students with the following characteristics: lack of curiosity, likes group assignments, depend on teachers, and a lack of competitive spirit. (2) Strong field-independent students have medium and high levels of thinking. They can master all aspects very well. Weak field-independent students have medium and high levels of thinking. They can master the evaluation aspect very well and other aspects well. Strong field-dependent students have low and medium levels of thinking. They can master the analysis and evaluation aspects very well, the inference aspects well, and are less able to master the interpretation aspects. Weak field-dependent students have low and medium levels of thinking. They can master the analysis and interpretation aspects well, but they cannot master the evaluation and inference aspects.

Keywords: cognitive style, critical thinking ability, problem-based learning, STEM.

干-综合问题型学习中基于认知风格的学生批判性思维能力

摘要：本研究旨在确定学生在干集成的基于问题的学习中的认知风格，以及基于场独立和场依赖认知风格的学生批判性思维能力的差异。这项研究的新颖之处在于将干融入基于问题的学习中，作为根据学生的认知风格分析他们的批判性思维能力的背景。这项研究是描述性和定性的。研究对象采用有目的的抽样技术进行选择，其中包括 SMA 内格里 8 三宝垄 X 级学生。本研究结果如下：（1）15 名场独立认知风格的学生具有以下特点：好奇心强、喜欢独立作业、自主结构化学习、具有高度竞争精神。21 名场依赖型认知型学生具有以下特点：缺乏好奇心、喜欢小组作业、依赖老师、缺乏竞争精神。(2)领域独立性强学生具有中高级思维水平。他们可以很好地掌握各个方面。场独立能力弱的学生具有中、高思维水平。他们可以很好地掌握评估方面和其他方面。场依存性强的学生具有中低水平的思维。他们能够很好地掌握分析和评价方面，很好地掌握推理方面，而不太能够掌握解释方面。弱领域依赖学生

的思维水平为中低水平。他们可以很好地掌握分析和解释方面，但不能掌握评价和推理方面.

关键词：认知风格、批判性思维能力、基于问题的学习、干。

1. Introduction

Education is essential in life. Education plays a role in developing students' potentials, including their thinking abilities. Technological advances in the 21st century require someone to master qualified skills. One of the abilities needed is the ability to think critically. Critical thinking is an aspect that is equally important in learning mathematics. The significant role of mathematics as a universal science can be seen from the significant demands on mathematical abilities that must be mastered. Mathematics subjects should be given to all students starting from elementary school to equip them with logical, analytical, systematic, critical, and creative thinking skills and the ability to work together. Most students do not think critically when studying, especially in mathematics. As a result, students receive explanations passively. In contrast, critical thinking is an ability that needs to be developed to face the era of the industrial revolution.

The Program for International Student Assessment (PISA) study results show that Indonesia's mathematics score has decreased to 379, which is below the OECD average score of 489. This result indicates that students in Indonesia still have low levels of high-level thinking abilities. The low level of students' critical thinking abilities is influenced by several factors, one of which is the learning process implemented by the teacher in the classroom. Some ongoing learning processes still position the teacher as the center (teacher-centered). Teachers do not encourage students to be active in learning, so students are less facilitated in developing their critical thinking skills.

One learning model that is seen as capable of building students' critical thinking skills is the problem-based learning model. The syntax of this learning model supports critical thinking skills. Several learning strategies and approaches can be implemented with the problem-based learning model. One approach that is currently popular and widely developed is the STEM approach. Integrating the STEM approach helps develop 21st-century skills. STEM-integrated problem-based learning is expected to be one solution that can be implemented to accommodate students' critical thinking abilities.

In addition to choosing a learning model, teachers must consider students' cognitive style factors. Cognitive style plays an essential role in developing students' critical thinking abilities. Therefore, the objectives of this research are (1) to determine and describe students' cognitive styles in problem-based learning integrated with STEM and (2) to observe differences in students' critical thinking abilities based on field-independent and field-dependent cognitive styles.

2. Literature Review

2.1. Critical Thinking Ability

According to Facione [5], critical thinking is a process of self-regulation in decision-making that consists of interpretation, analysis, evaluation, inference, and the presentation of evidence, concepts, methodology, criteria, or contextual considerations. Johnson [9] argues that critical thinking concentrates on mental activities such as problem-solving, decision-making, analyzing assumptions, and conducting scientific research. Critical thinking skills require several activities, such as analyzing, evaluating, and making conclusions [3, 13, 18].

Students' critical thinking abilities can be measured using measuring instruments, namely indicators of critical thinking abilities. This indicator is handy as a guide for precise measurements. Several experts have developed appropriate indicators of critical thinking abilities. Facione [5] states that there are six aspects contained in critical thinking skills: (1) interpretation, the ability to understand and define the meaning or intent of several types of information, data, experiences, conditions, events, habits, assessments, procedures, and criteria; (2) analysis, the ability to identify and explain relationships between statements, concepts, questions, and descriptions in other representations; (3) evaluation, the ability to assess or estimate the credibility of a statement and the truth of a relationship between various statements and concepts by applying strategies logically; and (4) inference, the ability to find elements used to make logical conclusions.

Apart from the four aspects mentioned above, Facione [5] also revealed two other aspects: explanation, which is defined as the ability to explain the results of thoughts based on evidence, and self-regulation, which is defined as how to regulate the thinking process to conclude. In this research, the indicators of critical thinking skills are adapted from Facione [5]. However, because the research was limited to using instruments in written tests, only four aspects were used: interpretation, analysis, evaluation, and inference.

2.2. Problem-Based Learning

Problem-based learning is a learning model that focuses on problems as the main/starting point of learning. Real-world problems are the primary context in which students learn to think critically, practice problem-solving skills, and gain the essence of knowledge from a subject. The problem-based learning model positions learning in the real world, encouraging students to be actively involved through group discussions and stimulating them to analyze, integrate, and use the presented problems [16, 18].

According to [21], applying the problem-based learning model helps students develop critical thinking skills, problem-solving, collaborating, and conveying ideas orally and in writing. According to [11], the problem-based learning model consists of five phases/stages, as presented in Table 1.

Table 1 Syntax of the problem-based learning model [11]

Phase	Teacher Activities
Phase 1: Student orientation to the problem	Conveying learning objectives, explaining what is needed, and motivating students to solve problems actively
Phase 2: Organizing students to study	Helping students interpret and organize learning tasks and activities related to the problem
Phase 3: Guiding individual and group investigations	Encouraging students to collect appropriate information from various sources and conduct investigations to obtain explanations to solve problems
Phase 4: Developing and presenting the work results	Assisting students in planning and preparing relevant work, such as reports, models, presentations, and sharing assignments with friends.
Phase 5: Analyzing and evaluating the problem-solving process	Asking the group to present the results of their work and evaluating learning outcomes regarding the material studied

2.3. STEM

STEM is an approach that simultaneously integrates science, technology, engineering, and mathematics. Furthermore, the educational process focuses on solving problems that arise in life. Quang et al. [14] argued that a STEM approach to learning can create active and meaningful learning experiences for students.

STEM is applied to problem-based learning based on real-world situations. Learning with a STEM approach has several characteristics, including (1) encouraging students to apply STEM knowledge, (2) involving the active participation of students through discussions and productive group work, (3) training students' sensitivity to issues that are developing in the real world, and (4) guiding students to solve problems.

2.4. Cognitive Style

Cognitive style is a term studied in cognitive psychology to describe an individual's thinking in responding to understanding broadly and consistently [6]. Cognitive style is a characteristic/distinctive way in which individuals think, process information, solve problems, and make decisions. There are several types of cognitive styles. In this research, the types studied are the field-independent (FI) and field-dependent (FD) cognitive styles popularized by Witkin et al. [19].

a. Field-independent cognitive style

Field-independent cognitive styles are possessed by individuals who tend to be analytical to abstract elements from their context. Witkin et al. [19] stated that individuals with field-independent cognitive styles are interested in mathematics, science, and health. This is because students with a field-independent cognitive style have the following characteristics: (1) preferring individual assignments, (2) being analytical and competitive, (3) being more influenced by motivation that comes from oneself (intrinsic) due to high curiosity, (4) having their own goals and strategies, and (5) being independent and structured in learning.

b. Field-dependent cognitive style

Field-dependent cognitive style is a cognitive style possessed by individuals who consider the environment to be involved in obtaining and processing information. Witkin et al. [19] stated that individuals with field-dependent cognitive styles are interested in interpersonal skills and social sciences domains. Students with a field-dependent cognitive style have the following characteristics: (1) preferring group assignments, (2) being less analytical because different contexts easily influence it, (3) being more influenced by external motivation (extrinsic) due to lack of curiosity, (4) being sensitive to the surrounding environment, and (5) not being sufficiently independent and structured in learning.

Field-independent and field-dependent cognitive styles can be measured using the Group Embedded Figures Test (GEFT). Regarding critical thinking skills, several studies have shown that students with a field-independent cognitive style have a higher level of critical thinking ability than students with a field-dependent style [1, 2].

3. Methods

This research is a type of descriptive research with a qualitative approach. Descriptive research attempts to describe a symptom or phenomenon as a whole on the basis of the research data obtained. A qualitative approach is used because in this research, the researcher is the main instrument directly involved in the research process from start to finish.

The subjects of this research were class X students of SMA Negeri 8 Semarang. They were selected using a purposive sampling technique. This research procedure was conducted in three stages: preparation, implementation, and data processing.

The research preparation stage includes making a proposal, preparing research instruments, expert validation, instrument testing, and requesting a research permit. The analysis results of the critical thinking ability test were four valid questions, and the reliability

value was 0.711, which means it was reliable.

The research implementation stage includes conducting the GEFT test, implementing STEM-integrated problem-based learning, giving a critical thinking test, selecting four research subjects based on field-independent and field-dependent cognitive style categories, and conducting interviews according to the guidelines.

The data processing stage includes collecting data from the GEFT results, learning observation data, data from critical thinking ability tests and interview results, and processing and analyzing data from the critical thinking ability test and interview results. Data collection techniques include observation, tests, interviews, and documentation. Supporting instruments include observation sheets, GEFT test sheets, critical thinking ability test sheets, interview guidelines, and documentation of results and activities. The data validity technique used in this research is technical triangulation of test and interview results. Conclusions are drawn by summarizing the research results based on problem formulation and suitability to the research objectives and providing suggestions.

4. Results and Discussion

4.1. Distribution of Students' Cognitive Styles

The GEFT test was given to 36 class X.5 students. Based on the GEFT test results analysis, the data obtained are presented in Table 2.

Table 2 Cognitive style of Class X.5 students at SMA Negeri 8 Semarang (The authors)

Cognitive Style	Many Students	Percentage (%)
Field-Independent	15	41.67
Field-Dependent	21	58.33
Amount	36	100

4.2. Distribution of Students' Critical Thinking Abilities

The distribution of the students' critical thinking ability test results is presented in Table 3.

Table 3 Distribution of students' critical thinking abilities (The authors)

Cognitive Style	Group	Critical Thinking Levels	Many Students	Percentage (%)
Field-Dependent	Weak	Low	4	11,11
		Medium	7	19.44
	Strong	Low	1	2.78
		Medium	9	25
Field-Independent	Weak	Medium	4	11,11
		High	4	11,11
	Strong	Medium	3	8.34
		High	4	11,11
Total			36	100%

One student was chosen as the research subject for each cognitive style group. Therefore, four research subjects were selected, as shown in Table 4.

Table 4 Research subjects (The authors)

Subject Code	Cognitive Style Group	GEFT Score	Critical Thinking Levels
S36	Weak field-dependent	2	Medium
S22	Strong field-dependent	9	Medium
S14	Weak field-independent	13	High
S16	Strong field-independent	15	High

4.3. Analysis of Students' Critical Thinking Abilities Based on Cognitive Styles

4.3.1. Field-Independent Subjects' Critical Thinking Abilities

The following is an example of subject S16's work on analysis aspects.

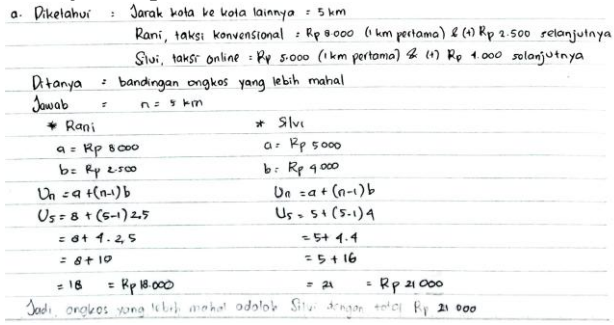

Fig. 1 The S16 subject work on analysis aspects (The authors)

These answers were then triangulated with the interview results, and no contradictions were found. Table 5 presents the results of data analysis for subject S16.

Table 5 Analysis of the S16 subject data (The authors)

Aspect	Indicator	Test	Interview	Conclusion
Interpretation	Explaining the meaning of the problem illustration	Able	Able	Able
Analysis	Explaining opinions with logical reasons based on the relationship between concepts	Able	Able	Able
Evaluation	Assessing the truth of statements and assumptions with evidence	Able	Able	Able
Inference	Making conclusions based on evidence according to the context of the question	Able	Able	Able

4.3.2. Field-Dependent Subjects' Critical Thinking Abilities

The following is an example of the S22 subject work on analysis aspects.

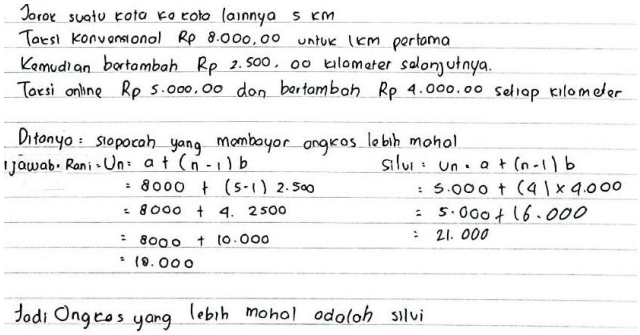

Fig. 2 The S22 subject work on analysis aspects (The authors)

The results of this work were then triangulated with the results of the interviews, and no contradictions were found. The following are the results of the S22 subject data analysis, as shown in Table 6.

Table 6 Analysis of the S22 subject data (The authors)

Aspect	Indicator	Test	Interview	Conclusion
Interpretation	Explaining the meaning of the illustration	Less Able	Less Able	Less Able
Analysis	Explaining opinions with logical reasons based on the relationship between concepts	Able	Able	Able
Evaluation	Assessing the truth of statements and assumptions with evidence	Able	Able	Able
Inference	Making a conclusion on the basis of evidence according to the context of the question	Able with a Little Shortcoming	Able with a Little Shortcoming	Able with a Little Shortcoming

4.4. Student Cognitive Style in the STEM-Integrated Problem-Based Learning Model

4.4.1. Field-Independent Students' Cognitive Style in the STEM-Integrated Problem-Based Learning Model

Based on research results, students with a field-independent cognitive style have a smaller percentage than students with a field-dependent cognitive style. In the STEM-integrated problem-based learning model, students with field-independent cognitive styles actively ask questions. This shows that students with this cognitive style have high curiosity.

However, during discussion activities in small groups, students with field-independent cognitive styles focused on their respective works. This shows that students with field-independent cognitive styles prefer individual assignments, can learn independently, and are structured. This aligns with Witkin et al.'s [19] opinion that field-independent individuals tend to work alone.

When taking competency tests individually, students with field-independent cognitive styles try to complete them independently and on time. They compete with each other to finish earlier than the others. Even so, they solved the questions with in structured and complete steps. This shows that students with field-independent cognitive styles are highly competitive when implementing their strategies. This finding agrees with the opinion of [20], who stated that one of the characteristics of students with a field-independent cognitive style is that they prefer to compete.

4.4.2. Field-Dependent Students' Cognitive Style in the STEM-Integrated Problem-Based Learning Model

Students with field-dependent cognitive style prevail over students with field-independent cognitive style. This agrees with the research results of Rifqiyana et al. [15], which show that the number of students with a field-dependent cognitive style is more significant than that of students with a field-independent cognitive style.

In STEM-integrated problem-based learning, field-dependent cognitive style students are not very active in asking questions or giving opinions. This shows that students' curiosity in the field-dependent cognitive style is still lacking. When discussing in small groups, they focus less on the discussion process. They must first receive guidance or explanation assistance to ignite their enthusiasm for the task. Desima [4] states that students with field-dependent cognitive styles need explanations and guidance in solving problems. This is a characteristic of students with a field-dependent cognitive style: not being independent enough in learning.

The surrounding environment easily sways their focus. Likewise, when taking a competency test, students with field-dependent cognitive styles are more relaxed and do not even use the available time to solve the questions. This shows another characteristic of students with a field-dependent cognitive style, namely that they lack a competitive spirit. The results of their work also appear simple without complete structured steps.

4.5. Similarities and Differences in Students' Critical Thinking Abilities Based on Cognitive Style in the STEM-Integrated Problem-Based Learning Model

4.5.1. Field-Independent Students' Critical Thinking Abilities

The results of this study indicate similarities and differences in critical thinking abilities between subjects S16 and S14. The similarity in the critical thinking abilities of subjects S16 and S14 lies in the evaluation aspect, where both subjects can equally assess the truth of a statement/assumption with appropriate and complete evidence, even though they

use different processing processes. Subject S16 uses the concept of arithmetic sequence formulas to determine the difference in sequences. Next, arithmetic series formulas are used to obtain final results as a basis for proving assumptions. Meanwhile, subject S14, after determining the difference, then looked for the second, third, and fourth term values manually and then added all the term values to obtain the final result as a basis for proving the assumption.

The differences in the critical thinking abilities of subjects S16 and S14 were found in three other aspects. In the interpretation aspect, with indicators explaining the meaning of the problem illustration, subject S16 could explain the meaning of the problem illustration accurately, altogether, and following the context. Meanwhile, although subject S14 could explain the meaning of the problem illustration wholly, accurately, and following the context, subject S14 still had some shortcomings. This deficiency lies in subject S14's error in linking the sentence "the number of steps" with the *n*th term of an arithmetic sequence, which should be related to *n* (many terms).

In the analysis aspect, with indicators explaining opinions with logical reasons related to the concept, subject S16 was able to explain opinions with logical reasons related to the concept. Subject S16 solves problems using structured steps by correctly creating mathematical models and using arithmetic sequence formulas. Meanwhile, subject S14, although able to explain opinions with logical reasons related to the concept, still has a few shortcomings. This deficiency lies in subject S14's error in writing the arithmetic sequence formula. Subject S14 writes the formula with the symbol "Sn," which should be "Un." Subject S14 said that this was because of forgetting. Subject S14 also skips one stage: creating a mathematical model.

In the inference aspect, with indicators of making conclusions based on evidence according to the context of the question, subject S16 was able to make conclusions correctly, according to the context of the question and accompanied by complete evidence. However, although subject S14 was able to make conclusions correctly, according to the context of the question and accompanied by complete evidence, they still had some shortcomings. This deficiency is the same as before, subject S14's error in writing the formula symbols for arithmetic sequences.

4.5.2. Field-Dependent Students' Critical Thinking Abilities

This study also shows similarities and differences in critical thinking abilities between subjects S22 and S36. The critical thinking abilities of subjects S22 and S36 were similar in analysis, with indicators explaining opinions with logical reasons related to concepts. Both subjects equally could explain their opinions with logical reasons related to the concept. Solving both subjects is also structured precisely using the concept of arithmetic sequences.

The differences in the critical thinking abilities of subjects S22 and S36 lie in three other aspects. In the interpretation aspect, with indicators explaining the meaning of the problem illustration, subject S22 was able to explain the meaning of the problem illustration, but the explanation was not precise. Subject S22 was not thorough in identifying the information in the illustration. Subject S22 incorrectly wrote the height of the first step. Subject S22 also did not write the variable "height" as a known measurement from the illustration. It is different from the S36 subject. Subject S36 could explain the meaning of the problem illustration accurately, thoroughly, and in context, but subject S36 still had a few shortcomings. This deficiency lies in the lack of writing the variable "height" to explain the size in the illustration.

In the evaluation aspect, with indicators of assessing the truth of a statement/assumption with appropriate evidence, subject S22 can assess the truth of a statement/assumption with appropriate and complete evidence. Subject S22 solves problems in a structured way using the concept of sequences and arithmetic series correctly. However, subject S36 could not assess the truth of a statement/assumption. The process of working on subject S36 stopped midway. This resulted in subject S36 being unable to obtain final results as a basis for assessing the truth of a statement of the problem.

In the inference aspect, with indicators of making conclusions based on evidence according to the context of the question, subject S22 could make conclusions based on the context of the question correctly. However, subject S22 still has a few shortcomings, such as not writing the "Un" element in the arithmetic sequence formula. Subject S22 also lacks a mathematical model. Meanwhile, subject S36 failed to draw conclusions. Subject S36 said that he was confused about the steps in the process, even though the concept used was the same as the analysis aspect.

Field-independent subjects have better critical thinking skills than field-dependent subjects. This is supported by [17], which shows that students with a field-independent cognitive style can master all FRISCO critical thinking indicators. In contrast, students with a field-dependent cognitive style can only master the Focus and Reason indicators.

Guisande et al. [7] stated that someone with a field-independent cognitive style does not find difficulty in identifying and sorting important information and is selective in digesting the information received. Meanwhile, someone with a field-dependent cognitive style tends to be the opposite. This shows that field-independent subjects have better performance than field-dependent subjects. Rifqiyana et al. [15] stated that the critical thinking skills of field-independent subjects, especially strong field-independent subjects, were better than those of field-dependent subjects.

Field-independent subjects can understand the problem by explaining the meaning better than field-dependent subjects. Ngilawajan [10] explained that field-independent subjects gave more apparent answers than field-dependent subjects, which indicated that field-independent subjects were better at processing information than field-dependent subjects. The same was expressed by [12], where field-independent subjects have higher analysis in receiving and processing information, so they are often referred to as analytical thinkers.

Based on the level of critical thinking ability, field-independent subjects were at medium and high levels, while field-dependent subjects were at low and medium levels. This aligns with the research results of [8], who stated that students from the field-dependent group had low critical thinking abilities. In contrast, students from the field-independent group had high and medium critical thinking abilities.

5. Conclusion

Based on the problem formulation, results, and discussion, it can be concluded that (1) there are 15 field-independent cognitive style students with the following characteristics: high curiosity, liking individual assignments, independent and structured learning, and a highly competitive spirit. There are 21 field-dependent cognitive style students with the following characteristics: lack of curiosity, liking group assignments, dependence on teachers, and a lack of competitive spirit; (2) strong field-independent students have medium and high levels of thinking. They can master all aspects very well. Weak field-independent students have medium and high levels of thinking. They can master the evaluation aspect very well and other aspects well. Strong field-dependent students have low and medium levels of thinking. They can master analysis and evaluation aspects very well and inference aspects well, but they are less able to master interpretation aspects. Weak field-dependent students have low and medium levels of thinking. They can master the analysis aspect very well and the interpretation aspect well, but they cannot master the evaluation and inference aspects.

The findings of this study agree with several other studies. Rifqiyana et al. [15] stated that there are more field-dependent cognitive style students than field-independent students. Likewise, [7], [15], [17] stated that field-independent students, especially the strong group, have better critical thinking abilities than field-dependent students.

This study implies that teachers need to facilitate and develop students' critical thinking abilities based on their cognitive style. To develop students' critical thinking abilities in mathematics learning, it is recommended that teachers accustom field-independent and field-dependent students to be actively involved in discussion activities to develop critical thinking skills, including interpreting, analyzing, evaluating, and inferring information or problems. Teachers who find strong and weak field-dependent students with many shortcomings are recommended to provide space for their independent expression and pay more attention so that they can improve themselves. Developing students' critical thinking abilities based on their cognitive styles can be performed by implementing differentiated learning.

Further research is needed regarding critical thinking abilities in terms of other aspects such as gender, learning style, age, and school level to obtain more comprehensive information in developing learning strategies.

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