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The Influence of Brain-Based Learning Model with Cultural Context on Critical Thinking Skills and Self-Efficacy

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Abstract. *This study examines the interplay between critical thinking and self-efficacy, two skills that reinforce each other in learning. Critical thinking enhances students' confidence, while self-efficacy drives the continuous development of critical thinking across contexts. The research aims to (1) evaluate the effect of a brain-based learning model integrating cultural context on students' critical thinking and self-efficacy and (2) assess the model's effectiveness in enhancing these skills. Using a quasi-experimental design, the study involved Year 7 students selected through purposive sampling and divided into experimental and control groups. The experimental group was taught using the brain-based learning model with cultural context, while the control group received conventional instruction. Data were collected through pretests, posttests, and self-efficacy questionnaires. Findings revealed that the brain-based learning model with cultural context significantly improved critical thinking and self-efficacy, with the experimental group outperforming the control. Furthermore, the experimental group showed a marked increase in both skills following the intervention. The study concludes that integrating brain-based learning and cultural context, particularly in mathematics, effectively fosters critical thinking and self-efficacy and recommends its adoption in teaching practices.*

Keywords*: Brain-based learning model, cultural context, self-efficacy*

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Introduction

Critical thinking has long been recognized as one of the essential skills of the 21st century, vital for navigating the complexities of the modern world (Saldıray & Doğanay, 2024). Critical thinking encompasses analysis, interpretation, evaluation, and inference, enabling students to think independently and responsibly (Facione, 2015; Laili, Fardhani, Mulyati, Fiel'ardh, & Habiddin, 2024). With these skills, students are better prepared to address academic challenges in both a structured and creative way, impacting their academic pursuits and everyday lives. Critical thinking skills can enhance an individual's confidence in completing tasks and solving problems, suggesting that critical thinking influences affective abilities, including self-efficacy.

Self-efficacy, or the belief in one's ability to achieve desired goals, is also a crucial factor in academic success (Bandura, 1997; Perepiczka, Chandler, & Becerra, 2011). Students with high self-efficacy are more likely to engage actively in learning, overcome obstacles, and achieve better academic outcomes (Shahzad, Xu, & Zahid, 2024). Research has shown that self-efficacy has a strong correlation with students' academic performance, where students who believe in their abilities tend to perform better across various subjects (Negara, Santosa, & Siagian, 2024; Negara, Wahyudin, Nurlaelah, Marzuki, Santosa, & Bahri, 2024; Wang, Gao, Wang, & Zhang, 2024). However, numerous reports and studies indicate that students' critical thinking skills and levels of self-efficacy in Indonesia still do not meet adequate standards. For instance, results from the Program for International Student Assessment (PISA) conducted by the OECD 2022 revealed that students in Indonesia exhibit low problem-solving and critical thinking skills compared to their peers in other Southeast Asian countries (OECD, 2023). Meanwhile, local studies suggested that low self-efficacy among Indonesian students poses a barrier to achieving their maximum potential (Bakdoolot & Dangin, 2024; Nasution & Nissa, 2024).

Various efforts have been made to enhance critical thinking skills within education; however, the results have been unsatisfactory. For instance, traditional teaching methods that emphasize rote memorization and repetition often fail to provide students with opportunities to develop their critical thinking abilities. Additionally, low self-efficacy remains a persistent barrier, making students feel less confident tackling complex academic problems (Bakdoolot & Dangin, 2024; Nasution & Khairun Nissa, 2024).

According to Santrock (2008), an interactive and culturally relevant learning environment is essential for fostering critical thinking and self-efficacy. Creating an interactive learning environment related to cultural context allows students to feel valued and comfortable, thereby facilitating a more effective learning process. From this perspective, a learning model more responsive to students' cognitive and cultural needs is necessary to address these issues. One approach to achieve this is through the implementation of the brain-based learning model in the educational process.

Brain-based learning is an approach rooted in neuroscience principles, designed to optimize the learning process by aligning it with the brain's natural functioning (Amjad & Tabbasam, 2024; Funa, Ricafort, Jetomo, & Lasala, 2024; Hashmi, Munawar, & Kanwal, 2024). The brain-based learning model emphasizes the importance of creating a learning environment that supports brain development and involves emotional engagement, motivation, and the relevance of teaching materials to students' everyday lives (Sari & Mariani, 2023).

The integration of cultural approaches within the brain-based learning model adds an important dimension to the learning process, allowing students to connect more deeply with the subject matter that aligns with their cultural backgrounds. Culture plays a vital role in shaping students' thinking and cognitive responses (Saing & Santoso, 2023; Morin & Herman, 2022). Hence, applying a brain-based learning model with cultural context is expected to enhance the effectiveness of learning in developing critical thinking skills and self-efficacy.

Various studies have been conducted in-depth to explore the application of brain-based learning model in mathematics education, with results showing a positive impact of this model on various aspects of student learning. For example, Amjad and Tabbasam (2024) conducted a study focusing on the impact of a brain-based learning model on students' extrinsic motivation in learning mathematics. Their finding revealed that the brain-based learning model can significantly increase student motivation, encouraging their engagement in the learning process. Another study by Funa et al. (2024) employed a meta-analysis approach to assess the brain-based learning model's effectiveness in improving students' understanding of mathematical concepts. This study found that integrating brain-based learning model principles, such as learning that emphasizes concrete experiences and active engagement, had a significant positive impact on students' conceptual understanding, indicating the importance of using a brain-based learning model in the mathematics learning process.

Hashmi et al. (2024) investigated teachers' perspectives on the implementation of a brain-based learning model in Early Childhood Education (ECE). Using a descriptive approach and purposive sampling, the study found that most teachers had a positive attitude toward implementing the brain-based learning model in ECE settings, indicating that teachers view this method as a beneficial approach to supporting early childhood development. Lastly, the research by Sari and Mariani (2023) showed that brain-based learning model supported by Multiple Intelligences (MI)-based E-Modules can be an effective solution to enhance students' critical thinking skills. These results indicate that the brain-based learning model is relevant for improving conceptual understanding and developing students' critical thinking skills, especially when combined with MI-based learning technology.

Building on previous research findings, this study broadens the scope of the brain-based learning model by incorporating cultural contexts and examining its effects on students' critical thinking skills and self-efficacy. The brain-based learning model is consistent with constructivist theory, which holds that students develop new understandings based on their own experiences (Vygotsky, 1978). By embedding cultural context within the brain-based learning model framework, students participate in a learning process that values and leverages local cultural elements, thereby enhancing engagement and fostering self-efficacy. This study aims to investigate two main aspects: (1) the impact of the brain-based learning model with cultural context on students' critical thinking skills and self-efficacy, and (2) the improvement of students' critical thinking skills and self-efficacy facilitated by this model.

Method

This study employed a quantitative approach with an experimental design. This approach was chosen because it allows researchers to objectively measure the effect of the independent variable (brain-based learning model with cultural context) on the dependent variables (students' critical thinking skills and self-efficacy). The method aims to identify causal relationships between the variables under investigation.

The research design utilized a quasi-experimental design with control and experimental groups. The experimental group received an intervention through a brain-based learning model incorporating cultural context, while the control group was taught using a conventional learning model. Thus, comparing the two groups allowed for assessing the teaching approach's impact on the dependent variable’s dependent variables.

The population of this study comprised students from an Islamic junior high school in Medan, Indonesia, sharing a homogeneous cultural background that could be integrated into the brain-based learning model. Purposive sampling was used to select two classes as the experimental and control groups, with each group comprising 34 students, resulting in a total sample of 68 students. This sample size is sufficient to detect significant effects according to sample size calculations for experimental research.

The first research instrument is a test of critical thinking skills. It was designed to assess students' critical thinking skills, consisting of four long answer questions aligned with the dimensions of critical thinking: 1) interpreting, 2) analyzing, 3) evaluating, and 4) concluding (Facione, 2015; Laili et al., 2024). Another research instrument was a self-efficacy questionnaire to measure students' self-efficacy, utilizing a self-efficacy scale adapted from Bandura (1997) and Negara et al., 2024. The questionnaire consists of 20 items that assess students' beliefs in their abilities to face academic challenges and complex tasks. Each item was measured using a 5-point Likert scale (1 = strongly disagree to 5 = strongly agree).

The research instruments employed in this study underwent a validation process and reliability testing to ensure measurement accuracy and consistency. The validation process was conducted by educational experts and practitioners in the field of mathematics to evaluate the relevance of the instruments to the research objectives and the alignment of each item with the indicators of critical thinking and self-efficacy. The validation results indicate that each item on the instrument of critical thinking and self-efficacy is highly relevant to the measured aspects.

Reliability testing was performed for each research instrument to ensure consistent measurement. The results indicate that the Cronbach’s Alpha coefficient for the critical thinking test was 0.75, demonstrating good reliability and supporting its use to measure critical thinking dimensions, including interpretation, analysis, evaluation, and conclusion. Similarly, the self-efficacy questionnaire yielded a Cronbach's Alpha coefficient of 0.82, indicating a very high level of reliability. This result suggests that the self-efficacy questionnaire consistently measures students' confidence in their ability to face academic challenges.

The research procedure included a preparation stage involving the development of a lesson plan based on brain-based learning model, integrating local cultural elements into the teaching materials for the experimental group. During the implementation stage, students in the experimental group received instruction using the brain-based learning model with the cultural context model, while the control group was taught using a conventional method. Each group had the learning process for six meetings.

In this study, data were analyzed using Multivariate Analysis of Variance (MANOVA), a statistical technique suitable for simultaneously testing differences among groups across multiple dependent variables. MANOVA was chosen because this research measures two dependent variables: students' critical thinking skills and self-efficacy. Both were expected to be influenced by implementing the brain-based learning model with cultural context. The MANOVA analysis was conducted using post-test data for both instruments. A comparison between post-test scores in both groups to examine the impact on the experimental and the control groups. MANOVA allows for identifying whether an effect occurred in one or both dependent variables, critical thinking skills, and self-efficacy while considering their interrelationship. A paired sample t-test was used to examine an increase for each dependent variable in the experimental class. Pre-test and post-test data in the experimental class addressed research questions on improving critical thinking skills and students' self-efficacy before and after learning using the brain-based learning model with a cultural context.

Results and Discussion

The aim of this study is to examine the impact of implementing the brain-based learning model with cultural context on students' critical thinking skills and self-efficacy. The discussion centers on presenting pre-test and post-test data, along with a comparative analysis between the experimental and control groups, to assess the extent to which this model influences the two variables under investigation. Relevant descriptive statistics are provided in Table 1.

The descriptive data in Table 1 indicates significant differences in students' critical thinking skills and self-efficacy between the experimental group with the brain-based learning model integrating cultural context and the control group using a conventional model. In the pre-test for critical thinking skills, the brain-based learning model group had an average score of 53.49 (SD = 19.29), indicating considerable variation among students. In contrast, the conventional group had a lower average score of 43.03 (SD = 15.83), reflecting lower initial scores. Following the intervention, the average post-test score for critical thinking skills in the brain-based learning model group rose significantly to 70.59 (SD = 12.74), demonstrating the effectiveness of this model in enhancing critical thinking skills. Meanwhile, the conventional group also showed an increase in the post-test, with an average of 58.74 (SD = 11.00), though the improvement was not as substantial as that of the brain-based learning model group. The brain-based learning model group's average gain in critical thinking skills was 0.34 (SD = 0.18). In contrast, the conventional group achieved a gain of 0.26 (SD = 0.13), indicating that students in the brain-based learning model group experienced greater enhancement in their critical thinking skills.

Table 1. Descriptive analysis of critical thinking skills and self-efficacy

	Model	Mean	Std. Deviation	N
Critical thinking pre-test	Brain-based learning	53.4926	19.29088	34
	Conventional	43.0294	15.82956	34
	Total	48.2610	18.28901	68
Critical thinking post-test	Brain-based learning	70.5882	12.73728	34
	Conventional	58.7353	10.99947	34
	Total	64.6618	13.23431	68
Self-efficacy of pre-test	Brain-based learning	61.7647	8.24643	34
	Conventional	52.3235	9.33784	34
	Total	57.0441	9.95277	68
Self-efficacy of post-test	Brain-based learning	80.6471	5.67227	34
	Conventional	68.1471	5.27505	34
	Total	74.3971	8.31855	68

Regarding self-efficacy, the brain-based learning model group scored 61.76 in the pre-test (SD = 8.25), reflecting higher confidence than the conventional group, with an average score of 52.32 (SD = 9.34). After the brain-based learning model intervention, the post-test average self-efficacy score for the brain-based learning model group increased to 80.65 (SD = 5.67), positively impacting students' self-confidence. The conventional group also showed improvement in the post-test, with an average of 68.15 (SD = 5.28), but still scored below the brain-based learning model group. The average gain in self-efficacy for the brain-based learning model group was 0.49 (SD = 0.12). In contrast, the conventional group recorded a gain of 0.30 (SD = 0.19), demonstrating a smaller increase than the brain-based learning model group.

Overall, the results of this descriptive analysis indicate that the brain-based learning model with the cultural context model is significantly more effective in enhancing students' critical thinking skills and self-efficacy than conventional methods. The greater increases in averages and gains in the brain-based learning model group reflect the positive impact of an approach relevant to students' cultural contexts in supporting their academic and emotional development. To strengthen this descriptive analysis, statistical testing using MANOVA was conducted. Prerequisite tests for the analysis were performed to ensure the appropriateness of applying MANOVA. Tables 2 and 3, respectively, present the results of the normality and homogeneity tests for the student's critical thinking skills and self-efficacy data across each class.

Table 2. The results of the normality test for the experimental and control classes

Data	Pre-test score		Post-test score	
	Experiment	Control	Experiment	Control
Critical thinking skills	0.066	0.071	0.073	0.050
Decision	The data are normally distributed			
Self-Efficacy	0.050	0.058	0.126	0.086
Decision	The data are normally distributed			

Table 2 illustrates that the data on students' critical thinking skills and self-efficacy were normally distributed. Subsequently, a homogeneity test was conducted for each data group, as presented in Table 3.

Table 3. The results of the homogeneity test for the experimental and control classes

Data	Pre-test score	Post-test score
Critical thinking skills	0.298	0.108
Decision	Homogeneous	Homogeneous
Self-Efficacy	0.677	0.881
Decision	Homogeneous	Homogeneous

Table 3 shows that the homogeneity assumption is met for students' critical thinking skills and self-efficacy ($p < 0.05$). Subsequently, a multivariate homogeneity test was conducted, and the results are presented in Table 4.

Table 4. The results of the multivariate homogeneity test

Box's Test of Equality of Covariance Matrices	
Box's M	4.064
F	1.307
df1	3
df2	691920.000
Sig.	0.270

Table 4 shows that the data on students' critical thinking skills and self-efficacy in the experimental and control classes have equal variance or are homogeneous ($p < 0.05$)). With all prerequisite tests satisfied, hypothesis testing could proceed. The hypothesis testing aims to determine whether (1) there is a difference in the effect of the brain-based learning model with cultural context on students' critical thinking skills and self-efficacy, and (2) there is an increase in students' critical thinking skills and self-efficacy before and after instruction using the brain-based learning model with cultural context. The results of the simultaneous MANOVA test are presented in Table 5.

Table 5. The results of the simultaneous MANOVA test

Multivariate $Test^a$

Effect		Value	F	Hypothesis df	Error df	Sig.	Observed Power
Learning model	Pillai's Trace	0.173	6.385^b	2.000	61.000	0.003	0.887
	Wilks' Lambda	0.827	6.385^b	2.000	61.000	0.003	0.887
	Hotelling's Trace	0.209	6.385^b	2.000	61.000	0.003	0.887
	Roy's Largest Root	0.209	6.385^b	2.000	61.000	0.003	0.887

The individual MANOVA test confirms the differences in the application of learning models for each dependent variable. Table 6 summarizes the results of this analysis for each variable separately.

Table 6. The results of the individual MANOVA test

Test of Between-Subjects Effect							
Source	Dependent Variable	Type III Sum of Square	df	Mean Square	F	Sig.	Observed Power
Learning model	Critical thinking skills	322.876	1	322.876	4.276	0.043	0.530
	Self-Efficacy	415.141	1	415.141	12.214	0.001	0.931

Table 6 presents the results of the individual MANOVA test, which aims to evaluate the effect on each dependent variable. The results indicate a significant difference in critical thinking skills between students in the experimental and control classes ($p < 0.05$), meaning that the brain-based learning model with cultural context has an effect on students' critical thinking skills. The impact of a brain-based learning model with cultural context on critical thinking skills is 0.530, which falls within the moderate category. Table 1 shows that the post-test score for critical thinking skills in the experimental class (70.59) is higher than the post-test score in the control class (58.74).

Additionally, the brain-based learning model with cultural context positively impacts self-efficacy ($p < 0.05$), indicating a difference in self-efficacy between students taught using the brain-based learning model with cultural context and those using the conventional learning model. The influence magnitude of the brain-based learning model with cultural context on self-efficacy is 0.931, categorized as high. As shown in Table 1, the post-test self-efficacy score in the experimental class (80.65) is higher than the post-test score in the control class (68.15). The paired sample t-test was used to test the second hypothesis, with the analysis based on pre-test and post-test data in the experimental class. The results are shown in Table 7.

Table 7. Paired sample t-test on the experimental class

		Mean	**Std. Deviation**	**t**	**df**	**Sig. (2-tailed)**
Pair 1	Critical thinking skill PostTest - Critical thinking skill PreTest	17.09559	13.26350	7.516	33	.000
Pair 2	PostTest_SE - PreTest_SE	18.88235	6.36641	17.294	33	000

Table 7 presents four measures—Pillai's Trace, Wilks' Lambda, Hotelling's Trace, and Roy's Largest Root—that assess the overall differences in the impact of the learning models on critical thinking skills and self-efficacy. The results indicate that applying the brain-based learning model with cultural context significantly affects critical thinking skills and self-efficacy compared to the conventional model ($p < 0.05$). The values in the Observed Power column reflect the probability of detecting significant differences in critical thinking skills and self-efficacy due to variations in the model application. The results in Table 7 also reveal a difference magnitude of 0.887 between the brain-based learning model with cultural context and the conventional model, showing a high enough power to detect significant effects of the learning models on the tested variables. This evidence supports the hypothesis regarding the differential impact of the brain-based learning model with cultural context on students' critical thinking skills and self-efficacy.

The results of the paired sample t-test indicate that applying the Critical thinking skill model with a cultural context significantly improved students' critical thinking skills and self-efficacy. In Pair 1, which compared critical thinking skills before and after the model's application, there was a mean difference of 17.10. This positive mean difference reflects an increase from the pretest to the posttest scores, demonstrating higher critical thinking performance after the model's application. This difference is statistically significant, underscoring the positive impact of the brain-based learning model on critical thinking skills ($t = 7.516$, $p < 0.05$). In Pair 2, comparing self-efficacy before and after the model's application, there was a mean difference of 18.88, indicating an increase in self-efficacy scores post-intervention. This increase is statistically significant ($t = 17.294$, $p < 0.05$), highlighting the role of the brain-based learning model with cultural context in enhancing students' self-efficacy.

Overall, these results demonstrate the effectiveness of this learning model in developing students' critical thinking skills and self-confidence within the learning process. The results in Table 7 confirm the hypothesis that students' critical thinking skills and self-efficacy improved after applying a brain-based learning model with a cultural context.

Culture significantly influences individuals, fostering confidence in achieving their goals. The cultural context in this study focuses on the Mandailing culture, an indigenous culture of North Sumatra that is widely recognized among the region's people. Figure 1 illustrates an example from this study's culturally based mathematics learning material.

Figure 1. Books in cultural context

This book uses a cultural context that is close to students' lives. Mathematics material is presented using ornaments with ulos cloth motifs, a beautiful traditional fabric from North Sumatra. The ulos motifs are used to illustrate plane geometry, enriching the context of the mathematics being studied. The student worksheets also feature cultural elements, including motivational slogans that emphasize persistence and resilience in the face of challenges, supporting the development of self-efficacy in mathematics learning. Figure 2 shows the format of the student worksheet used in this learning approach.

The brain-based learning model with a cultural context enhances students' self-efficacy by aligning the brain-based learning model with cultural elements that resonate with students' natural cognitive functions. It fosters active and meaningful learning experiences for students, which can ultimately improve their self-efficacy. This finding aligns with research by Rusyda, Suherman, Suhendra, and Rusdinal (2020), which shows increased self-efficacy among students taught using the brain-based learning model. Brain-based learning model facilitates students in enhancing their self-efficacy through its stages. Overall, the stages within the brain-based learning model positively impact students' self-efficacy. In particular, the pre-exposure stage is critical, as it reinforces students' confidence by setting positive expectations and encouraging them to set goals to achieve by the end of the session.

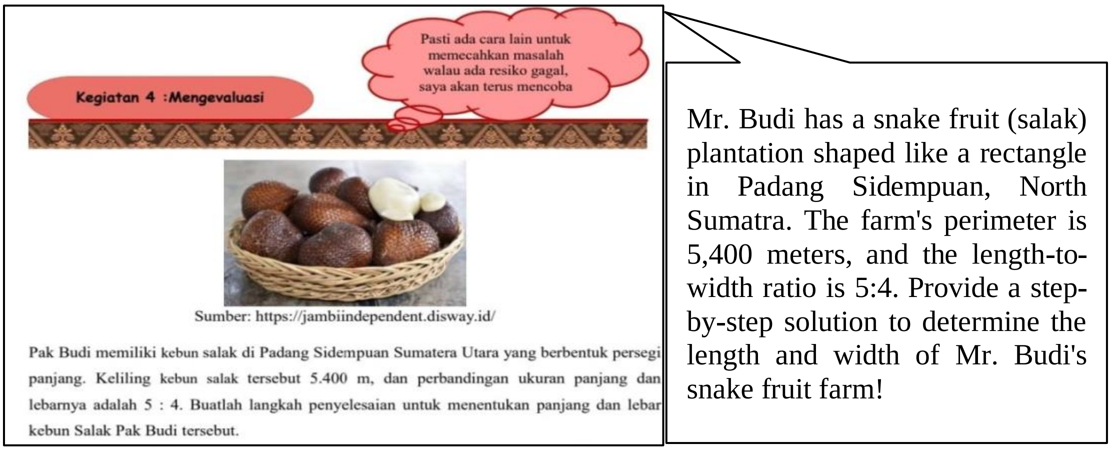

Figure 2. The student worksheet based on culture and self-efficacy

Njega Njoka and Ndung'u (2019) also emphasized a strong positive correlation between self-efficacy and students' learning abilities. This finding is further supported by Ugwuanyi, Okeke, and Asomugha (2020), who highlight self-efficacy as a key psychological factor in students' success in mathematics, suggesting that academic achievement is closely linked to self-efficacy. Furthermore, Sukoco and Mahmudi (2016) noted that the teacher's role in the brain-based learning model is dual—as a facilitator and a motivator, guiding students in problem-solving strategies. Consequently, the brain-based learning model can facilitate students in improving their self-efficacy, particularly through performance experiences, vicarious experiences from peers or teachers, and verbal/social encouragement from teachers.

The brain-based learning model with a cultural context positively impacts students' self-efficacy. Integrating cultural elements in classroom activities provides meaningful benefits, making concepts more relevant to students' lives and allowing them to engage deeply with cultural ideas. Combined with a brain-based learning model, this concept significantly enhances students' critical thinking skills and self-efficacy. The concepts introduced closely relate to students' lives, allowing them to explore cultural horizons more intimately. Moreover, using motivational statements in student worksheets can instill confidence in students. As a result, students become more motivated and enthusiastic about solving problems, directly correlating with their critical thinking abilities.

Research on cultural integration in learning has gained considerable attention, as connecting students' real-life experiences, such as their cultural backgrounds, can motivate them to learn. Previous studies (Husin, Wiyanto & Darsono, 2018; Kurniasari, Puspitasari, & Mutiara, 2023) that integrate learning materials with cultural contexts can enhance students' interest and learning outcomes. This evidence indicates that activating both hemispheres of the brain while incorporating cultural elements into the curriculum significantly improves students' critical thinking skills and self-efficacy.

Conclusion

This study demonstrates that a brain-based learning model with a cultural context effectively improves students' critical thinking skills and self-efficacy. The data analysis reveals several key findings that support this conclusion. First, the brain-based learning model with cultural context significantly enhances students' critical thinking skills and self-efficacy. This suggests that integrating cultural elements into the learning process can foster deeper cognitive and emotional engagement, supporting critical thinking development. Second, there is a noticeable improvement in students' critical thinking skills and self-efficacy before and after implementing a culturally relevant brain-based learning model. This effect highlights that, in addition to enhancing critical thinking, students' confidence in their ability to tackle mathematical tasks is also strengthened. When students perceive that the learning process is directly connected to their culture and daily life experiences, their confidence in facing academic challenges increases.

As a practical implication, this study recommends that teachers incorporate cultural context into the learning process and select teaching models that optimize left and right brain functions. However, this study has several limitations, including the cultural context's potential inability to represent the full diversity of students' backgrounds, limited generalizability due to the specific sample, the short duration of the intervention, and the use of a relatively simple self-efficacy measurement instrument. Therefore, these findings are intended to serve as a foundation for future research on culture-based learning to further support students' cognitive and emotional engagement in mathematics education.

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