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Cultural connections: How culturally responsive teaching transforms mathematical learning

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Abstract: Culturally Responsive Teaching (CRT) integrates students' backgrounds and experiences into the educational process to foster an inclusive and relatable learning environment. This study evaluates the impact of the CRT method on students' mathematics proficiency levels. A quasi-experimental design was employed, involving two instructional phases to assess math abilities before and after applying CRT with 70 eighth-grade students. The data were analyzed using the Wilcoxon Signed-Rank Test to compare test results across evaluation cycles. The findings showed a significant enhancement in students' skills, with the average score increasing from 67.12 in the first cycle to 75.35 in the second. A substantial effect size of 5.11 highlights the effectiveness of CRT in improving mathematical abilities. These findings suggest that CRT not only boosts performance but also narrows achievement gaps among students. By connecting mathematical concepts to students' cultural contexts, CRT enhances comprehension and fosters deeper learning experiences. This study advocates for inclusive curriculum designs that consider student diversity while emphasizing the importance of training educators to implement CRT strategies effectively.

Keywords: *Culturally responsive teaching, Mathematics skills, Culture, Education.*

1. Introduction

In recent decades, there has been a paradigm shift in education, particularly in teaching that accommodates students' cultural diversity. As global mobility and cultural diversity increase in classrooms, educators' challenges are increasingly complex. In many countries, schools are faced with student populations that are culturally, ethnically, linguistically, and socioeconomically diverse [1]. This calls for learning approaches that can address the needs of all students without ignoring their cultural identity. One approach that has emerged as an innovative solution is Culturally Responsive Teaching (CRT).

Culturally Responsive Teaching (CRT), as defined by Gay [2] is a pedagogical approach that consciously integrates students' cultures, experiences, and perspectives into the learning process. It is about understanding that students come from different backgrounds and how educators can use those differences to enrich learning. Research in the past five years has shown that CRT can improve learning motivation, student engagement, and academic outcomes [3, 4].

In the context of learning mathematics, many students need help understanding abstract concepts presented in the traditional curriculum. Students from different cultural backgrounds often feel the material is irrelevant to their daily lives, so they are less motivated to learn. CRT offers a different approach by linking mathematics learning materials to students' cultural contexts, making them feel more connected to what they are learning [5]. Furthermore, research shows that approaching culture can create an inclusive learning environment where all students feel accepted and valued. According to

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[6] the success of CRT in improving student learning outcomes depends on the extent to which educators can integrate cultural knowledge into teaching. This can be done in mathematics using contextual problems relevant to students' life experiences. For example, research by Sleeter and Carmona [7] showed that students who learned math in their cultural context significantly improved concept understanding. By using math problems that reflect students' cultural environment and daily lives, they can better connect abstract concepts and real situations with which they are familiar. This bridges students' experiences and math learning, often perceived as complex and isolated from the real world. However, the application of CRT in mathematics teaching has yet to be widely practiced, especially in schools with student populations with homogeneous cultural backgrounds. Some educators must still learn how to implement CRT in the mathematics curriculum effectively. Gay [2] emphasized that teacher training in implementing culturally sensitive approaches is critical to the success of CRT. Teachers need to be trained to understand their students' cultural backgrounds and how to use that knowledge in lesson design.

Research by Hammond [8] also highlights the importance of developing cultural awareness among teachers. Teachers who are aware of the importance of cultural sensitivity tend to be more successful in teaching students from diverse backgrounds. In addition, Hammond [8] also found that teachers who have a deep understanding of CRT are more likely to create an inclusive and collaborative classroom environment, which is indispensable in learning mathematics that requires cooperation and discussion.

In Indonesia, the challenges of teaching mathematics in primary and secondary schools are also influenced by the cultural diversity of students. Along with demographic changes and technological developments, today's students face more challenges in understanding mathematical concepts. Therefore, teaching approaches sensitive to the local cultural context are expected to bridge the understanding gap. Research conducted in Indonesia [9] found the CRT approach has a positive effect on students' activeness in participating in learning and students' learning outcomes. Another study by Rahayu, et al. [10] confirmed that implementing CRT can improve learning outcomes and students' activity. Students who learn in their cultural context feel more confident and motivated to learn as they see the relevance of the material to their daily lives. In this study, using folklore and traditional games in teaching mathematics proved effective in helping students understand difficult concepts.

In addition, the challenges of teaching mathematics in culturally diverse environments also include the use of language. According to Mustafa, et al. [11] the language used in teaching mathematics is often a barrier for students from different language backgrounds. CRT offers a solution by allowing teachers to use students' everyday language to explain mathematical concepts. This not only helps students understand but also respects their linguistic identity. More recent research by Hammond [8] suggests that a critical aspect of CRT is the teacher's ability to understand and respond to students' different learning styles. Students may have other ways of processing information and solving problems in a diverse classroom. Teachers who implement CRT tend to be more flexible in their teaching methods, using various strategies to meet the needs of different students. In mathematics, teachers can use various approaches such as visualization, manipulatives, and digital technology to accommodate multiple learning styles. These approaches make learning more interesting and allow students to learn in the way that suits them best. A concrete example of using CRT in math learning, for example, is teaching the concept of fractions in a Traditional Food Context. The teacher teaches fractions using traditional cakes such as "layer cakes." Students are asked to divide the layer cake into equal parts. If one layer of cake is cut into eight layers, each layer represents $\frac{1}{8}$ of the whole cake. The teacher can then ask, "If we eat three layers, what fraction of the whole cake has been eaten?" The answer is $\frac{3}{8}$. Amidst these developments, many education systems worldwide are beginning to adopt CRT approaches as part of educational reform. For example, schools in urban areas with multicultural student populations have implemented CRT positively in the United States. Research by Hammond [8] shows that schools that adopted this approach experienced significant improvements in academic achievement, especially in subjects such as math and science.

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Within this framework, this study focuses on the effect of CRT on students' mathematical skills in primary school. The main objective of this study was to measure the extent to which this approach can improve students' understanding of the mathematical concepts being taught. By analyzing the significant differences between cycle 1 and cycle 2 in mathematics test results, this study provides insight into the effectiveness of CRT in the Indonesian educational context. Math skills are often one of the biggest challenges for students, especially those from culturally diverse backgrounds. Traditional approaches usually address the specific needs of students from different cultures. CRT emerged as an approach that integrates students' cultural backgrounds into the learning process, hoping to increase their engagement and understanding of the subject, including mathematics [2]. Some studies have shown that CRT can improve student learning outcomes [3] but more research is needed on how this approach can affect specific math skills. Based on this background, this study aims to examine the effect of the CRT approach on students' math skills. This study aims to measure the impact of the Culturally Responsive Teaching approach on students' mathematics skills and to understand how significant the improvement achieved after implementing this approach is.

2. Literature Review

Culturally Responsive Teaching (CRT) is a pedagogical approach that considers students' cultural backgrounds as part of the learning process. Gay [2] defines CRT as a strategy that places students' lived experiences, language, and culture as the primary foundation in curriculum development and teaching methods. This approach effectively improves student engagement and learning outcomes, especially in culturally heterogeneous environments [3].

The Culturally Responsive Teaching (CRT) approach has been widely applied as an effective strategy to address education needs in multicultural environments. According to Paris and Alim [3] CRT emphasizes connecting students' cultural context with the subject matter. This is important because many students from different cultural backgrounds often feel they must be more represented in the traditional curriculum. CRT seeks to make students' culture an integral part of the learning process, ultimately increasing their engagement in learning [4]. One of the main aspects of CRT is the recognition of different ways of learning that are influenced by culture. Hammond [8] points out that students from different cultural backgrounds often have different ways of processing information, making a one-size-fits-all approach ineffective. The CRT approach allows teachers to customize their teaching methods according to students' learning styles so that each student can reach their maximum potential.

Research by Sleeter and Carmona [7] confirms that in CRT, teachers are not only tasked with delivering knowledge but also become facilitators who help students relate new knowledge to their cultural experiences. In other words, teachers bridge students' culture and curriculum content, which is often overlooked in conventional teaching methods. This is particularly relevant in teaching mathematics, where abstract concepts can be more easily understood if they are linked to contexts that are familiar to students.

Mathematics is often considered a universal subject, but culture influences teaching heavily [5] suggesting that mathematical concepts can be taught more meaningfully if adapted to students' life experiences. Mathematics teaching based on the CRT approach focuses on more than just the delivery of mathematical facts but also on how the concepts are relevant to students' daily lives. Hammond [8] also emphasized that a culture-centered approach to mathematics teaching can help students understand abstract concepts better. Teachers can use examples relevant to students' cultural backgrounds in this case. For example, for students who grow up in farming communities, the concepts of percentage and proportion can be taught using examples of harvesting or distributing agricultural products. In addition, Ladson-Billings [4] pointed out that mathematics teaching using the CRT approach also plays an important role in strengthening students' cultural identity. When students see that their culture is valued in learning, they are more motivated to participate actively in the learning process. Furthermore,

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they tend to develop a sense of ownership of their knowledge, positively impacting long-term learning outcomes.

Literature reviews on the influence of the CRT approach in education, particularly in mathematics learning, have shown that applying this strategy has great potential to improve student learning outcomes. In Indonesia, the implementation of culture-based education is gaining attention as an effort to accommodate the diversity of student backgrounds. As a country with various cultures, approaches that consider the uniqueness of local cultures in learning can significantly impact student engagement and to improve students' mathematical communication skills [12]. According to research by Wulandari, et al. [13] implementing contextual learning that integrates local culture in mathematics classes will elicit a positive sensation that ignites excitement and impacts the learning process and outcomes. In the study, using folklore and examples of daily life related to local culture can make it easier for students to understand abstract mathematical concepts. This aligns with the CRT principle, where cultural relevance in teaching materials can help bridge students' understanding gaps.

Some research in Indonesia also shows that CRT can serve as a means to improve inclusiveness in education. For example, Greer, et al. [14] showed that implementing culture-based learning helped students from low economic backgrounds be more engaged in mathematics learning. They found that students who engaged in culturally relevant learning were more motivated and showed significant improvement in learning outcomes compared to traditional learning methods. Research by [15] supports the effectiveness of the CRT approach in improving critical thinking and problem-solving skills. The CRT is relevant for social science-related subjects and significantly impacts STEM fields, including mathematics. By presenting cultural context in teaching materials, students can more easily understand complex concepts through an approach closer to their lives. In addition, a study by Kurniawati and Taufiq [16] found that applying CRT that links mathematics learning with the local cultural and environmental context can effectively increase students' self-confidence in learning mathematics materials. Using examples and problems relevant to students' culture, they feel more valued and recognized. This increases active participation in the class and makes the learning process more enjoyable. CRT helps to create an inclusive learning atmosphere and fosters a sense of ownership in students towards learning.

Recent studies have shown that CRT impacts student engagement and improves cognitive skills, including critical thinking and problem-solving skills. According to Alim, et al. [17] when students feel that their cultural experiences are recognized and valued, they are more motivated to develop their cognitive abilities. This is especially important in mathematics, where problem-solving skills are indispensable. The research results of Hammond [8] show that students who learn in their cultural context tend to process information better and more meaningfully. They not only learn to memorize concepts but also relate them to real situations they encounter in their daily lives. This helps students in developing a deeper and more sustainable understanding. Research by Paris and Alim [3] highlighted that CRT can improve students' academic outcomes by assisting them to connect academic material with their cultural experiences. In this case, students' cognitive skills develop faster as they learn new concepts and how to apply them in relevant contexts. This approach improves students' ability to think critically and solve problems, two important skills needed in learning mathematics.

According to Ladson-Billings [4] one of the main challenges in implementing CRT is the need for more integration between this approach and the existing standard curriculum. The mathematics curriculum often needs to allow flexibility in accommodating students' cultural needs. Therefore, educators must innovate in developing curricula more responsive to students' needs. Sleeter and Carmona [7] asserts that although CRT is effective, its success depends mainly on how much teachers can integrate it into the existing curriculum. Teachers must be free to adapt the curriculum to make it more relevant to students' culture. In addition, support from more inclusive education policies is needed to ensure that CRT can be widely implemented in various educational institutions. However, several researchers also recognize the challenges of implementing CRT in Indonesia. Anuas, et al. [18] stated that could not be implemented effectively due to inadequate teacher knowledge. Limited teacher

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training is one of the main obstacles. Many teachers still need to receive special training on how to integrate cultural elements into learning effectively. As a result, the implementation of CRT still needs to be improved, and the results vary between schools.

The support from the school environment, such as the availability of resources and supportive school policies, plays a significant role in successfully implementing CRT. Schools that provide teaching materials integrated with local culture and opportunities for teachers to participate in training tend to be more successful in implementing CRT than schools that do not offer such support. Regarding education policy, the Indonesian government has encouraged the development of curricula that are more inclusive and responsive to student diversity. Curriculum 2013, for example, emphasizes the importance of contextual and culture-based learning. However, its implementation in the field still needs to be improved, including teacher readiness and limited resources. Jayadi, et al. [19] showed that collaboration between schools and local communities can increase the effectiveness of CRT implementation. Involving the community in developing teaching materials relevant to local culture can enrich the learning process and contextualize learning. Thus, CRT implementation improves academic outcomes and strengthens the link between education and local culture. The literature in the last five years shows that CRT has excellent potential to be implemented in Indonesia, especially in improving students' mathematics learning outcomes. However, successful implementation is highly dependent on teacher readiness, policy support, and the availability of adequate resources. Therefore, continued efforts are needed to overcome these challenges and ensure that education in Indonesia can be more inclusive and relevant to students' needs.

3. Research Methods

3.1. Research Design

This study used a quasi-experimental design with two learning cycles. This design was chosen to measure students' math skills before and after implementing the Culturally Responsive Teaching (CRT) approach. Each cycle involved measuring math skills through formative tests conducted before and after the intervention. The data was analyzed to see if there was a significant difference between the two cycles.

3.2. Population and Sample

The population in this study was class VIII students from two purposively selected junior high schools. The sample size was 70 students taken from two different classes. Each student was measured twice (in cycle 1 and cycle 2), with the CRT approach applied in both cycles. The purposive sampling technique was used to select students based on specific criteria set by the research objectives.

3.3. Instrument

The main instrument used was the math skills test, designed to measure students' understanding of the math concepts taught. Each test consisted of questions covering various aspects of math skills, such as understanding basic concepts, applying concepts in everyday situations, and problem-solving. In addition, observations of student engagement during the learning process were made to complement the quantitative data.

3.4. Data Collection Technique

Data were collected through math skills tests at the end of each cycle. The math skills test was given to students at the end of each cycle, while observations were made during the learning process to see how the CRT approach affected student engagement. Data collection was done directly in the classroom with teacher assistance.

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3.5. Data Analysis Technique

The data obtained were analyzed using the Wilcoxon Signed-Rank Test to measure significant differences between cycle 1 and cycle 2. The Wilcoxon test was chosen because the data were not normally distributed, based on the normality test results (Shapiro-Wilk). This test aimed to determine whether the application of CRT significantly improved students' math skills between the two cycles.

3.6. Validity

The instrument's validity was tested using content validity, involving mathematics education and pedagogy experts, to ensure that the test questions met the desired learning objectives.

4. Research Results

Before the research was implemented, validity and reliability tests were conducted on the instruments. The validity test aims to ensure that the research instrument, in this case, the math skills test, actually measures what it is supposed to measure. In the context of this study, the validity test was conducted to ensure that the mathematics test accurately measured students' understanding of mathematics concepts taught with the Culturally Responsive Teaching (CRT) approach. The validity test uses a content validity approach. The steps in the content validity test are as follows: 1) Consultation with experts: The experts involved are math subject teachers. In content validity, these experts will ensure that all important aspects of the math skills being taught are covered in the test. 2) Relevance of the Materials: The expert evaluated each item to determine whether the questions were relevant to the learning objectives, especially the CRT approach of linking the mathematics materials to students' cultural backgrounds. 3) Adequacy of Coverage: In addition to relevance, the expert also assesses whether the item coverage includes all the important elements of the math skills to be measured. If parts of the material have yet to be measured, additional items can be developed. 4) Instrument Revision: Based on expert feedback, test items may need to be revised, improved, or added to make them more valid in measuring student understanding. Thus, the test instrument measures the mathematical concepts taught and is relevant to the research objectives.

This study's results focused on comparing students' math skills between Cycle 1 and Cycle 2 after the implementation of CRT. Data collected from 70 students were analyzed using the Wilcoxon Signed-Rank Test to test for significant differences between the two cycles. Based on the results of the descriptive analysis, the students' average scores experienced a significant increase. In Cycle 1, the average student score was 67.12; in Cycle 2, the average score increased to 75.35. This increase indicates a positive change in students' math skills after applying CRT. This score increase indicates that implementing culture-based learning strategies successfully improved students' understanding of mathematics materials.

Table 1.
Descriptive Statistics Data Analysis.

Statistic	Cycle 1 (Formative)	Cycle 2 (Formative)
Mean	67.12	75.35
Std Dev	18.51	14.30
Min	41.6	50.0
Max	100.0	100.0

In Cycle 1, the student's average score was 67.12; in Cycle 2, it increased to 75.35. This increase indicates a positive change in students' math skills after implementing Culturally Responsive Teaching (CRT). This increase in mean scores indicates that the culture-based learning strategy improved students' understanding of mathematics materials. The standard deviation in Cycle 1 was 18.51, indicating a more significant variation in student scores, meaning a significant difference between low and high-scoring students. In Cycle 2, the standard deviation decreased to 14.30, indicating that the

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variation in scores between students became smaller. This means that students' results were more uniform after the implementation of CRT, and fewer students scored significantly below or above the average. In Cycle 1, the minimum score achieved by students was 41.6, indicating that some students had significant difficulties understanding the material. After the implementation of CRT, the minimum score in Cycle 2 increased to 50.0, indicating that the lowest-scoring students also improved significantly. This shows that the CRT helped students struggling with understanding the material to achieve a better level of understanding. The maximum score in both cycles remained 100.0, indicating that some students already had a very good knowledge of the math material even before the implementation of the CRT. However, the consistency of these maximum scores suggests that CRT did not detract from the performance of already good students but helped students who were more in need.

The table above shows that after implementing Culturally Responsive Teaching (CRT) in Cycle 2, students' math skills significantly improved. The mean score increased, the variation in scores decreased, and the minimum score increased, indicating that the CRT approach improved students' general skills and narrowed the gap between high and low-achieving students.

Furthermore, to measure the significant difference between cycle 1 and cycle 2, the Wilcoxon Signed-Rank Test was used to measure whether there is a significant difference in the distribution of scores between the two cycles. The hypotheses tested were:

> Null Hypothesis (H_0): There is no significant difference between students' scores in Cycle 1 and Cycle 2 after implementing Culturally Responsive Teaching (CRT). In other words, applying CRT does not significantly impact students' math skills.
>
> Alternative Hypothesis (H_1): A significant difference exists between students' Cycle 1 and 2 scores. This indicates that the application of CRT significantly affects students' mathematical skills.

The Shapiro-Wilk Test results for normality show a test statistic of 0.957 with a p-value of 0.017. Since the p-value is smaller than 0.05, we reject the null hypothesis that the score difference data is normally distributed. That is, the distribution of the score difference between "Formative Cycle 1" and "Formative Cycle 2" does not follow a normal distribution, which supports the use of the Wilcoxon Test as an appropriate approach for analyzing this data.

In the Wilcoxon test, each pair of data (student scores in Cycle 1 and Cycle 2) was compared. The difference between the scores in the two cycles is calculated for each student; then, the differences are ranked in order of magnitude. After that, a positive or negative sign was given based on whether the score in Cycle 2 was greater or less than in Cycle 1. The sum of the positive and negative ratings was then analyzed to determine if there was a significant difference. The Wilcoxon Test results for this study showed that:

Test Statistic = 357.5
p-value = 0.004

Since the p-value is much smaller than 0.05, we reject the null hypothesis (H_0) and accept the alternative hypothesis (H_1). In other words, there is a significant difference between students' scores in Cycle 1 and Cycle 2. The application of CRT has a significant effect on improving students' math skills.

The test results show a p-value of 0.004, smaller than the commonly used significance level (usually 0.05). Thus, we reject the null hypothesis (which states that there is no difference between the two cycles) and accept the alternative hypothesis (which states that there is a significant difference). In practical terms, this indicates that the scores on the "Cycle 1 Formative" and "Cycle 2 Formative" are significantly different. That is, there is a meaningful change in the scores between the two cycles,

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possibly due to the intervention, the change in the learning method, or other factors that affected the test results.

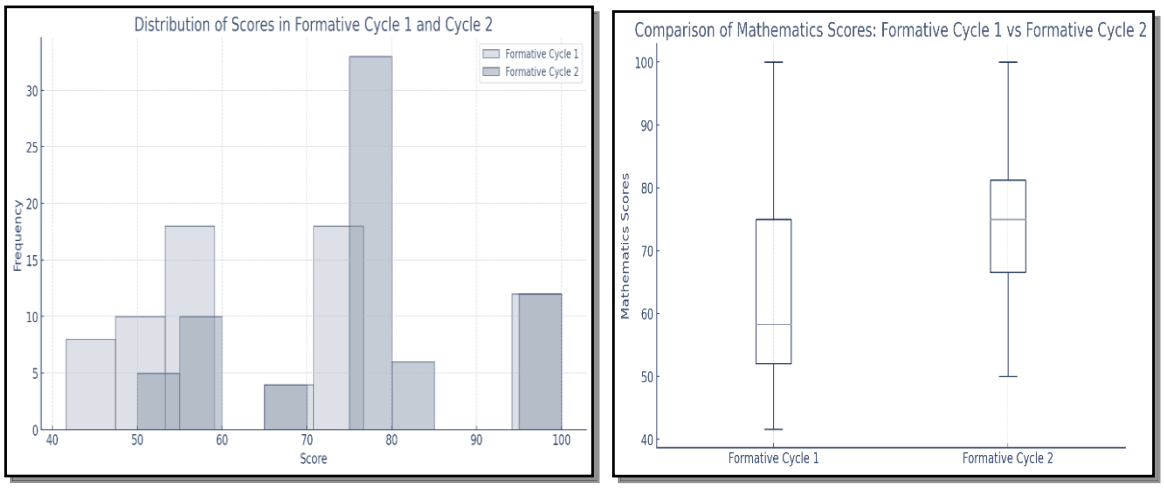

Figure 1.
Comparison of Cycle 1 and Cycle 2 Math Scores.

The figure above shows the distribution of scores for "Formative Cycle 1" and "Formative Cycle 2." This histogram shows the frequency of scores in both cycles. By comparing the distributions, we can see if there is a change in the pattern of scores between Cycle 1 and Cycle 2, such as a shift to higher or lower scores. From the histogram, the distributions of the two cycles are not identical, which supports the Wilcoxon Test results that there is a significant difference between the two cycles.

Furthermore, to calculate the effectiveness of the effect of the CRT approach, we can use effect sizes, such as r (Wilcoxon effect size), which is calculated by the formula:

$$r = \frac{z}{\sqrt{N}}$$

Z is the Wilcoxon test statistic converted to the Z score, and N is the total number of observations. The calculated effect size, $r = 5.11$, indicates a considerable effect of implementing the CRT approach on students' math skills. Usually, a value of $r > 0.5$ is considered a significant effect. In this case, the result is well above that threshold, indicating that the CRT approach significantly improved students' mathematics performance.

Effect size is a quantitative indicator of how much influence or impact a treatment or intervention has on a particular variable. In the context of the Wilcoxon Test, the effect size r indicates the magnitude of the change in scores from one condition to another. The general interpretation for the effect size r is as follows:

$$r < 0.1: \text{Very small effect}$$
$$0.1 \leq r < 0.3: \text{Small effect}$$
$$0.3 \leq r < 0.5: \text{Moderate effect}$$
$$r \geq 0.5: \text{Large effect}$$

In this analysis, the value of $r = 5.11$ is well above 0.5, which means that the influence of the CRT approach on students' math skills is very large. This indicates that the application of CRT has a statistically significant impact and real and strong practical implications in improving students' math skills. In other words, the approach effectively enhanced students' learning outcomes with meaningful changes in the scores between "Formative Cycle 1" and "Formative Cycle 2". Based on the Wilcoxon Test results, the implementation of CRT significantly impacted students' math skills. The significant

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improvement between the scores in Cycle 1 and Cycle 2 shows that this culture-based learning strategy not only helps improve students' understanding in general but also improves the results of students who have difficulties in mathematics.

5. Discussion

This study's results indicate that applying the CRT approach significantly improves students' math skills. The Wilcoxon Signed-Rank Test results showed a significant difference between the math scores on the "Cycle 1 Formative" and "Cycle 2 Formative," with a p-value of 0.004. The effectiveness of this approach is reflected in the effect size of $r = 5.11$, which indicates a significant effect. The average increase of 8.22 in math scores indicates the positive impact of CRT in improving student learning outcomes.

The CRT approach is a pedagogical strategy emphasizing the importance of linking subject matter to students' cultural experiences and backgrounds. According to Gay [2] CRT can create an inclusive and relevant learning environment, thus motivating students to engage more actively in learning. Applying this approach in mathematics allows students to understand abstract concepts through a context that is closer to their daily experiences, which can improve understanding and academic achievement.

The results of the normality test show that the distribution of score differences does not follow a normal distribution pattern, which supports the use of the Wilcoxon Test. This is important because non-parametric statistical techniques such as the Wilcoxon Test are more appropriate for data that are not normally distributed. This finding aligns with other research showing that contextual and culture-based approaches can overcome students' learning ies in understanding mathematical concepts [6]. Overall, 51 students experienced significant changes in their math scores, either increased or decreased. This reflects that the effect of CRT was not uniform for all students, and there was variation in the response to this approach. Nonetheless, the average results showed a consistent positive trend in improving students' overall scores. This suggests that CRT serves as a tool to improve test scores but can also increase student engagement in the learning process.

The relatively large standard deviation of the difference (21.09) indicates considerable variation in the change in students' scores. According to Hammond [8] the effectiveness of CRT is greatly influenced by how teachers integrate cultural content into lessons. Learning outcomes will likely be optimal if teachers connect strongly with the subject matter and the student's cultural background. Thus, teacher training in applying CRT is crucial to ensure the success of this approach. In this case, the effectiveness of the CRT approach can be explained by the theory of constructivism, which emphasizes that learning occurs when students can relate new knowledge to previous experiences or knowledge. Vygotsky's theory of the zone of proximal development (ZPD) is also relevant, where students learn better when they get support from teachers or more experienced peers. CRT can facilitate this process by providing relevant cultural context to bridge the material being taught and students' understanding.

The results of this study are also relevant to Ladson-Billings [4] findings that CRT can improve learning outcomes for students from diverse backgrounds, especially for students who often experience academic gaps. Using cultural context as a frame of reference allows students to see the relevance of the subject matter in their lives, thus increasing motivation and engagement in learning.

This research has significant practical implications, especially in education policies that increasingly emphasize the importance of inclusive education that is responsive to students' needs. Implementing CRT can be one strategy to address the academic achievement gap and ensure that all students have equal opportunities to succeed. However, challenges in its implementation include the need for adequate teacher training and sufficient resource support. The non-normal distribution of score differences also suggests that not all students benefit equally from implementing CRT. According to Nieto [20] the effectiveness of CRT may differ depending on various factors, including teachers' skills, students' backgrounds, and support from the school environment. Therefore, CRT implementation requires a flexible approach and is tailored to the specific conditions of each school and classroom. The histogram

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results showing the variation in score differences confirm that although the average improvement is positive, several students may require additional approaches to achieve optimal learning outcomes. Research by Howard [21] shows that a practical CRT approach requires continuous evaluation and adjustment based on feedback from students and learning outcomes obtained.

Theoretically, CRT can significantly contribute to learning theories emphasizing context-based learning and cultural relevance. By linking subject matter to students' life experiences, CRT can facilitate deeper understanding and more effective knowledge transfer. This is supported by recent research that found that culture-based approaches can improve critical thinking and problem-solving skills in STEM subjects, including mathematics [22]. This research also provides a strong foundation for curriculum development that is more inclusive and responsive to student diversity. Educators can help students build meaningful connections between classroom learning and everyday life by integrating culturally relevant elements into the subject matter. This aligns with educational approaches focusing on lifelong learning and developing 21st-century competencies.

In conclusion, this study's results support the effectiveness of the CRT approach in improving students' mathematical skills. The findings suggest that CRT not only contributes to the improvement of test scores but also to the formation of positive attitudes toward learning mathematics. Thus, this approach can be one solution to improving education quality amid greater cultural diversity. The effect of the CRT approach on students' mathematical skills is significant in improving concept understanding and analytical skills. Applying CRT, which integrates cultural elements into mathematics learning, can help students understand abstract concepts more quickly. Research by Hartono, et al. [23] found that using mathematical examples relevant to the local cultural context can improve students' ability to understand complex mathematical problems because students more easily relate mathematical concepts to their daily experiences. CRT is also important in increasing students' motivation to learn mathematics, which is often difficult. When students feel that the material being taught is relevant to their culture and life, they tend to be more motivated to learn and actively engage in the learning process. Prasetyo and Handayani [24] showed that implementing a culture-based approach to mathematics learning can reduce students' learning anxiety and increase positive attitudes toward this subject. This higher motivation ultimately contributes to improved learning outcomes.

The CRT helps develop critical thinking and problem-solving skills in a mathematical context. By presenting relevant cultural contexts, students can be trained to analyze real situations and apply mathematical concepts to solve problems. According to Yulia, et al. [25] cultural integration in mathematics teaching encourages students to develop logical and analytical thinking skills, which are essential in mathematics education. Thus, CRT impacts academic achievement and enriches students' life skills. Using CRT in mathematics learning also positively impacts the inclusivity and participation of students from diverse backgrounds. By valuing and integrating cultural diversity in the classroom, CRT provides a fairer opportunity for all students to participate and succeed. Rahmawati, et al. [26] found that students from underrepresented groups showed significant improvement in math achievement after the implementation of CRT, as they felt more valued and supported in the learning process.

Improving the effectiveness of CRT requires an integrated and sustainable approach involving various aspects of education, such as teacher training, policy support, and community involvement. Here are some strategies to improve the effectiveness of CRT, namely: 1) Continuous Teacher Training. Teachers should have ongoing training in CRT implementation. This training should include understanding cultural diversity, integrating culture into teaching materials, and strategies for creating an inclusive classroom environment. Research by Ebersole, et al. [27] showed that teachers who received ongoing training on CRT had better skills in connecting subject matter to students' cultural backgrounds, positively impacting engagement and learning outcomes. 2) Provision of Culturally Based Learning Resources. Improving access to culturally-based learning resources can help teachers implement CRT. These resources can be books, multimedia, or other teaching materials that contain local cultural content or student experiences. The availability of learning resources relevant to students'

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cultural backgrounds can increase learning motivation, as students feel that their experiences are valued and made part of the learning process. 3) Community Engagement in Education. Involving communities in the learning process can increase the cultural relevance of teaching materials and make learning more meaningful for students. Research by Peng and Abd Rahman [28] found that collaboration with local communities, such as through invitations to cultural figures or visits to cultural sites, can provide hands-on learning experiences that strengthen students' understanding of the subject matter. 4) Adjustment of Curriculum to Support CRT. The curriculum should allow flexibility in integrating cultural elements into various subjects. A curriculum that supports CRT can include themes related to diversity, social justice, and local history relevant to students. Krasnof [29] suggest that schools have a curriculum policy that allows teachers to adapt teaching materials to the cultural needs of students without leaving the established educational standards. 5) Use of Technology to Facilitate CRT. Technology can be an effective tool in enhancing the effectiveness of CRT. Teachers can access diverse learning resources and interact with other cultures outside the classroom using digital platforms. According to Patras, et al. [30] using technology in CRT allows students to explore other cultures through virtual field trips or multimedia materials, broadening their horizons about the wider world. 6) A Multimodal Approach to Learning. Using various learning methods that accommodate different learning styles can increase the effectiveness of CRT. With a multimodal approach, teachers can use stories, music, visuals, or games related to the student's culture to introduce academic concepts. The study by Kiviranta, et al. [31] showed that using a culture-based multimodal approach in the classroom improved students' understanding and retention of the subject matter. 7) Culturally Responsive Evaluation and Assessment. Using evaluation methods that value students' cultural knowledge and ways of learning can help ensure that assessment is more inclusive and fair. Alternative assessment methods, such as portfolios or culture-based projects, can comprehensively assess students' understanding. These evaluations allow students to demonstrate their knowledge in a way that best suits their cultural background. 8) Raising Awareness about Diversity in the School Environment. Awareness of cultural diversity among staff and students can help create a more inclusive school environment. Training programs or workshops on diversity and inclusiveness can increase understanding of the importance of valuing differences and how culture affects learning [29]. 9) Implementation of a Project-Based Learning Approach. Project-based learning related to local culture or social issues can strengthen the application of CRT. This approach allows students to engage directly with real problems relevant to their community, thus enhancing the meaning of learning. According to Wahyudi, et al. [32] project-based learning enhances critical thinking skills and creativity, especially when the projects reflect cultural or social issues close to students' lives. 10) Encourage Self-Reflection for Teachers and Students. Teachers and students must continuously reflect on the learning process and the effectiveness of CRT. Self-reflection helps teachers assess the approach used and find ways to improve it, while reflection can help students realize the importance of culture in learning. Abdalla and Moussa [33] showed that structured self-reflection in CRT can deepen students' understanding and increase cultural awareness.

The CRT approach is an effective pedagogical strategy to improve students' math skills through a learning context closer to their lives. Research by Susanti, et al. [34] concluded that CRT can change students' view of mathematics from an abstract and complicated subject to something relevant and exciting. School culture plays a crucial role in creating a conducive learning environment for students. A conducive learning environment can help improve the quality of education and student learning outcomes [35]. Using cultural background as a bridge to understanding mathematical concepts, CRT can improve learning outcomes and build a strong foundation for students to develop further mathematical skills.

6. Conclusion

The conclusion of this study shows that the Culturally Responsive Teaching (CRT) approach significantly improves students' math skills. Analysis using the Wilcoxon Signed-Rank Test showed a

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significant difference between the math scores of "Formative Cycle 1" and "Formative Cycle 2", with a large effect size ($r = 5.11$), reflecting the strong impact of this intervention. The average score increase of 8.22 points indicates that the CRT approach substantially improved student learning outcomes. Normality test results showed that score differences did not follow a normal distribution pattern, reinforcing the choice of non-parametric statistical methods such as the Wilcoxon Test in this analysis. Indivi dually, 51 students experienced a significant change in scores, indicating that the approach was effective for most students, although there were variations in responses that required further customization. The sizable standard deviation (21.09) also indicates variation in student achievement. This study supports the theory of constructivism and Vygotsky's zone of proximal development principle, where learning relevant to students' cultural context can facilitate better understanding. By linking the subject matter to students' experiences and cultural backgrounds, CRT improves math skills and helps build positive attitudes toward learning. The implementation of CRT has proven effective in improving students' mathematics skills and can be adopted as one of the strategies to improve the quality of education. However, CRT implementation requires adequate teacher training and customization based on student characteristics and school context to achieve optimal results.

Transparency:

The authors confirm that the manuscript is an honest, accurate, and transparent account of the study; that no vital features of the study have been omitted; and that any discrepancies from the study as planned have been explained. This study followed all ethical practices during writing.

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