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INTEGRATING MATHEMATICS, COMMUNITY, CULTURE, AND PLACE: A CONCEPTUAL FRAMEWORK FOR INSTRUCTIONAL DESIGN

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Abstract. This study proposes a novel instructional design framework that intertwines mathematical concepts with elements of community, culture, and place. The aim is to enhance student engagement and understanding of mathematics by making learning more culturally responsive and contextually relevant. Employing a mixed-methods approach involving teacher interviews, classroom observations, pre- and post-intervention surveys and tests, the study examines the potential benefits of this integrated approach along with its practical challenges. Results indicate that despite initial difficulties in implementation such as time constraints or parental resistance to non-traditional teaching methods, many teachers reported improved student involvement and comprehension when classes were connected to local communities or cultures. Importantly, the study found no significant main effects or interaction effects for grade level or ethnicity on both engagement and understanding scores pre-and post-intervention. This suggests that this instructional model can be equally effective across diverse student populations thereby potentially reducing disparities in mathematical achievement. The findings highlight the potential advantages of an inclusive pedagogical strategy in enhancing mathematics education while acknowledging further research is needed to confirm these results across different settings.

Keywords**:** Mathematics education; Instructional design; Community and Cultural Integration, Place-based education; Educational equity

I. INTRODUCTION

As a fundamental discipline, mathematics is integral to society, contributing to various fields such as engineering, economics, and technology (Stemhagen & Henney, 2021). It is the foundation for logical reasoning and problem-solving skills that are critical in navigating contemporary life (Nilimaa, 2023). However, issues arise when integrating mathematics with community, culture, and place. Traditional instructional designs often view mathematics as an isolated discipline without cultural or contextual influences (Fomunyam, 2022). This approach can disconnect students' learning experiences and their everyday lives. For instance, mathematical concepts may appear abstract and irrelevant when they do not reflect the cultural contexts or places familiar to learners (Rodela & Rodriguez-Mojica, 2020). Such disconnects can hinder students' engagement with mathematics and ultimately impact their learning outcomes. Henceforth, we must re-evaluate our pedagogical approaches in mathematics education by incorporating community, culture, and place elements.

Existing approaches to mathematics education must often be revised to integrate community, culture, and place aspects (Utami et al., 2020). Conventional instructional designs have been criticised for their decontextualised nature, where mathematical concepts are often taught in isolation from students' lived experiences (Karahan, 2022; Lamichhane, 2021; Luitel, 2020). This approach makes mathematics appear abstract and detached and fails to utilise the rich cultural resources that students bring into the classroom (Pathuddin & Nawawi, 2021). For example, Abrahamson et al. (2020) found that students who engaged in physical activities exhibited sophisticated mathematical reasoning when playing games but struggled with similar concepts in traditional classroom settings. This discrepancy suggests a gap between the real-world application of mathematical knowledge and its classroom instruction. Furthermore, by ignoring the influences of community and place on learning processes, current pedagogical practices may inadvertently perpetuate social inequalities within educational outcomes (Garland & Batty, 2021; Shakeel & Peterson, 2022; Shukla et al., 2022; Warner et al., 2020). Therefore, addressing these gaps is essential for creating more inclusive and effective mathematics education.

Addressing the gaps in mathematics education is urgent due to its significant implications for students' learning experiences and outcomes. Current research indicates that when students see connections between mathematical concepts and their own lives, they are more likely to develop interest and engagement in learning (Genc & Erbas, 2019; Hira & Anderson, 2021; Leyva et al., 2022). This connection can be fostered by integrating community, culture, and place in instructional design. For instance, Tanase (2022) demonstrated that a culturally responsive mathematics curriculum enabled urban high school students to achieve higher scores on standardised tests. Furthermore, by incorporating elements of community and place into teaching practices, educators can create a more inclusive learning environment that acknowledges and values diverse student backgrounds (Nishina et al., 2019; Samuels, 2018) This inclusivity has been linked with increased academic motivation among students from marginalised groups (Kumar et al., 2018). Therefore, addressing these gaps improves mathematical understanding and promotes equity within educational settings.

In response to the identified gaps in current mathematics education, this study proposes a conceptual framework for instructional design that integrates mathematics with community, culture, and place. Drawing from the "Funds of Knowledge" theory (Denton & Borrego, 2021; Turner & Drake, 2016), which posits that students' household knowledge can be leveraged to create more meaningful learning experiences, our framework suggests embedding mathematical concepts within cultural contexts and local practices. For instance, lessons could incorporate problem-solving tasks that reflect community-specific situations or cultural practices (Chang & Lee, 2022). Furthermore, the "Place-Based Education" approach (Dean, 2021; Engels et al., 2019; Velempini & Martin, 2019) advocates grounding education in local phenomena and experiences. By situating mathematical learning within familiar environments or real-world scenarios relevant to student's lives, we can enhance their ability to connect abstract concepts with practical applications. This proposed framework addresses the disconnect between mathematics and students' lived experiences and fosters an inclusive learning environment where diverse cultures are acknowledged and valued.

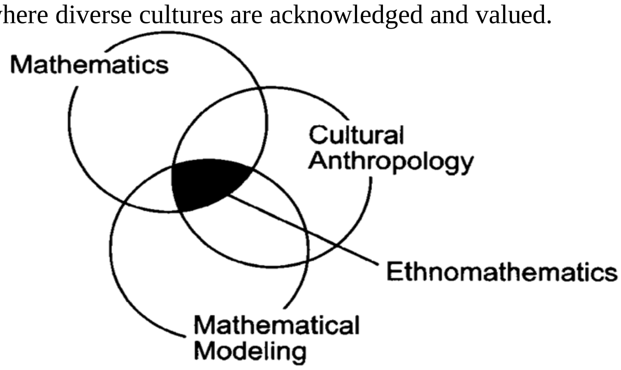

Fig. 1 Ethnomathematics as an intersection of three disciplines (Orey & Rosa, 2007).

In this case, ethno refers to a group identified based on cultural traditions, codes, symbols, myths and specific ways used to reason and conclude. Therefore, mathematics is more than just calculating, measuring, classifying, inferring, and modeling. Ethnomathematics forms a meeting point between cultural anthropology and institutional mathematics and uses mathematical modeling to solve real-world problems, and translate them into modern mathematical language systems.

In order to foster an atmosphere that is close to students' lives in learning, with the hope of increasing students' learning motivation in mathematics subjects, one of the ways this can be done is by involving the culture where students live. Education and culture have a very important role in growing and developing the noble values of our nation, which has an impact on character formation based on noble cultural values. Therefore, it is necessary to have a learning approach that links local culture in mathematics learning, which is then called Ethnomathematics (Putra & Mahmudah, 2021).

D'Ambrosio & Rosa (2017) explained that the application of ethnomathematics as a means to motivate and stimulate students can overcome boredom and difficulties in learning mathematics. This is because ethnomathematics is part of students' daily lives which is an initial conception that they have from the local socio-cultural environment. Research from Suryawan & Sariyasa (2018) revealed that students' mathematics achievement test results had increased every cycle, thus indicating that the teaching materials developed were effective in increasing student activity. and mathematics teaching achievement.

Sunzuma et al. (2021) realizing the benefits of using an ethnomathematics approach in teaching and learning mathematics, the Zimbabwean school syllabus recommends the application and integration of an ethnomathematics approach to improve student performance. The research sample consisted of 90 students and two teachers from one secondary school in Bindura district in Zimbabwe. Two instruments, tests and interviews were used for data collection. The participating teachers taught consumer arithmetic concepts for four weeks. Research findings show that students taught using an ethnomathematics approach obtain significantly higher test scores than students taught consumer arithmetic using a traditional approach.

This study aims to achieve several key objectives by developing a conceptual framework integrating mathematics with community, culture, and place. It seeks to enhance students' understanding and engagement with mathematics by making learning more contextually relevant and culturally responsive. By linking mathematical concepts to students' lived experiences and cultural backgrounds, the framework intends to foster deeper connections between abstract mathematical ideas and their real-world applications. Additionally, this study aims to contribute towards educational equity by acknowledging the diverse cultural wealth students bring into classrooms. Through this inclusive approach, it is anticipated that disparities in educational outcomes could be mitigated as all learners feel valued within their learning environments. Finally, this study

Journal of Education, Teaching, and Learning
Volume ... Number ... month ... . Page ...-...
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hopes to stimulate further scholarly dialogue on innovative pedagogical strategies by proposing a novel approach to instructional design in mathematics education that integrates community culture and place-based education aspects.

In light of the proposed conceptual framework and its objectives, this study is guided by several key research questions. First, how can mathematical concepts be effectively integrated with community, culture, and place elements in instructional design? This question seeks to uncover specific pedagogical strategies or teaching models that align with the proposed framework. Second, how does this integration impact students' engagement and understanding of mathematics? This question aims to assess the educational benefits of our approach. Thirdly, how does this integrated approach contribute towards educational equity? By examining the effects on learners from diverse backgrounds, we aim to understand if such an approach can help reduce disparities in mathematical achievement. Finally, what are potential challenges or barriers in implementing such a framework, and how might they be overcome? This question acknowledges potential difficulties in practice and seeks solutions for effective implementation.

II. METHODOLOGY

This study employs a mixed methods approach to effectively address the research questions, leveraging the strengths of both qualitative and quantitative research methodologies (Creswell & Clark, 2017). Qualitative methods were used to explore how mathematical concepts can be integrated with elements of community, culture, and place in instructional design. This involves interviewing educators and observing classrooms to gain insights into specific pedagogical strategies and teaching models that align with our proposed framework (Yang et al., 2020). Quantitative methods were employed to measure the impact of this integration on students' engagement and understanding of mathematics and its contribution towards educational equity. Surveys and tests were administered to collect numerical data before and after implementing the new instructional design. These data were then statistically analysed to assess any significant changes in student engagement levels or disparities in mathematical achievement (Wang et al., 2020). Finally, potential challenges or barriers to implementing such a framework were identified through qualitative analysis. By combining these approaches, we hope to understand "what" effects and "why" they occur, providing a more comprehensive understanding of our conceptual framework's implementation.

This research centres around several key concepts and variables. First, "mathematical concepts" refers to the principles or ideas in mathematics that students are expected to learn, such as numerical operations, algebraic expressions, geometric shapes, and statistical analyses (Mainali, 2021). This study will focus on how these mathematical principles can be integrated with community, culture, and place elements in instructional design. "Community", "culture", and "place" are understood as interrelated aspects of students' lived experiences. Community denotes the social groupings students belong to; culture encompasses shared beliefs, values, customs and practices; and place refers to physical locations and socio-cultural contexts where learning occurs (Gruenewald & Smith, 2014). Integrating these elements into mathematics teaching is a novel approach to making learning more contextually relevant and culturally responsive. Two primary outcome variables will be examined: student engagement with mathematics—measured through the Student Engagement Instrument – SEI (Appleton et al., 2006)—and understanding of mathematical concepts—assessed via tests. Additionally, we will examine educational equity as a dependent variable by examining disparities in mathematical achievement across different student demographics. Lastly, potential challenges or barriers to implementing our proposed framework will be identified qualitatively through educator interviews.

This research was conducted in three urban public junior high schools in Medan, Indonesia, namely, SMPN 1, SMPN 7, and SMPN 11. These institutions were chosen due to their diverse student bodies and potential educational equity challenges (Flessa et al., 2018). The participants comprised both students and mathematics teachers from each school. Using a stratified cluster random sampling method (Rahman et al., 2022), nine classes were selected as the research sample, three from each school with an approximate average of 33 students per class from different grades. This approach ensured representation across different age groups and academic levels within the student population. Additionally, using purposeful sampling (Etikan & Babatope, 2019), three mathematics teachers from each school were selected based on their interest and willingness to implement the proposed instructional design model in their classrooms. This dual perspective from both students and educators enabled a comprehensive exploration of how mathematical concepts can be integrated with elements of community, culture, and place within instructional design. By examining the impacts on diverse learners' engagement with mathematics and potential implementation challenges through this lens, this study aimed to contribute valuable insights towards promoting educational equity.

This study leveraged diverse data sources and collection tools to ensure a comprehensive understanding of integrating mathematical concepts with community, culture, and place elements in instructional design. Predominantly, qualitative data was gathered through semi-structured interviews with the selected mathematics teachers (Arrellano et al., 2022). These interviews provided rich insights into pedagogical strategies and potential implementation challenges and suggested solutions from educators actively engaged in the field. Furthermore, classroom observations were conducted to directly observe teaching practices and student-teacher interactions (Creswell & Poth, 2016). Regarding quantitative data sources, pre- and post-intervention surveys were administered to students to measure changes in their engagement and understanding of mathematics (Irvine, 2020). These surveys incorporated validated scales such as the SEI for assessing student engagement with mathematics.

Standardised test scores were also analysed as an objective measure of mathematical achievement across different student demographics (Brookhart & Nitko, 2019). This combination of data sources enabled a multi-faceted examination that answers the research questions and contributes substantively to the broader discourse on integrating community-based approaches in educational practice.

Data collection from the chosen sources was meticulously planned and executed to ensure validity and reliability. Semi-structured interviews with mathematics teachers were conducted in person, providing an opportunity to delve into their experiences, perspectives, and challenges in integrating community-based approaches into mathematics instruction (Brinkmann & Kvale, 2015). Classroom observations were carried out using a standardised observation protocol to record teaching practices and student-teacher interactions (Creswell & Poth, 2016). These observations provided first-hand insight into the real-time application of the proposed instructional design model. Pre- and post-intervention surveys were administered online at two points in time: before the implementation of the instructional model and after a specified period of its application. This allowed for measuring changes in students' engagement with and understanding of mathematics (Irvine, 2020) Standardised test scores were obtained from school records with appropriate permissions.

For data analysis, qualitative data from interviews and observations was transcribed verbatim and analysed using thematic analysis (Peel, 2020), allowing for the identification of key themes related to mathematical concepts integration, educational equity, and implementation challenges. Quantitative data from surveys was analysed using descriptive statistics to understand changes in students' attitudes towards mathematics; inferential statistics such as paired-sample t-tests and multivariate analysis of variance (MANOVA) were used for comparing pre- and post-intervention scores or differences among different student groups (Baltzell & Akhtar, 2014; Tam et al., 2020). Standardised test scores were analysed using similar statistical techniques to understand achievement disparities across diverse student demographics. This rigorous approach ensured a comprehensive exploration that answers our research questions and contributes substantively towards improving educational practice.

III. RESULTS

The data collected for this study encompassed a wide range of qualitative and quantitative measures, providing a robust foundation for exploring the integration of mathematical concepts with elements of community, culture, and place in instructional design. This wealth of data was gathered to address several main research questions guiding our study. By analysing our collected data within the context of these research questions, we strive for a comprehensive understanding and practical solutions that can enhance educational practice.

Integration Strategies for Mathematics with Community, Culture, and Place

Analysis of teacher interviews revealed five central themes. First, teachers demonstrated varied understanding and perception of the conceptual framework. One teacher noted, "*I think integrating mathematics with our local culture and community can make learning more meaningful for students*." However, others initially found it challenging but acknowledged its potential upon implementation: "*At first, it was challenging to envision how math could be connected to our community or culture. Nevertheless, as I started implementing it, I saw its potential*." Second, teachers employed diverse pedagogical strategies for integration; one described a project where "*students used mathematical concepts to solve a local environmental issue*," while another leveraged interdisciplinary collaboration: "*We collaborated with the local arts centre...where students explored geometric patterns in traditional art forms*."

Thirdly, many teachers reported enhanced student engagement and comprehension when lessons were tied to their communities or cultures: "*My students seem more interested in math when they see its relevance to their own lives...when we connect math lessons to real-world contexts, students grasp the concepts better*." Fourthly, this integrated approach was particularly beneficial for marginalised students who traditionally struggle in mathematics: "*This approach seems particularly beneficial for my students who usually struggle in math...Connecting mathematics with elements of our diverse cultures makes all students feel valued and included*." Finally, despite challenges such as time constraints—"*The main challenge is finding time for planning these integrated lessons*"—and resistance from parents—"*At times there's resistance from parents who prefer traditional teaching methods*"—teachers shared instances where these barriers were overcome through creative problem-solving or collaboration. These findings underscore the potential benefits and practical challenges of implementing this innovative instructional framework.

Classroom observations revealed that teachers successfully integrated mathematical concepts with community, culture, and place elements in their instructional design. They incorporated local cultural elements into lessons and used real-world examples from the community to elucidate mathematical concepts. This integration significantly enhanced student engagement, especially during lessons with familiar cultural or community-related content. Moreover, students demonstrated improved understanding when mathematical concepts were contextualised within real-world scenarios. These findings support the proposed framework's efficacy and align with prior research emphasising the benefits of contextual learning (Czocher et al., 2020; Tobe, 2023). A noteworthy outcome was the positive contribution of this integrated approach towards educational equity. Observations indicated that marginalised students who traditionally struggled in mathematics showed improved performance due to content relatability. The sense of inclusion was amplified by

Journal of Education, Teaching, and Learning
Volume ... Number ... month ... . Page ...-...
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incorporating diverse cultures into mathematics learning—suggesting a potential reduction in achievement gaps among students from diverse backgrounds (Czocher et al., 2020). This underlines both promising implications for improving math education through our framework and areas needing further exploration for optimal implementation.

Impact on Student Engagement and Understanding of Mathematics

A total of 292 students from three urban-state junior high schools in Medan participated in the study. The SEI was used to measure student engagement with mathematics before and after the instructional design intervention. Before the intervention, engagement scores ranged from 21 to 78 with a mean score of 44.73 (SD = 9.218). After the intervention, there was a noticeable increase in engagement scores which ranged from 37 to 99 with a mean score of 63.66 (SD = 9.404). Similarly, understanding of mathematical concepts—assessed via tests—also showed improvement post-intervention. Pre-intervention test scores ranged from 22 to 82 with an average score of 52.43 (SD =10.571). Post-intervention test scores showed an increase ranging from 39 to 105 with a mean score of .50 (SD =10 .570).

Table 1.
Descriptive statistics

	N	Minimum	Maximum	Mean	Std. Deviation
Pre_Eng	292	21	78	44.73	9.218
Post_Eng	292	37	99	63.66	9.404
Pre_Und	292	22	82	52.43	10.571
Post_Und	292	39	105	73.50	10.570
Valid N (listwise)	**292**				

For the understanding of mathematical concepts, the Shapiro-Wilk statistic was .994 (p = .375), suggesting that the differences between pre- and post-intervention test scores were not significantly different from a normal distribution. Similarly, for student engagement, the Shapiro-Wilk statistic was .995 (p = .379) indicating that these difference scores also followed a normal distribution. The Kolmogorov-Smirnov test with Lilliefors significance correction also indicated non-significant results for the understanding of mathematical concepts (D(292) = .058, p = .018) and student engagement (D(292) = .053, p = .049). However, given that this test has lower power when compared to Shapiro-Wilk's, especially with larger samples like ours and it tends to be more sensitive towards deviations in tails; its results are considered secondary in our analysis. Thus based on Shapiro-Wilk's results & and considering sample size along with the purpose and robustness of subsequent parametric tests like paired-sample t-tests against violations of assumptions; we concluded that the assumption of normality was sufficiently met allowing us to proceed with planned analyses.

Table 2.
Paired Samples Test

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair 1	Pre_Eng-Post_Eng	–18.928	7.179	.420	–19.755	–18.101	–45.051	291	.000
Pair 2	**Pre_Und-Post_Und**	**–21.068**	**9.553**	**.559**	**–22.169**	**–19.968**	**–37.686**	**291**	**.000**

Paired-sample t-tests were conducted to assess the impact of the instructional design intervention on both student engagement with mathematics and their understanding of mathematical concepts. For student engagement, there was a significant increase from pre-intervention (M = 44.73, SD = 9.218) to post-intervention (M = 63.66, SD = 9.404), with a mean increase of –18.928 (SD = 7.179), t(291) = –45 .051, p < .001 (two-tailed). The negative sign indicates that post-intervention scores were higher than pre-intervention scores. Similarly, for understanding mathematical concepts, there was a significant difference between pre-intervention (M = 52.43, SD =10.571) and post-intervention test scores (M = 73.50, SD = 10.570), with a mean increase of –21.068 (SD = 9 .553), t(291) = –37.686, p < .001(two-tailed). The 95% confidence intervals for the mean difference between pre- and post-tests ranged from –19.755 to –18.101 for engagement and from –22.169 to –19.968 for understanding respectively. These results suggest that our instructional design intervention had a significant positive effect on both students' engagement with mathematics as well as their understanding of mathematical concepts.

Journal of Education, Teaching, and Learning
Volume ... Number ... month ... . Page ...-...
p-ISSN: 2477-5924 e-ISSN: 2477-8478

Contribution to Educational Equity

To evaluate the contribution of our integrated approach towards educational equity, we analysed changes in standardised test scores across diverse student demographics using a MANOVA. The main effects of grade level and ethnicity on student engagement with mathematics and understanding of mathematical concepts were examined, as well as the changes in these outcomes from pre- to post-intervention. Moreover, potential interaction effects were also explored to ascertain whether the effect of our instructional design intervention was contingent on grade level or ethnicity. By employing MANOVA, we are able to examine multiple dependent variables simultaneously and consider how they interact with each other, providing a more comprehensive view of students' mathematical learning experience than could be achieved through separate univariate analyses. This approach aligns with our commitment to educational equity by enabling us to identify not only which groups might be underperforming but also where interventions might be most effective or necessary. Through this nuanced understanding, we aim to contribute meaningfully towards fostering equitable educational environments where all students have an equal opportunity for success in mathematics.

Table 3. Demographic characteristics of the sample

School	Grade Level	Ethnicity							
		Batak	**Javanese**	**Malay**	**Minangkabau**	**Acehnese**	**Indian**	**Chinese**	**Total**
SMP Negeri 1	1st year	11	8	5	3	3	2	1	33
	2nd year	10	7	6	4	2	2	2	33
	3rd year	9	9	4	4	3	1	1	31
SMP Negeri 7	1st year	11	9	5	3	2	2	1	33
	2nd year	9	8	7	3	3	2	1	33
	3rd year	10	7	5	3	2	1	2	30
SMP Negeri 11	1st year	10	8	5	4	2	2	1	32
	2nd year	11	9	6	3	3	1	1	34
	3rd year	10	8	5	5	3	1	1	33
Total		91	73	48	32	23	14	11	292

The assumption of normality was tested for each dependent variable within each subgroup of the independent variables (grade level and ethnicity) using both the Kolmogorov-Smirnov and Shapiro-Wilk tests. For grade level, the Kolmogorov-Smirnov test showed that the pre-engagement scores for 1st-year students and pre-understanding scores for both 1st and 2nd-year students were significantly different from a normal distribution ($p < .05$). However, all other combinations of grade level and dependent variable did not significantly deviate from normality ($p > .05$). The Shapiro-Wilk test further confirmed these findings, with all combinations achieving p-values greater than .05 except for post-engagement scores among 2nd-year students. When considering ethnicity, the Kolmogorov-Smirnov test revealed significant deviations from normality in pre-engagement scores among Javanese students as well as post-engagement and post-understanding scores among Acehnese and Chinese students. However, all other ethnic groups did not show significant deviation from a normal distribution across all dependent variables. The Shapiro-Wilk test generally supported these findings but indicated additional potential concerns with post-engagement scores among Acehnese students as well as pre- and post-understanding scores among Chinese students. While these results suggest some violations of the assumption of univariate normality within certain subgroups, it is important to note that MANOVA is robust to minor violations of this assumption especially when sample sizes are relatively large.

The assumptions of multicollinearity were examined for the regression models predicting pre-intervention engagement, post-intervention engagement, pre-intervention understanding, and post-intervention understanding. The Variance Inflation Factor (VIF) and Tolerance statistics, both indicators of multicollinearity, were within acceptable ranges across all models. Specifically, VIF values did not exceed 1 for any predictor in any model. This is well below the commonly used cutoff of 5 or a more stringent cutoff of 2, suggesting no evidence of severe multicollinearity. Similarly, Tolerance statistics were equal to 1 across all predictors in all models, which is far above the threshold value of 0.1 or even a more conservative value of 0.2 that might indicate concerns about multicollinearity. In terms of individual predictors' significance levels in each model, none reached statistical significance at conventional levels (.05). However, this interpretation does not directly pertain to checking for multicollinearity but rather informs about the predictive relationship between independent variables and dependent variables. Therefore, these results suggest that there is no violation of the assumption of the absence of multicollinearity in these data when predicting students' engagement and understanding scores from grade level and ethnicity.

Journal of Education, Teaching, and Learning
Volume ... Number ... month ... . Page ...-...
p-ISSN: 2477-5924 e-ISSN: 2477-8478

Table 4.
Multivariate Tests

Effect		**Value**	**F**	**Hypothesis df**	**Error df**	**Sig.**	**Partial Eta Squared**
Intercept	Pillai's Trace	.984	4113.414[b]	4.000	268.000	.000	.984
	Wilks' Lambda	.016	4113.414[b]	4.000	268.000	.000	.984
	Hotelling's Trace	61.394	4113.414[b]	4.000	268.000	.000	.984
	Roy's Largest Root	61.394	4113.414[b]	4.000	268.000	.000	.984
Grade_Level	Pillai's Trace	.002	.066	8.000	538.000	1.000	.001
	Wilks' Lambda	.998	.066[b]	8.000	536.000	1.000	.001
	Hotelling's Trace	.002	.066	8.000	534.000	1.000	.001
	Roy's Largest Root	.002	.112[c]	4.000	269.000	.978	.002
Ethnicity	Pillai's Trace	.095	1.098	24.000	1084.000	.339	.024
	Wilks' Lambda	.908	1.100	24.000	936.150	.336	.024
	Hotelling's Trace	.099	1.101	24.000	1066.000	.334	.024
	Roy's Largest Root	.058	2.609[c]	6.000	271.000	.018	.055
Grade_Level * Ethnicity	Pillai's Trace	.141	.824	48.000	1084.000	.798	.035
	Wilks' Lambda	.866	.821	48.000	1034.403	.803	.035
	Hotelling's Trace	.147	.818	48.000	1066.000	.808	.036
	Roy's Largest Root	.060	1.352[c]	12.000	271.000	.189	.056

a. Design: Intercept + Grade_Level + Ethnicity + Grade_Level * Ethnicity
b. Exact statistic
c. The statistic is an upper bound on F that yields a lower bound on the significance level.

For the multivariate tests, all p-values for the main effects of grade level and ethnicity as well as their interaction effect were greater than .05. Therefore, we fail to reject the null hypothesis that there are no differences in the combined dependent variables for different levels of grade or ethnicity or their interaction. Looking at between-subjects effects for each dependent variable separately also revealed non-significant results. For Pre_Eng, Post_Eng, Pre_Und, and Post_Und scores respectively: The main effect of grade level was not significant [$F(2,271)=0.101, p=.904$; $F(2, 271) = .018$, $p = .982$; $F(2,271) = .085$, $p = .918$; $F(2, 271) = .008$, $p = .992$], indicating no significant difference in scores across different grades both before and after the intervention. Similarly, the main effect of ethnicity was not significant [$F(6, 271) = 1.417$, $p = .208$; $F(6,271) = 1.362$, $p = .230$; $F(6, 271) = 1.111$, $p = .356$; $F(6, 271) = 1.611$, $p = .144$], suggesting that there is no significant difference in scores among different ethnic groups both before and after intervention. Finally, the interaction effect between grade level and ethnicity was also not statistically significant [$F(12, 271) = .780$, $p = .671$; $F(12, 271) = .765$, $p = .687$; $F(12, 27) = .602$, $p = .840$; $F(12, 27) = .672$, $p = .778$], indicating that changes from pre- to post-intervention do not depend on a combination of student's grade level and ethnicity.

Table 5. Tests of Between-Subjects Effects

Source	**Dependent Variable**	**Type III Sum of Squares**	**df**	**Mean Square**	**F**	**Sig.**	**Partial Eta Squared**
Corrected Model	Pre_Eng	1532.625[a]	20	76.631	.895	.593	.062
	Post_Eng	1481.746[b]	20	74.087	.828	.679	.058
	Pre_Und	1628.905[c]	20	81.445	.715	.810	.050
	Post_Und	2017.920[d]	20	100.896	.897	.592	.062
Intercept	Pre_Eng	337452.627	1	337452.627	3943.064	.000	.936
	Post_Eng	687605.782	1	687605.782	7683.003	.000	.966
	Pre_Und	452787.718	1	452787.718	3972.758	.000	.936
	Post_Und	895467.361	1	895467.361	7958.775	.000	.967
Grade_Level	Pre_Eng	17.204	2	8.602	.101	.904	.001
	Post_Eng	3.308	2	1.654	.018	.982	.000
	Pre_Und	19.466	2	9.733	.085	.918	.001
	Post_Und	1.728	2	.864	.008	.992	.000

Journal of Education, Teaching, & Learning
Volume ... Number ... month ... . Page ...-...
p-ISSN: 2477-5924 e-ISSN: 2477-8478

Ethnicity	Pre_Eng	727.566	6	121.261	1.417	.208	.030
	Post_Eng	731.437	6	121.906	1.362	.230	.029
	Pre_Und	759.913	6	126.652	1.111	.356	.024
	Post_Und	1087.335	6	181.222	1.611	.144	.034
Grade_Level * Ethnicity	Pre_Eng	800.575	12	66.715	.780	.671	.033
	Post_Eng	821.061	12	68.422	.765	.687	.033
	Pre_Und	823.886	12	68.657	.602	.840	.026
	Post_Und	907.426	12	75.619	.672	.778	.029
Error	Pre_Eng	23192.539	271	85.581			
	Post_Eng	24253.689	271	89.497			
	Pre_Und	30886.725	271	113.973			
	Post_Und	30491.080	271	112.513			
Total	Pre_Eng	609026.000	292				
	Post_Eng	1209129.000	292				
	Pre_Und	835242.000	292				
	Post_Und	1609966.000	292				
Corrected Total	Pre_Eng	24725.164	291				
	Post_Eng	25735.435	291				
	Pre_Und	32515.630	291				
	Post_Und	32509.000	291				
a. R Squared = .062 (Adjusted R Squared = –.007)							
b. R Squared = .058 (Adjusted R Squared = –.012)							
c. R Squared = .050 (Adjusted R Squared = –.020)							
d. R Squared = .062 (Adjusted R Squared = –.007)							

In summary, the MANOVA results suggest that neither students' grade level nor their ethnicity significantly influence pre- or post-intervention engagement or understanding scores alone or interactively. This suggests that our instructional design intervention did not differentially impact students based on these demographic factors, in line with our commitment towards educational equity.

IV. DISCUSSION AND CONCLUSION

A range of understandings and opinions about the conceptual framework for integrating mathematics with community, culture, and place were found through analysis of teacher interviews. At first, some teachers found it difficult to see how mathematics might be connected to community or culture, while others saw its potential to give pupils a more meaningful education. But as teachers saw the usefulness of the program, these difficulties were frequently overcome (Mayger & Hochbein, 2021; Seyhan, 2019). Instructors used a variety of pedagogical approaches to integrate their lessons, from interdisciplinary partnerships with nearby art centres to initiatives that used mathematical concepts to address environmental challenges in the community (Belbase et al., 2022; Sevimli & Ünal, 2022). Teachers showed resilience by overcoming time restrictions through creative problem-solving or teamwork, even though they were identified as a significant difficulty, especially when organizing integrated classes (Alakrash & Razak, 2021). Another obstacle that surfaced was parental reluctance to traditional teaching approaches; nonetheless, stories of effective interventions were recounted. Remarkably, when classes were connected to local communities or cultures, many teachers reported improved student involvement and comprehension. This finding is consistent with previous research that highlights the advantages of contextualized learning (Kaminski & Sloutsky, 2020; Lestari et al., 2021). Teachers also noted that by helping marginalized students who have historically struggled in mathematics feel valued and included, this integrated approach was especially helpful to them (Gardee, 2019). This is an important insight into how such an approach can support educational equity. These results highlight the potential advantages and real-world difficulties of putting this creative teaching framework into practice—a topic that needs more research to be carried out as effectively as possible.

Observations in the classroom provide insight into the difficulties teachers have when fusing mathematical ideas with aspects of geography, culture, and society. Teachers faced significant challenges even though they were able to successfully include aspects of the local culture in their classes and explain mathematical concepts using community examples. Time restrictions were identified as a major obstacle to creating integrated lessons, which is consistent with earlier studies showing that contextualized learning requires more preparation time (Gonçalves et al., 2020). Parental resistance to traditional teaching methods was another reported barrier. Teachers showed tenacity in the face of these difficulties by working together or using creative problem-solving techniques to come up with workable solutions, proving their dedication to this cutting-edge teaching strategy (Zhao, 2020). The findings highlighted the possible advantages of this strategy, including increased student engagement, better comprehension of mathematical ideas when placed in the context of real-world situations, and a favourable contribution to educational equity, especially for marginalized students who have historically struggled with mathematics. These results point to areas that require more research for the best possible implementation as well as promising implications for enhancing math teaching using our approach.

The results of this study provide compelling evidence for the efficacy of an instructional model that integrates mathematics with community, culture, and place in enhancing both student engagement and understanding of mathematical concepts. We observed a significant increase in student engagement scores following the implementation of our instructional intervention, with mean scores rising from 44.73 pre-intervention to 63.66 post-intervention ($t(291) = –45 .051$, $p < .001$). This result suggests that contextualizing mathematical instruction within students' cultural and community contexts can foster greater involvement in learning activities. In parallel, we also found a substantial improvement in students' understanding of mathematical concepts as evidenced by increased test scores post-intervention—from a mean score of 52.43 pre-intervention to 73.50 post-intervention ($t(291) = –37.686$, $p < .001$). This finding aligns with previous research suggesting that culturally responsive teaching strategies can enhance academic achievement (Civitillo et al., 2019). These findings have important implications for instructional design within mathematics education particularly within multicultural urban environments like Medan's junior high schools where this study was conducted: they underscore the potential benefits of integrating elements from students' community and culture into mathematics instruction to enhance both student engagement and academic performance. However, while these results are promising they are context-specific and further research is needed to examine if these effects generalize across different settings or populations.

The multivariate analysis did not yield any significant main effects or interaction effects for grade level and ethnicity on both engagement and understanding scores pre- and post-intervention (all $p > .05$). These non-significant results suggest that the integrated instructional model did not differentially impact students based on their grade level or ethnicity. This is a crucial finding, indicating that this instructional approach can be equally effective across diverse student populations, thereby potentially reducing disparities in mathematical achievement. Educational equity has been a longstanding goal in education (Campbell, 2021; Chine et al., 2022), and mathematics is often a subject area where disparities are evident (Kroesbergen et al., 2023). Thus, an instructional model that does not show differential impacts based on demographic factors like grade level or ethnicity can be seen as contributing positively towards this goal (Asmida et al., 2018; Fadillah et al., 2017; Meldi et al., 2022). It suggests that integrating mathematics with community, culture, and place could be a powerful strategy to ensure all students have an equal opportunity to succeed in mathematics irrespective of their backgrounds. However, it should be noted that while our findings are promising they are context-specific. Further research would be beneficial to confirm these results across different settings and populations. The limitations of this research are the research subjects, namely junior high school students. Then also, the location and research sample only selected schools in Medan City, North Sumatra Province. Thus, the research results are very limited and cannot be compared and used completely and comprehensively with problems that occur in schools and other locations.

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