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EXAMINING THE ROLE OF CULTURAL KNOWLEDGE IN THE RELATIONSHIP BETWEEN REALISTIC LEARNING AND STUDENTS' MATHEMATICS ACHIEVEMENT: A MULTIFACETED ANALYSIS

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ABSTRACT

This study examines the role of cultural knowledge in moderating the effectiveness of Realistic Mathematics Education (RME) on students' mathematics achievement in primary schools. Utilizing the theoretical framework of ethnomathematics and RME, this research hypothesizes that integrating RME with culturally relevant contexts enhances students' understanding and performance in mathematics. The methodology involved moderation analysis with covariates such as gender, age, and geographical location. The results indicate that age and geographical location significantly moderate the impact of RME on students' mathematics achievement, with an F-value of 524.558 and a p-value of 0.000. These findings support the theory that contextualized learning improves students' comprehension and performance. The implications of this study underscore the importance of incorporating cultural knowledge into RME to enhance contextual relevance and student engagement, ultimately leading to improved mathematics learning outcomes across diverse educational settings. These findings are expected to inform educators and policymakers about the significance of considering cultural factors in teaching practices.

KEYWORDS: Etnomatematics, Mediation, Moderation, Primary Student.

1. INTRODUCTION

Mathematics education has long been a field of intense research, with educators continually seeking strategies to improve student achievement and engagement (Fauzan et al., 2020). Among the myriad of instructional approaches, Realistic Mathematics Education (RME) has gained prominence for its emphasis on contextual learning and problem-solving (Rawani et al., 2023). This approach, rooted in the idea that mathematics should be grounded in real-world contexts, aims to make learning more meaningful and relevant to students. However, while RME has shown promise in enhancing students' mathematical understanding and performance, its effectiveness can be significantly influenced by various factors, including cultural knowledge (Lata Sharma & Sarkar, 2019; Supriyanto et al., 2020).

Cultural knowledge, or the understanding and appreciation of cultural differences, plays a crucial role in educational contexts, particularly in diverse classrooms where students come from varied cultural backgrounds (Cimen, 2014; Mogege, 2017). Recent studies have indicated that cultural knowledge can impact not only the pedagogical strategies employed by educators but also the learning experiences and outcomes of students (Ambrosio, 1985; Prahmana et al., 2021; Yosopranata et al., 2018). Cultural knowledge is crucial in applying Realistic Mathematics Education (RME) in mathematics instruction. RME emphasizes contextual learning relevant to students' daily lives (Abdullah et al., 2022). Understanding students' cultural backgrounds allows teachers to design more meaningful and relatable lessons. Integrating cultural knowledge into RME helps students grasp mathematical concepts more easily by connecting them to familiar contexts. This approach also bridges understanding gaps due to diverse backgrounds, giving all students equal opportunities to excel in mathematics (Prahmana et al., 2023; Umbara et al., 2021). The result is improved student achievement, as they feel more connected and motivated in their learning process.

Despite the growing body of research on both RME and cultural knowledge, there remains a notable gap in understanding how these two elements interact to influence student outcomes. While existing studies have explored the benefits of RME in isolation and have examined the impact of cultural factors on education more broadly, there is limited research that combines these aspects to provide a comprehensive analysis of their interplay (Abdullah et al., 2022; Prahmana et al., 2023; Utami et

al., 2019). Specifically, there is a lack of detailed exploration into how cultural knowledge may mediate or moderate the effects of RME on students' mathematics achievement.

This article aims to address this gap by providing a multifaceted analysis of the role of cultural knowledge in the relationship between RME and students' mathematics achievement. The novelty of this study lies in its integration of cultural knowledge as a variable within the RME framework, offering new insights into how cultural factors may influence the effectiveness of realistic learning approaches. By examining this interaction, the study seeks to contribute to a deeper understanding of how educational practices can be tailored to better support diverse student populations. To achieve this, **the research will address several key questions**

1. How valid are the constructs of cultural knowledge, RME, and mathematics achievement within the context of this study?
2. What is the direct relationship between cultural knowledge and students' mathematics achievement when RME is applied?
3. How do cultural knowledge and RME interact to mediate or moderate the relationship between RME and students' mathematics achievement?

By addressing these questions, this study aims to provide valuable insights into the role of cultural knowledge in enhancing the effectiveness of realistic mathematics education. The findings are expected to inform educators and policymakers about the importance of integrating cultural considerations into instructional practices and developing strategies that can accommodate diverse cultural backgrounds, ultimately leading to improved educational outcomes for all students.

2. LITERATURE REVIEW

2.1. Trend of Ethnomathematics

Ethnomathematics is an emerging field that examines the relationship between mathematics and culture, exploring how mathematical concepts and practices are embedded in various cultural contexts (Suherman et al., 2021). This interdisciplinary area of study has gained traction as educators and researchers increasingly recognize the significance of incorporating cultural perspectives into mathematics education (Faiziyah et al., 2020). The trend towards ethnomathematics is driven by the desire to make mathematics more relevant and accessible to students from diverse cultural backgrounds.

At the core of ethnomathematics is the recognition that mathematical knowledge is not universally

uniform but rather varies across different cultures. The theoretical foundation of ethnomathematics is grounded in the work of Ubiratan D'Ambrosio, who first coined the term in the early 1980s (Ambrosio, 1985). D'Ambrosio's work emphasized that mathematical ideas are culturally situated and that understanding these cultural contexts is crucial for appreciating the diversity of mathematical practices. According to D'Ambrosio, ethnomathematics involves studying the ways in which people from various cultures use and understand mathematics in their daily lives, rituals, and traditional practices (Cimen, 2014).

Recent research has highlighted several key trends in the field of ethnomathematics. One significant trend is the integration of ethnomathematics into school curricula to enhance students' engagement and learning outcomes. Studies have shown that incorporating cultural contexts into mathematics instruction can lead to improved understanding and retention of mathematical concepts. For instance, research by (Utami et al., 2019) demonstrated that when students are exposed to mathematical practices from their own culture, they develop a deeper connection to the material, which can lead to higher levels of achievement and motivation.

Another trend is the growing recognition of the role of ethnomathematics in promoting equity and inclusivity in education. By valuing and incorporating diverse mathematical traditions, educators can create a more inclusive learning environment that respects and celebrates cultural differences. This approach has been supported by various studies, including those by (Prahmana et al., 2021), which revealed that students from non-Western cultures often possess sophisticated mathematical knowledge that is not always acknowledged in traditional educational settings. By recognizing and integrating these diverse mathematical practices, educators can help bridge the gap between students' cultural experiences and formal mathematical education (Yosopranata et al., 2018).

A related trend is the use of ethnomathematics as a tool for developing critical thinking and problem-solving skills. Ethnomathematics encourages students to explore and solve problems within the context of their own cultural practices, which can enhance their analytical abilities and creativity (Gaias et al., 2019; Kurpis, 2017). Research (Boyle, 1999; Horst & Albertyn, 2018; Wilson, 1982) has shown that engaging students in culturally relevant problem-solving tasks can improve their mathematical

reasoning and ability to apply mathematical concepts in real-world situations. Despite these positive trends, there are also challenges associated with implementing ethnomathematics in educational settings (Hirsch, 2005; Malewski, 2012). One challenge is the need for educators to have a deep understanding of the cultural contexts they are teaching. Without adequate training and knowledge, teachers may struggle to effectively integrate ethnomathematics into their curricula (Cera et al., 2014). Additionally, there is a risk of misrepresenting or oversimplifying cultural practices, which can lead to perpetuating stereotypes rather than fostering genuine understanding.

In summary, the trend of ethnomathematics represents a significant shift towards recognizing and valuing the cultural dimensions of mathematics. By integrating cultural contexts into mathematics education, researchers and educators aim to make learning more relevant and inclusive, promote equity, and develop students' critical thinking skills. However, successful implementation requires careful consideration of cultural accuracy and teacher preparedness. As the field continues to evolve, further research and development will be essential to address these challenges and maximize the benefits of ethnomathematics in education.

2.2. Realistic Mathematics Education in Primary School

Realistic Mathematics Education (RME) is an instructional approach grounded in the belief that mathematics should be taught in a manner that reflects its real-world applications and contexts (Septriyana et al., 2019). Originating from the Netherlands, RME has gained global recognition for its emphasis on connecting mathematical concepts to everyday experiences and practical problem-solving. This approach is founded on the theoretical work of Hans Freudenthal, who argued that mathematics is a human activity and should therefore be taught through meaningful and contextualized experiences (Maulina et al., 2020). Freudenthal's concept of "mathematics as a human activity" posits that learning mathematics should not merely involve abstract procedures but should be rooted in real-world contexts that are relevant to students' lives. This perspective emphasizes the importance of situating mathematical problems in realistic scenarios, thereby making the learning process more engaging and applicable. According to (den Heuvel-Panhuizen & Drijvers, 2014), RME involves designing instructional activities that are both mathematically rich and contextually meaningful,

allowing students to build on their existing knowledge and experiences.

Recent research supports the effectiveness of RME in primary school education, highlighting several key benefits. One significant advantage is the approach's ability to enhance students' problem-solving skills. Studies have shown that when students are exposed to mathematics through real-world problems, they develop better problem-solving strategies and a deeper understanding of mathematical concepts. For example, a study by Gravemeijer in (Paroqi et al., 2020) demonstrated that students who engaged in RME-based instruction showed significant improvements in their ability to solve complex mathematical problems compared to those who received traditional instruction.

Another benefit of RME is its role in fostering students' mathematical reasoning and conceptual understanding. By engaging in tasks that are grounded in real-life contexts, students are encouraged to think critically and make connections between different mathematical concepts. Research by (den Heuvel-Panhuizen & Drijvers, 2014) found that RME promotes the development of conceptual understanding and mathematical reasoning by providing students with opportunities to explore and discuss their ideas in meaningful contexts. RME also supports the development of students' mathematical communication skills. Through collaborative problem-solving and discussions about real-world problems, students learn to articulate their mathematical thinking and engage in productive mathematical discourse. A study by (Appiah & Mfum-appiah, 2019) highlighted that RME fosters students' ability to communicate their mathematical ideas effectively, which is crucial for developing a deeper understanding of mathematics.

Despite its advantages, implementing RME in primary school settings presents several challenges. One challenge is the need for teachers to design and facilitate contextually rich problems that align with students' real-world experiences. This requires a deep understanding of both the mathematical content and the contexts in which it is applied. Research by (Prahmana et al., 2023) emphasizes that effective implementation of RME requires teachers to have strong pedagogical content knowledge and the ability to create and adapt problems that are both mathematically meaningful and contextually relevant. Additionally, there are concerns about the scalability and adaptability of RME practices across diverse educational contexts. While RME has been successful in many settings, adapting the approach to different cultural and educational contexts can be

challenging. Studies such as those by (Schleicher, 2019) suggest that while RME is effective in certain educational systems, its implementation may require modifications to fit local curricular standards and teaching practices.

In conclude, Realistic Mathematics Education represents a progressive approach to teaching mathematics in primary schools, emphasizing the importance of context and real-world applications. The theoretical foundation of RME, as articulated by Freudenthal, highlights the significance of teaching mathematics through meaningful and contextualized experiences. Research supports the effectiveness of RME in enhancing problem-solving skills, conceptual understanding, and mathematical communication. However, challenges related to teacher preparation and adaptability across different contexts remain. Continued research and development are essential to address these challenges and further refine the implementation of RME in diverse educational settings.

2.3. Conjecture of Study

This study conjectures that cultural knowledge plays a pivotal role in moderating the effectiveness of Realistic Mathematics Education (RME) on students' mathematics achievement in primary schools. Based on the theoretical framework of ethnomathematics and Realistic Mathematics Education, it is hypothesized that when RME is integrated with culturally relevant contexts, students will experience enhanced mathematical understanding and performance. The visualization of our conjecture can be seen in figure 1.

Drawing from D'Ambrosio's concept of ethnomathematics, which emphasizes the cultural embeddedness of mathematical practices, it is conjectured that cultural knowledge will significantly influence how students engage with and benefit from RME. Specifically, it is expected that students with high cultural knowledge will be better able to relate RME activities to their own cultural contexts, leading to improved problem-solving skills and higher levels of achievement in mathematics. This is in line with Freudenthal's assertion that mathematics should be taught through meaningful and real-world contexts, suggesting that culturally relevant RME practices will resonate more effectively with students' prior knowledge and experiences.

Furthermore, the study hypothesizes that cultural knowledge will mediate the relationship between RME and mathematics achievement. This means that the impact of RME on student outcomes will be stronger when cultural knowledge is high, as

students will be more likely to connect the mathematical content to their cultural realities.

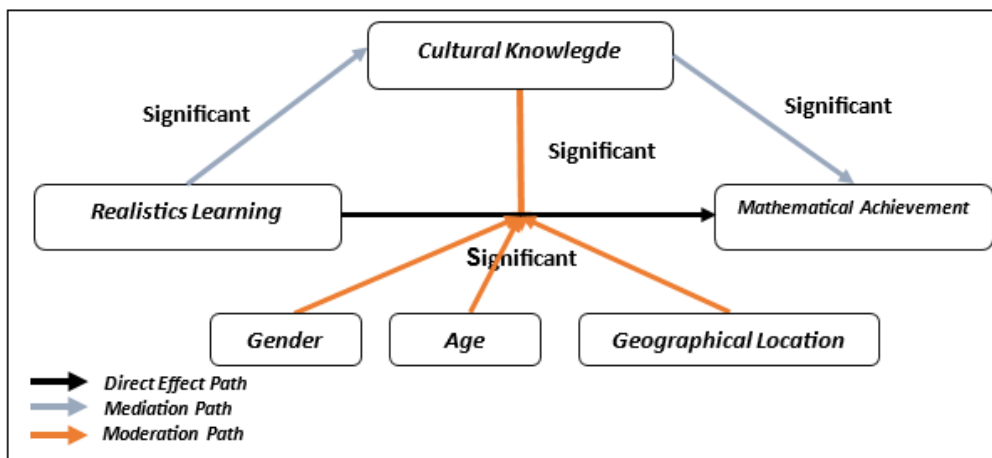


Figure 1: Conceptual Framework of the Study.

Additionally, it is conjectured that cultural knowledge will moderate this relationship, implying that the effectiveness of RME will vary depending on the level of cultural knowledge, with higher knowledge leading to greater improvements in achievement. In essence, this study posits that integrating cultural knowledge into RME not only enhances the contextual relevance of mathematical problems but also optimizes student engagement and learning outcomes, thereby bridging the gap between culturally diverse educational practices and effective mathematics instruction.

3. METHODS

3.1. Research Design

This study adopts an explanatory quantitative research design with a survey approach, utilizing a questionnaire as the data collection instrument (Hair et al., 2019). This design allows for the systematic measurement of the variables involved and the application of appropriate statistical analyses to address the research questions. The primary focus of the study is to investigate the role of cultural knowledge in the relationship between realistic learning approaches and students' mathematics achievement in primary schools. Mediation and moderation analyses will be employed to gain a deeper understanding of the interactions among these variables.

3.1.1. Participants

The participants in this study were students enrolled in Grades 9, 10, and 11 from several secondary schools in Indonesia. A simple random sampling technique was used to ensure that all

students had an equal probability of being selected, while still maintaining variation in demographic characteristics such as age, gender, and school location (Creswell, 2014). Prior to data collection, all students received an information sheet, and participation was voluntary with consent obtained from both students and school administrators.

A total of 415 students participated in this study, which provides sufficient statistical power for the planned analyses. Demographic data were collected to contextualize the sample and to allow for further examination of potential moderating and mediating variables. The demographic characteristics of the participants are presented in Table 1.

Table 1: Demographic Characteristics of Participants.

Aspect	Amount	Percentage (%)
Gender		
Male	162	39.04
Female	253	60.96
Grade Level		
Grade 9	82	19.76
Grade 10	178	42.89
Grade 11	155	37.35
School Location		
Rural	281	67.71
Urban	134	32.29

Source: Research Data

The demographic profile of the 415 student participants is summarized in Table 1. The gender distribution consists of 39.04% (n = 162) male students and 60.96% (n = 253) female students. In terms of grade level, 19.76% (n = 82) of the students were in Grade 9, 42.89% (n = 178) in Grade 10, and 37.35% (n = 155) in Grade 11. These proportions

reflect a balanced distribution across the three grade levels. Additionally, a majority of the students were enrolled in rural schools (67.71%, n = 281), while the remainder attended schools located in urban areas (32.29%, n = 134). This composition offers a representative overview of students from diverse educational settings, allowing for a comprehensive analysis of the variables examined in this study.

3.1.2. Measurement

In this study, the researcher utilizes two questionnaire instruments and one documentation instrument for data collection. The survey instruments are used to measure cultural knowledge and students' responses to realistic learning in the classroom. The documentation instrument is employed to track students' mathematics achievement throughout the period of realistic learning in the classroom. The details of the instruments are as follows

Cultural Knowledge In this study, the researcher adapted instruments from Abdollah et al. (2016) to measure cultural values. This questionnaire consists of seven main dimensions, each with five items (totaling 35 items). However, only five dimensions are used in this research, as the other two are deemed irrelevant for primary school students. The instrument has been pre-tested, achieving an average reliability score of 0.87. The details of the instrument are presented in Table 2 below.

Table 2: Cultural Values Measurement.

No	Dimenssion	Item
1	Social Harmony	1-5
2	Oneself values	6-10
3	Ethnic Ancestry	11-15
4	Environmental	16-20
5	Human oriented	21-25
Total		25 item

Realistic Learning

For the measurement of realistic learning, the researcher adapted an instrument from Fokides et al. (2018). This questionnaire includes four main dimensions, each with three items (totaling 12 items). The instrument has been pre-tested and obtained an average reliability score of 0.83. Details of this instrument are shown in Table 3 below.

Table 3: Realistic Learning Measurement.

No	Dimenssion	Item
1	Personal Context	1, 5, 9
2	Environmental Context	3, 7, 12
3	Tangible Context	2, 8, 11
4	Mathematization Context	4, 6, 10
Total		12 item

Mathematical Achievement

For mathematical achievement, the researcher modified an instrument from Wang et al. (2023). This questionnaire consists of five main dimensions, each with three items (totaling 15 items). The instrument has been pre-tested and has an average reliability score of 0.78. Details of the instrument are provided in Table 4 below.

Table 4: Mathematical Achievement Measurement.

No	Dimenssion	Item
1	Perceived usability	1-3
2	Immersion	4-6
3	Enjoyment	7-9
4	Motivation	10-12
5	Usefulness	13-15
Total		15 item

The two survey instruments will be distributed to participants via email or accessible online survey platforms. Meanwhile, documentation of students' mathematics grades will be obtained from the teachers. Participants will be asked to respond to each question honestly and provide accurate information. The data collection process will span three months. Once the data is collected, the results will be statistically analyzed to address the research questions.

3.2. Data Analysis

In the preliminary study, Confirmatory Factor Analysis (CFA) was utilized to test the constructs of each research instrument using JSP software. Principal Axis Factoring (PAF) was employed for extraction, and Promax was used for rotation (Ramsay & Silverman, 2015). Subsequently, descriptive data analysis was conducted using SPSS to provide an overview of participant characteristics, such as average age, gender, and geographical location. The Robust Maximum Likelihood Estimation (RMLE) model was applied for CFA, based on Pearson correlation matrices, assuming that the observed variables are measured on an interval scale.

When assumptions are met, this method maximizes the likelihood function of the observed data to estimate the unknown parameters of the model. To ensure item validity and reliability, Construct Reliability (CR) and Average Variance Extracted (AVE) formulas were used. Mediation and moderation roles were tested using the SPSS PROCESS feature to explore the complexity of relationships among the three variables. Simulations were conducted to identify potential mediators and moderators.

4. RESULTS

4.1. Preliminary Study

To address the first research question (RQ1), the researchers conducted a Confirmatory Factor Analysis (CFA). The acceptance criteria for the CFA analysis were set by considering the Comparative Fit Index (CFI) and the Root Mean Square Error of Approximation (RMSEA) values. A CFI indicates acceptance of the factor structure > 0.90 and an RMSEA ≤ 0.08 , as recommended by Hair *et al.* (2019). Additionally, Hair (2019) suggests that the Composite Reliability (CR) should exceed 0.70 and the Average Variance Extracted (AVE) should be greater than 0.50.

Cultural Knowledge

The CFA results for Cultural Knowledge showed a CFI of 0.98 and an RMSEA of 0.03. This indicates that the factor structure is highly fitting and rigorously estimates the students' Cultural Knowledge. All items were retained as none needed to be removed to achieve the fit criteria. The instrument's CR and AVE values were 0.87 and 0.66, respectively. Therefore, the CFA results demonstrate that the factor structure for Cultural Knowledge is fit, valid, and reliable.

Realistic Learning

The CFA results for Realistic Learning showed a CFI of 1.00 and an RMSEA of 0.00, indicating an excellent fit for the factor structure in measuring

students' responses to Realistic Learning. However, two indicators, RL5 and RL7, were removed, leaving 10 out of 12 items that meet the fit criteria for factor structure to be used in mediation and moderation analysis. The instrument's CR and AVE values were 0.95 and 0.76, respectively. Thus, the CFA results demonstrate that the factor structure for Realistic Learning is fit, valid, and reliable.

Mathematical Achievement

The CFA results for Mathematical Achievement showed a CFI of 0.93 and an RMSEA of 0.04, indicating a good fit for the factor structure in measuring Mathematical Achievement within realistic learning. No items were removed, and all will be used for mediation and moderation analysis. The instrument's CR and AVE values were 0.86 and 0.68, respectively. Hence, the CFA results show that the factor structure for Mathematical Achievement is fit, valid, and reliable.

4.2. Direct Effect

Before testing the hypotheses, the researchers conducted a descriptive data analysis to gain an overview of the data distribution. The focus was on the mean and standard deviation values for each variable, including the covariate data on gender, age, and geographical location of the participating schools. The results of the descriptive data analysis are presented in Table 5:

Table 5: Mathematical Achievement.

	N	Minimum	Maximum	Mean	Std. Deviation
Cultural Knowledge	415	48	92	62.02	7.834
Realistics Learning	415	92	189	134.14	12.626
Mathematical Achievement	415	54	92	35.86	4.608
Gender	415	1	2	1.32	.495
Age	415	1	3	2.25	.985
Geographical	415	1	2	2.71	1.341

Source: SPSS Data

Based on the data in Table 5, it is evident that each variable has high accuracy. The mean value of Cultural Knowledge is 62.02, which is greater than its standard deviation of 7.834.

For Realistic Learning, the mean value is 134.14, which exceeds the standard deviation of 12.626. Similarly, for Mathematical Achievement, the mean value is higher than the standard deviation (35.86 $>$ 4.608). A larger standard deviation indicates a wider range of values and less accuracy compared to the mean, while a smaller standard deviation indicates more similar values and higher accuracy with the mean.

To address the second research question, the researchers tested the hypothesis regarding the effect of Realistic Learning on students' Mathematical Achievement. The researchers used SPSS software to perform linear regression analysis. The acceptance criterion for the hypothesis was a p-value > 0.05 . The results of the hypothesis testing are presented in Table 6.

From Table 6, the F value is 524.558, with a significance value of $0.000 < 0.05$. This indicates that the regression model can be used to predict the effect of Realistic Learning on Mathematical Achievement. In other words, Realistic Learning directly influences

Mathematical Achievement.

Table 6: ANOVA Test Results.

Model	R	R Square	F	Sig.
1	0.743	0.551	524.558	0.000 ^b
a. Dependent Variable: Teachers Skill				
b. Predictors: (Constant), Digital Competence				
Source: SPSS Data				

4.3. Mediation and Moderation

To determine whether the variable Cultural Knowledge (CK) can act as a mediator influencing the relationship between Realistic Learning (RL) and Mathematical Achievement (MA), a mediation test was conducted. The mediation test is accepted if the significance value $p < 0.05$. The mediation test results are presented in Tables 7 and 8.

Table 7: First Mediation Path → RL to CK.

Model	Coeff	Se	t	p
Contant	2.7387	.7905	3.5433	.0025
Realistics Learning	.8736	.0315	41.1542	.3229

Table 8: Second Mediation Path → RL to MA and CK to MA.

Model	Coeff	Se	t	p
Contant	2.9275	1.1183	2.3398	.0310
Realistics Learning	.8244	.0892	9.3455	.0000
Cultural Knowledge	.0726	.0949	1.0543	.2993

Tables 7 and 8 present the mediation analysis results for Path 1 and Path 2. The results for Path 1 show the effect of the RL variable on CK, with a significance value of 0.32. Since the significance value is $0.32 > 0.05$, the RL variable does not influence students' CK. In Path 2, the significance values obtained from the relationships of RL and CK with MA are 0.29 and 0.00, respectively. This indicates that

only the effect of RL on MA has a significance value $\alpha < 0.05$. Thus, these results are consistent with the linear regression test showing that RL can directly affect MA. Additionally, these results indicate that the hypothesis that CK serves as a mediator between RL and MA is not supported. To aid in understanding the mediation analysis results, a visualization is provided in Figure 2.

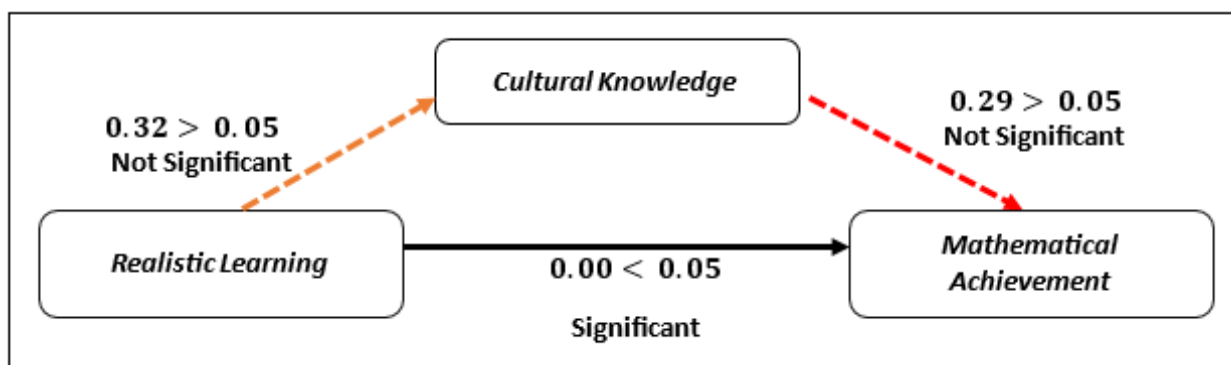


Figure 2: Visualization of the Mediation Analysis Results.

From the mediation analysis results, it is evident that the variable CK cannot act as a mediator. This is because CK does not significantly influence either RL or MA. Furthermore, this finding confirms that RL can directly influence MA (as shown by the ANOVA results) with a significance value of $0.00 < 0.05$. The absence of mediation demonstrates that CK does not operate as a psychological or pedagogical mechanism that links RL to MA. CK represents a stable and long-term cultural knowledge construct that does not undergo substantive changes through the implementation of RL within the same

instructional period. Consequently, the improvement in MA observed in this study is fully explained by the direct effect of RL, rather than by CK as an intermediary pathway.

To address the research question regarding the role of CK as a moderator influencing the relationship between RL and MA, the researchers conducted a moderation analysis. The moderation test is accepted if the significance value $p < 0.05$. The results of the moderation test are presented in Table 9.

Table 9: Moderation Test Results.

Model	Coeff	Se	t	p
Content	-8.9009	1.8925	-4.7091	.0007
Realistic Learning	1.4945	.1195	12.5842	.0023
Cultural Knowledge	.0225	.0693	.1.0543	2956
Int_1	.0175	.0093	7.6904	.0211

Since the Int_1 value is 0.02 or < 0.05 , it can be concluded that the CK variable can act as a moderator. Because the resulting Coeff value is positive, the effect of CK aligns with the variables RL and MA.

The higher the students' CK, the stronger its influence on the relationship between RL and MA. To further delve into the moderation analysis, the researchers also tested the covariate variables of gender, age, and geographical location as moderators. The test results are as follows:

Table 10: Gender Variable Moderation Test Results.

Model	Coeff	Se	t	p
Content	13.2142	7.3165	.7231	.4382
Realistic Learning	1.2704	.4650	2.6167	.0123
Gender	-15.9070	5.1453	-2.3016	.0025
Int_1	.3357	.1599	2.1917	.2152

Table 11: Age Variable Moderation Test Results.

Model	Coeff	Se	t	p
Content	-52.2474	14.2303	-3.9391	.0213
Realistic Learning	2.234	.4016	6.1227	.0034
Age	13.5364	11.3047	1.5203	.2133
Int_1	-.3059	.2478	-1.7365	.0246

Table 12: Geographical Location Variable Moderation Test Results.

Model	Coeff	Se	t	p
Content	13.2222	7.8875	.7463	.4590
Realistic Learning	1.1784	.4652	2.5189	.0143
Geographical Location	-15.3470	5.9453	-2.6131	.0295
Int_1	.3353	.1499	2.1125	.0323

The moderation analysis results show that the Int_1 values for the covariate variables of gender, age, and geographical location are 0.21, 0.02, and 0.03, respectively. Thus, among these three covariate variables, age and geographical location can moderate the influence of RL on MA. To aid in understanding the moderation analysis flow, a visualization is provided in Figure 3.

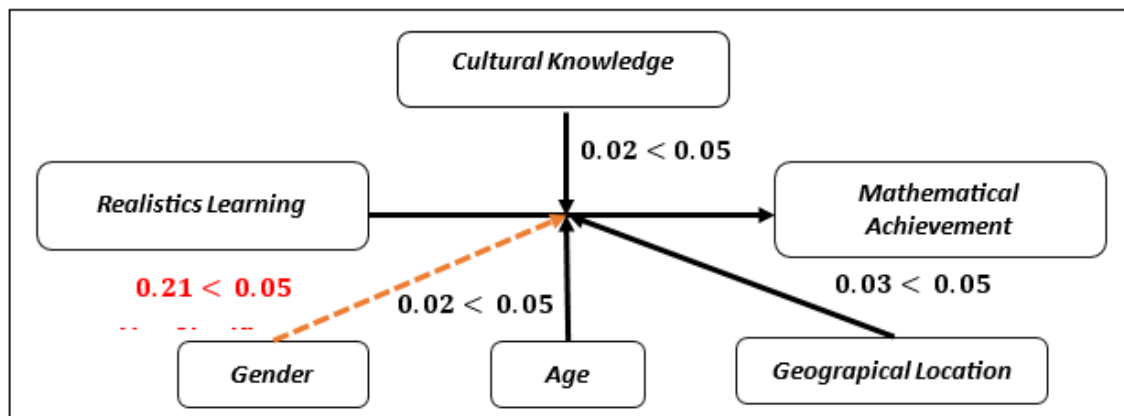


Figure 3: Visualization of the Moderation Analysis Results.

5. DISCUSSION

5.1. Realistic Context and Mathematic

The findings from the regression analysis indicate a significant impact of Realistic Learning on Mathematical Achievement, evidenced by an F value of 524.558 and a p-value of 0.000, which is well below the 0.05 threshold. This supports the notion that Realistic Learning can serve as a potent instructional approach in mathematics education. To better understand these findings, it is essential to compare them with existing theories and previous research on realistic contexts and their effects on mathematics

achievement.

Realistic Mathematics Education (RME), developed by Freudenthal in the Netherlands, is a prominent theory that emphasizes the importance of contextualizing mathematical problems in real-world situations (den Heuvel-Panhuizen & Drijvers, 2014). Freudenthal argued that students are more likely to understand and retain mathematical concepts when they can relate them to real-life experiences (Prahmana, 2021). This theoretical framework posits that mathematics should not be presented as an abstract subject but rather as an integral part of the students' reality.

Our study's finding that Realistic Learning

significantly enhances Mathematical Achievement aligns with Freudenthal's theory, reinforcing the idea that contextualizing mathematics within real-world scenarios can enhance understanding and performance.

Further supporting this perspective, a study by (den Heuvel-Panhuizen & Drijvers, 2014) demonstrated that students who were taught mathematics using realistic contexts showed better problem-solving skills and deeper conceptual understanding than those who were taught using traditional methods. The significant impact of Realistic Learning observed in our study echoes these findings, suggesting that embedding mathematics instruction within a realistic context helps students grasp complex mathematical concepts more effectively (Güth & van Vorst, 2023). This approach not only improves their academic performance but also equips them with practical skills that are transferable to everyday situations.

Another relevant theory is Vygotsky's Social Constructivism, which emphasizes the social context of learning and the importance of interaction and collaboration in cognitive development (Slavin, 2018). Realistic Learning often involves collaborative activities where students work together to solve real-world problems, thereby facilitating social interaction and peer learning (Liu & Matthews, 2005). The positive correlation between Realistic Learning and Mathematical Achievement observed in our study can be partially attributed to these social interactions. When students engage in collaborative problem-solving, they can share diverse perspectives and approaches, which enhances their collective understanding and individual mastery of mathematical concepts.

Moreover, the theory of Situated Learning, proposed by (Brousseau, 2002), also provides a supportive framework for our findings. This theory posits that learning is inherently tied to the activity, context, and culture in which it occurs. Realistic Learning embodies this principle by situating mathematical problems within familiar and meaningful contexts (Hudson & Schneuwly, 2007). The significant impact of Realistic Learning on Mathematical Achievement, as indicated by our study, aligns with the Situated Learning theory, suggesting that students learn mathematics more effectively when it is embedded in a context that is relevant and meaningful to them.

Comparing our results with previous empirical studies reveals consistent findings. For instance, a meta-analysis by (Spreitzer et al., 2022; Vásquez, 2015) found that students taught using realistic and

context-based approaches performed better in mathematics than those taught using traditional methods. Boaler's research highlights the benefits of connecting mathematics to real-world contexts, which not only enhances student engagement but also improves their conceptual understanding and problem-solving skills. Our study corroborates these findings, providing further evidence that Realistic Learning is an effective instructional strategy for improving mathematical achievement (Delacour, 2016; Ferretti et al., 2018; Payne, 1972).

However, it is important to consider some limitations and potential areas for further research. While our study confirms the positive impact of Realistic Learning on Mathematical Achievement, it does not explore the long-term effects of this instructional approach (Rawani et al., 2023). Future research could investigate whether the benefits of Realistic Learning persist over time and whether students continue to apply their mathematical knowledge in real-world contexts beyond the classroom. Additionally, exploring the specific elements of Realistic Learning that contribute most significantly to student achievement could provide valuable insights for educators and curriculum developers.

In summary, our study's findings underscore the effectiveness of Realistic Learning in enhancing Mathematical Achievement, aligning with theoretical frameworks such as Realistic Mathematics Education, Social Constructivism, and Situated Learning. By situating mathematical problems within real-world contexts, Realistic Learning not only improves students' academic performance but also prepares them to apply mathematical concepts in practical situations. These findings support the continued integration of Realistic Learning approaches in mathematics education to foster deeper understanding and improved outcomes for students.

5.2. Cultural Context and Mathematics Learning

The role of cultural context in mathematics learning has garnered significant attention in educational research. Our study delves into this by examining the mediation and moderation effects of Cultural Knowledge (CK) in the relationship between Realistic Learning (RL) and Mathematical Achievement (MA). The mediation analysis results for Path 1 show that RL does not significantly influence CK, with a significance value of 0.32 ($p > 0.05$). For Path 2, the relationships of RL and CK with MA have significance values of 0.29 and 0.00, respectively, indicating that only RL directly affects

MA. Consequently, the hypothesis that CK mediates the relationship between RL and MA is not supported. However, the moderation analysis shows that CK significantly moderates the relationship between RL and MA, with an Int_1 value of 0.02 ($p < 0.05$). This discussion contextualizes these findings within existing theoretical frameworks and empirical research.

Cultural context in education refers to the ways in which cultural backgrounds and experiences influence learning processes and outcomes. According to (Abdollah *et al.*, 2016), culturally responsive teaching involves recognizing the importance of including students' cultural references in all aspects of learning. Our findings suggest that while RL, which emphasizes real-world problem-solving, directly enhances MA, CK does not mediate this relationship. This contrasts with the expectation that integrating cultural knowledge into realistic learning contexts would enhance mathematical understanding by making learning more relevant and meaningful to students (Malton *et al.*, 2012). However, CK does moderate the relationship, indicating that students with higher CK can leverage their cultural experiences to strengthen the impact of RL on their mathematical achievement (Lorenzen, 2019).

The lack of a mediating effect of CK might be understood through the lens of cognitive load theory (Cimen, 2014). Realistic learning contexts could impose a high cognitive load, potentially overwhelming students and hindering the effective integration of cultural knowledge into the learning process. This might explain why CK did not emerge as a significant mediator in our study. Students might need additional scaffolding to effectively integrate their cultural knowledge within complex, real-world problem-solving tasks. In contrast, the significant moderation effect of CK suggests that when students possess a strong cultural knowledge base, they are better equipped to connect realistic learning scenarios with their existing knowledge frameworks. This aligns with Vygotsky's theory of social constructivism (Glassman, 2001), which posits that learning is inherently a social process, and students learn more effectively when they can relate new information to their prior cultural and social experiences. The positive moderation effect indicates that CK can enhance the efficacy of RL by providing students with a richer context for understanding and applying mathematical concepts (Zhou, 2020).

Empirical studies also highlight the importance of cultural context in learning. For example, (Horst & Albertyn, 2018; Kurpis, 2017; Wilson, 1982) found

that students who engaged in mathematics tasks that were culturally relevant and connected to their personal experiences demonstrated higher levels of engagement and achievement. Similarly, (Van Der Horst & Albertyn, 2018) emphasized that culturally relevant pedagogy could bridge the gap between students' lived experiences and academic content, fostering deeper understanding and retention of mathematical concepts. Our study's finding that CK moderates the relationship between RL and MA is consistent with these studies, underscoring the importance of cultural relevance in enhancing the effectiveness of realistic learning approaches.

However, the absence of a mediating effect in our study suggests a complex interplay between cultural knowledge and realistic learning that warrants further investigation (Alexander, 2019; Garcia-Mila *et al.*, 2021). It may be that while cultural knowledge enhances the contextual relevance of learning, it does not directly translate into improved mathematical achievement without additional supports and instructional strategies. Future research could explore the specific instructional practices that facilitate the integration of cultural knowledge into realistic learning contexts, potentially uncovering mechanisms that could turn the moderating effect into a mediating one.

Therefore, our study contributes to the understanding of how cultural context interacts with realistic learning in mathematics education. While CK does not mediate the relationship between RL and MA, it significantly moderates this relationship, suggesting that cultural knowledge enhances the impact of realistic learning on mathematical achievement. These findings highlight the importance of culturally responsive teaching practices and suggest avenues for further research to optimize the integration of cultural knowledge in mathematics education. By acknowledging and leveraging students' cultural backgrounds, educators can create more inclusive and effective learning environments that foster both engagement and achievement in mathematics.

5.3. Age and Geographical Location

The influence of age and geographical location on learning outcomes has been a significant area of research in educational psychology. Our study investigates how these factors moderate the relationship between Realistic Learning (RL) and Mathematical Achievement (MA). The moderation analysis reveals that the interaction terms (Int_1) for gender, age, and geographical location are 0.21, 0.02, and 0.03, respectively. Therefore, age and

geographical location significantly moderate the effect of RL on MA. This discussion explores these findings in the context of existing theories and empirical research.

Age as a moderating factor in education is well-supported by developmental theories. Piaget's stages of cognitive development suggest that children's ability to understand and process information evolves with age (Eggen & Kauchak, 2016). Younger children are typically in the concrete operational stage, where they can think logically about concrete events but struggle with abstract concepts. In contrast, older students enter the formal operational stage, where abstract thinking and hypothetical reasoning become more developed (Michael & Judith, 1984). The significant moderation effect of age in our study aligns with Piaget's theory, indicating that older students may benefit more from RL due to their advanced cognitive capabilities. This might explain why RL, which often involves complex problem-solving and abstract reasoning, has a more pronounced effect on older students' mathematical achievement.

Empirical studies also support the moderating role of age in educational outcomes. For example, a study by Siegler and Jenkins in (Johnson & Johnson, 2009; Y. Wang, 2020) found that older students are better able to apply problem-solving strategies effectively, which could enhance the benefits of RL approaches. Similarly, research by (Makhortykh et al., 2021) highlighted that as students age, their self-regulation and metacognitive skills improve, making them more adept at navigating realistic learning scenarios. Our findings that age moderates the influence of RL on MA suggest that developmental differences play a critical role in how students engage with and benefit from RL.

Geographical location, another significant moderator identified in our study, intersects with educational access and quality. Theories of educational inequality, such as those proposed by Bourdieu in (Krakowiak-Bal et al., 2017), emphasize the impact of socioeconomic and cultural capital on educational outcomes. Students in urban areas often have greater access to educational resources, such as advanced technology, experienced teachers, and diverse learning materials, compared to their rural counterparts (Griffin et al., 2018). This disparity can affect how effectively students can engage with RL approaches, which often require access to various resources and a supportive learning environment. The moderation effect of geographical location found in our study underscores the importance of considering these contextual factors in educational

interventions.

Studies have documented the impact of geographical disparities on educational achievement. For instance, a study by (Canales et al., 2018; Ennis & Chen, 1995) found that students in rural areas often face challenges such as limited access to qualified teachers and educational resources, which can hinder their academic performance. Similarly, research by (Li & Laidlaw, 2006) highlighted that rural students may struggle with relevance and application of school-based learning to their lived experiences, affecting their engagement and achievement. Our findings align with these studies, indicating that geographical location significantly influences how students benefit from RL.

The intersection of age and geographical location with RL and MA provides a nuanced understanding of educational outcomes. Vygotsky's theory of social constructivism emphasizes the role of social and cultural contexts in learning (Slavin, 2018). This theory supports the idea that both age-related cognitive development and geographical context significantly impact how students construct knowledge. Our study's findings that age and geographical location moderate the effect of RL on MA suggest that these contextual factors must be considered when designing and implementing RL approaches to ensure they are effective for diverse student populations. Furthermore, the significant moderation effects of age and geographical location indicate that a one-size-fits-all approach to RL may not be effective (Loucaides, 2004). Educational interventions need to be tailored to address the developmental stages of students and the specific challenges and resources of their geographical contexts. This tailored approach can help maximize the benefits of RL, ensuring that it meets the diverse needs of students across different age groups and locations. Therefore, our study highlights the critical roles of age and geographical location in moderating the relationship between RL and MA. These findings underscore the importance of considering developmental and contextual factors in educational research and practice. By acknowledging and addressing these factors, educators can design more effective RL interventions that enhance mathematical achievement for all students, regardless of their age or geographical location. This comprehensive approach is essential for promoting equitable educational outcomes and fostering academic success across diverse student populations.

6. CONCLUSION

This study demonstrates that Realistic Learning

has a direct and significant effect on students' Mathematical Achievement, while the moderation analyses reveal that age and geographical location strengthen this relationship. Older students, who possess more developed cognitive abilities, benefit more from Realistic Learning activities. Likewise, students in urban areas show greater gains, reflecting the influence of resource availability and learning environments. In contrast, gender does not moderate the effect of Realistic Learning, and Cultural Knowledge does not serve as a mediating variable. These findings indicate that Realistic Learning operates primarily through direct instructional

mechanisms rather than through cultural knowledge pathways and that its effectiveness varies across developmental and contextual factors. Overall, the study highlights the importance of aligning Realistic Learning strategies with students' developmental readiness and contextual conditions. Tailoring instructional approaches to these factors can enhance learning outcomes and contribute to reducing disparities across student groups. Future research should further investigate how contextual supports and culturally responsive practices can optimize the implementation of Realistic Learning in diverse educational settings.

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