HistoMath: Integrating Ethnomathematics and Augmented Reality Based on Malay Sultanate of Deli's Culture to Enhance Geometry Learning in Inclusive Classrooms

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Abstract **– The integration of cultural context and digital technology is a promising approach to improve mathematics learning in inclusive classrooms with diverse learner needs. Previous research suggests that ethnomathematics and augmented reality (AR) can enhance conceptual understanding and student engagement, yet application-based implementations in inclusive elementary settings are limited. This study examines the development and impact of HistoMath, an interactive application combining ethnomathematics and AR to contextualize plane geometry through local architectural heritage. Using a Research and Development design based on the Lee and Owens model, HistoMath was developed and validated by experts before being implemented in three inclusive elementary schools in Medan City. Participants included fourth-grade students who used HistoMath within a Discovery Learning framework. The application features competency modules, 3D visualizations, AR videos, audiovisual quizzes, and competency assessments, with a teacher dashboard for monitoring progress and responses. Findings show that HistoMath achieved high expert validity and usability, and implementation produced improvements in students' geometry outcomes and learning engagement. Statistical analysis indicates a large portion of variance is associated with HistoMath, while remaining variance is attributable to internal and external learner factors. The study provides recommendations for scale-up and further longitudinal research in diverse contexts. In conclusion, HistoMath offers a culturally grounded, technology-enhanced medium that supports inclusive mathematics learning and promotes local heritage exploration and supports teacher professional development and classroom adaptation.**

Keywords **– 3D, ethnomathematics, Augmented Reality, plane figure.**

1. Introduction

Indonesia, with its extensive cultural diversity across the archipelago, highlights the importance of integrating cultural values into education. The term culture is derived from the Sanskrit word *buddayah*, which is the plural form of *buddhi*, meaning thought or intelligence [1], [2]. In a broader sense, culture represents the collective knowledge, beliefs, arts, morals, customs, and skills of a community. Therefore, incorporating cultural elements into the educational curriculum is essential, particularly in subjects such as mathematics at the elementary level. Integrating cultural contexts into education can enrich the learning process and foster a deeper understanding of knowledge among students.

Mathematics plays an important role in human development and is closely related to various aspects of life such as religion, social interaction, language, and economic activities [3], [4], [5], [6]. It also addresses fundamental needs such as measurement, modeling, and problem solving in everyday situations [7], [8].

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Mathematics is not separated from cultural contexts, but rather intertwined with the social and cultural characteristics of different communities. This relationship has led to the concept of ethnomathematics [9]. Previous studies indicate a strong connection between cultural practices and mathematical understanding, highlighting the importance of ethnomathematics in education [10], [11], [12], [13], [14].

Ethnomathematics enables students to understand, express, and apply mathematical concepts through their everyday cultural experiences [15]. This concept has been widely explored in various communities and shows how cultural contexts can enrich mathematics learning [16], [17], [18], [19], [20]. Ethnomathematics is also consistent with constructivist learning theory, which emphasizes that knowledge is constructed based on students' prior experiences and interactions with their environment [21], [22], [23], [24], [25]. In addition, recognizing the cultural diversity of students can support inclusive learning environments and increase students' confidence in the learning process [26], [27], [28], [29], [30].

Culturally focused education can be categorized into three types, namely learning about culture, learning with culture, and learning through culture. Four important aspects of culturally based education include content and competencies, relevance, learning processes, and evaluation within cultural contexts [31], [32], [33], [34], [35], The implementation of ethnomathematics in education is also aligned with the objectives of the Merdeka Curriculum introduced by the Indonesian Ministry of Education, Culture, Research, and Technology. This curriculum promotes flexible, student centered, and meaningful learning environments that appreciate local wisdom [36], [37], [38], [39], [40].

Inclusive schools are educational institutions that integrate regular students and students with special needs in the same learning environment [41], [42], [43]. These schools aim to provide equal access to quality education for all learners. To support inclusive learning, adjustments in curriculum, teaching methods, facilities, and assessment strategies are necessary so that all students can develop their potential optimally [44]. According to data from the North Sumatra Provincial Education Office in 2020, there are 71 inclusive elementary schools in the province. The study was conducted in three inclusive elementary schools in Medan City, selected based on their implementation of inclusive education practices.

To address these issues, the integration of technology and local cultural contexts is considered important in mathematics learning.

Government regulations also emphasize the revitalization of cultural values and local wisdom in educational practices. Therefore, the research team proposes an innovative learning medium called HistoMath. HistoMath is an interactive learning application based on ethnomathematics related to the cultural heritage of the Deli Sultanate. The application utilizes the architectural elements of Masjid Raya Al Mashun and Maimun Palace and integrates Augmented Reality technology to support the learning of plane geometry concepts in inclusive classrooms. A preliminary survey also showed that a large proportion of students were interested in using digital applications for culturally based mathematics learning.

The novelty of this research lies in the development of the HistoMath application, which integrates ethnomathematics with Augmented Reality technology to support geometry learning in inclusive classrooms. The application includes several features such as competency modules, three dimensional visualizations of Masjid Raya Al Mashun and Maimun Palace, ethnomathematics based Augmented Reality videos, learning materials, interactive quizzes, and competency tests. These features are designed to help students understand geometric concepts through culturally meaningful representations.

Previous studies have also shown that historical buildings and cultural artifacts contain mathematical concepts that can be used as learning contexts. For example, studies have identified geometric elements in mosque architecture and cultural ornaments that reflect mathematical principles [45], [46], [47]. Building on these findings, this study aims to examine the validity, practicality, and effectiveness of the HistoMath application in improving the quality of plane geometry learning for students in inclusive elementary schools in Medan City. In addition, the study aims to expand students' understanding of geometric concepts by exploring mathematical ideas embedded in local historical architecture through interactive three dimensional and Augmented Reality visualizations.

2. Methodology

This study employs a Research and Development (R&D) approach based on the instructional design framework proposed by [48]. The R&D approach was selected to systematically develop and evaluate an educational media application named HistoMath, which integrates Augmented Reality (AR) technology with ethnomathematics concepts. The development process follows five main stages, namely assessment or analysis, design, development, implementation, and evaluation.

The assessment phase aimed to identify the learning needs of teachers and students in inclusive elementary schools in Medan. The study was conducted in three inclusive elementary schools in Medan City, namely UPT SDN 067261 Medan (School A), UPT SDN 064007 Medan (School B), and UPT SDN 064999 Medan (School C). Data were collected through observations, interviews, and surveys with fourth-grade teachers and students, focusing on learning difficulties, technological needs, and the integration of local cultural elements in mathematics.

The results informed the development of culturally relevant instructional media, incorporating architectural elements from Masjid Raya Al Mashun and Maimun Palace.

In the design phase, a prototype of the HistoMath application was developed based on ethnomathematics principles, integrating geometric concepts with local cultural heritage while ensuring usability and accessibility for inclusive classrooms. The workflow of the HistoMath media development process is illustrated in Figure 1, which describes the sequential stages of analysis, design, development, implementation, and evaluation in the application development process.

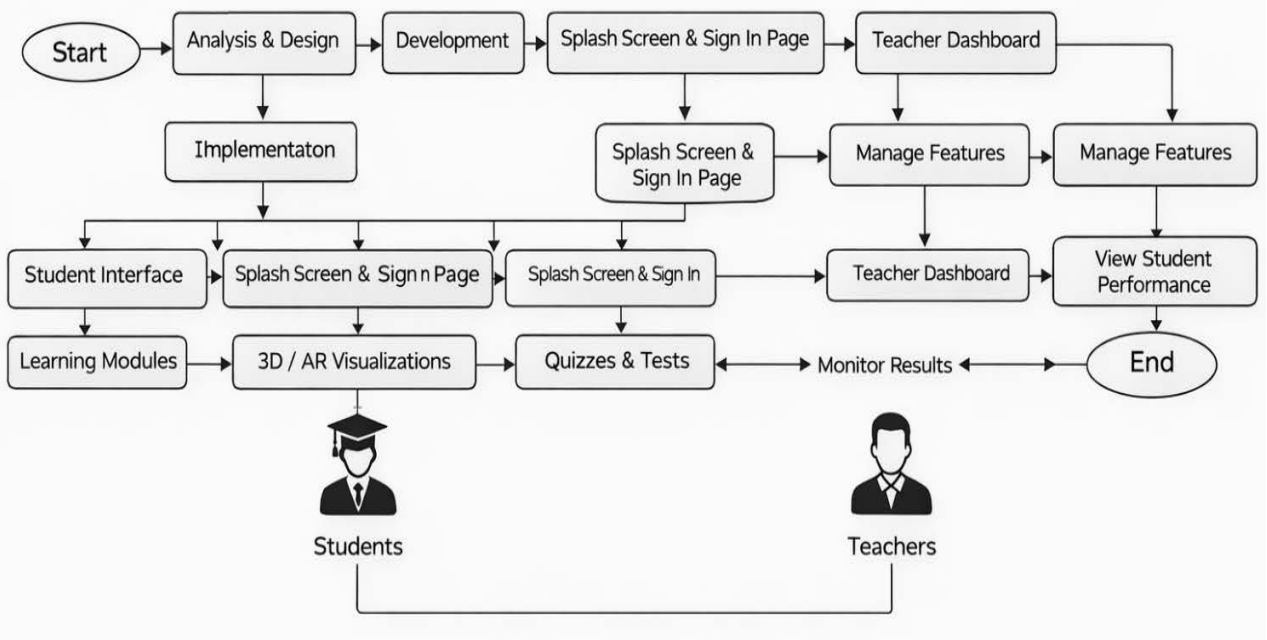

Figure 1. HistoMath media workflow

The development phase involved transforming the design prototype into a functional digital learning application using 3D visualization and Augmented Reality technology. During this stage, content validity was assessed through expert judgment involving specialists in media, subject content, language, and cultural studies, while the reliability of the instruments was evaluated using Cronbach's alpha. The purpose of this validation process was to evaluate the feasibility, accuracy, and cultural appropriateness of the application. Feedback from the expert validators was used to revise and improve the application before it was implemented in the classroom.

The implementation phase involved pilot testing the HistoMath application in the three participating schools. Teachers and students participated in the learning activities using the application.

During this phase, data related to usability and practicality were collected through response questionnaires, interviews, and classroom observations.

The evaluation phase aimed to examine the effectiveness of the HistoMath application in improving students' understanding of plane geometry concepts. The evaluation was conducted using pre-tests and post tests administered to students, as well as qualitative data collected through observation sheets, interviews, and response questionnaires. These data were analyzed to determine the impact of the application on students' learning outcomes and learning engagement.

Through this methodological framework, the study integrates both quantitative and qualitative data to ensure the reliability and validity of the research findings while addressing the learning needs of students in inclusive classrooms.

3. Results

This section presents the findings obtained from the development and implementation of the HistoMath application. The results include the analysis of the media development process, the improvement of students' learning outcomes, students' responses toward the application, and the statistical analysis examining the impact of HistoMath on students' learning performance. These results provide evidence of the feasibility, practicality, and effectiveness of the developed learning media in supporting geometry learning in inclusive elementary classrooms.

3.1. HistoMath Media Development Analysis

This section presents the results of the development of the HistoMath learning media based on the Research and Development model [48]. The development process consisted of five stages: analysis, design, development, implementation, and evaluation. Each stage was conducted systematically to ensure that the HistoMath application meets pedagogical, technological, and cultural requirements for mathematics learning in inclusive classrooms.

The final product of this study is an educational mobile application called HistoMath, a three-dimensional interactive ethnomathematics learning media based on the cultural heritage of the Deli Sultanate. The application integrates Augmented Reality technology and three-dimensional visualization to facilitate the learning of plane geometry concepts for students in inclusive elementary schools in Medan.

1) Analysis Phase

In the analysis phase, the research team conducted a needs assessment and front-end analysis to identify students' characteristics and learning difficulties. Data were collected through classroom observations, interviews with teachers, and surveys administered to students.

The needs assessment aimed to identify the gap between the current learning conditions and the expected learning outcomes. It also examined the difficulties faced by students in understanding plane geometry concepts and identified the factors contributing to these challenges. The analysis involved fourth-grade students from School A, School B, and School C. In addition, interviews were conducted with fourth grade teachers from the three schools to obtain insights regarding the learning process, instructional challenges, and the need for technology-based learning media in mathematics education.

2) Design

During the design phase, the researchers developed the conceptual structure of the HistoMath application. This stage involved preparing the learning content and designing the application features based on ethnomathematics principles. A flowchart was created to describe the structure and navigation of the interactive learning media. The flowchart illustrates the sequence of application features and user interactions, enabling users to understand the application workflow more easily. The design phase also included the preparation of evaluation instruments used to assess the validity and practicality of the developed media, including expert validation sheets and questionnaires for both students and teachers. The interface of the HistoMath application, as shown in Figure 2, presents several main features, including the main menu, access to learning modules, ethnomathematics-based materials, and Augmented Reality (AR) visualization components. The interface is designed to be user-friendly and accessible for inclusive classrooms, allowing students to interact with geometric concepts through visual and interactive representations. These features support students in understanding abstract mathematical concepts by linking them to cultural contexts.

Figure 2. HistoMath media app

3) Development Phase

The development phase involved producing the HistoMath application based on the previously designed prototype. The application was developed by integrating three-dimensional visualization and Augmented Reality technology to support the learning of geometric concepts.

To ensure the quality of the media, a validation process was conducted by five experts from different fields, including content experts, media experts, linguists, cultural experts, and research instrument experts.

As shown in Table 1, the validators consist of professionals from both academic institutions and elementary schools, representing diverse expertise relevant to the development of the HistoMath application. These include a material expert from an inclusive elementary school, a media expert from a university, a linguist, a cultural expert, and an instrument expert. This diversity of expertise ensures that the developed application meets standards in terms of content accuracy, media design, language clarity, cultural relevance, and assessment validity.

Table 1. Expert validators

Expert	Validator Name	Agency
Material	Ajeng Laras Suci Nasution, S.Pd	School A
Media	Dra. Tuti Zubaidah, M.Pd.	Syah Kuala University
Language	Prof. Amrin Saragih, MA, PhD	Medan State University
Culture	Hasan Al-Banna, S.Pd	Sumatran Cultural Writers

The validation process aimed to evaluate the feasibility, accuracy, and appropriateness of the developed learning media. The experts provided suggestions and recommendations that were used to revise and improve the application before its implementation in the classroom. As shown in Table 2, all aspects of the HistoMath application achieved high validation scores across different expert categories. The material expert rated the application at 92%, while the media expert and linguist provided scores of 91% and 91.24%, respectively. The cultural expert assigned the highest score of 100%, indicating strong alignment with local cultural values.

In addition, the validation of supporting instruments, including lesson plans, pre-tests, post-tests, and response questionnaires, also showed high validity scores ranging from 86% to 92%. Overall, the average validation score reached 90.63%, which falls into the “highly valid” category. These findings indicate that the HistoMath application meets the required standards in terms of content accuracy, media design quality, language clarity, cultural relevance, and instructional effectiveness, making it suitable for implementation in inclusive elementary classrooms.

Table 2. HistoMath media validity analysis

Validator		Valuation	Category
Material Expert		92%	Highly Valid
Media Expert		91%	Highly Valid
Linguist		91,24%	Highly Valid
Cultural Expert		100%	Highly Valid
Instrument Expert	Lesson Plan (RPP)	86%	Highly Valid
	Pre-test	88%	Highly Valid
	Post-test	88%	Highly Valid
	Student Response Questionnaire	87,27%	Highly Valid
	Teacher Response Questionnaire	92%	Highly Valid
Average		90,63%	**Highly Valid**

4) Implementation Phase

The implementation phase involved testing the practicality of the HistoMath application through one to one testing and small group testing.

The one-to-one trial was conducted on June 20, 2024 at SD Swasta Tri Bakti involving three students. This stage aimed to evaluate the usability and clarity of the application from the perspective of individual users.

The small group trial was conducted on June 21, 2024 at the same school involving ten fourth grade students. This stage aimed to assess the functionality of the application and its ability to support collaborative learning activities.

The results of the practicality analysis are presented in Table 3. The average practicality score of the HistoMath application reached 85 percent, which is categorized as very practical.

Table 3. HistoMath Media Practicality Analysis

Trial	Valuation	Category
One to One Trial	84%	Very Practical
Small Group Trial	86%	Very Practical
Average	85%	**Very Practical**

5) Evaluation Phase

The evaluation phase aimed to determine the effectiveness of the HistoMath application in improving students' understanding of plane geometry concepts and their learning engagement. The effectiveness criteria were defined based on two indicators: (1) at least 85% of students achieved a minimum score of 75, and (2) there was an improvement in students' learning responses during the learning process. The evaluation employed a mixed-method approach, utilizing quantitative data from pre-tests and post-tests, as well as qualitative data obtained from observations, interviews, and student response questionnaires. The analysis was conducted by comparing the results of Trial I and Trial II. As presented in Table 4, students' learning outcomes improved across all participating schools, indicating a better understanding of plane geometry concepts after using the HistoMath application. In addition, Table 5 shows a significant increase in students' response scores, reflecting higher engagement and more positive perceptions toward the learning process.

The Improvement in both learning outcomes and student responses indicates that the integration of ethnomathematics and Augmented Reality in HistoMath provides meaningful, contextual, and interactive learning experiences. This approach enables students, particularly in inclusive classrooms, to better visualize abstract concepts and actively participate in learning activities. These findings are consistent with constructivist learning theory, which emphasizes that knowledge is constructed through meaningful experiences.

Therefore, it can be concluded that the HistoMath application meets the effectiveness criteria and is effective in enhancing both cognitive and affective aspects of learning.

3.2. The Improvement of Student Learning Outcomes Using HistoMath

This section presents the analysis of students' learning outcomes based on the results of pre-tests and post-tests conducted during Trial I and Trial II. The comparison between these scores was used to measure the improvement in students' understanding of plane geometry concepts after using the HistoMath application. As presented in Table 4, students' learning outcomes showed consistent improvement across all participating schools. The average score in School A increased from 79.12 in Trial I to 81.96 in Trial II. Similarly, School B demonstrated a significant improvement from 75.38 to 81.96, while School C showed an increase from 75.56 to 81.85.

In addition to the increase in average scores, the lowest scores in each school also improved, indicating that students with lower initial performance experienced learning gains. Furthermore, the highest scores remained stable or increased slightly, suggesting that the application supports both low- and high-achieving students.

Overall, these results indicate that the use of the HistoMath application contributes positively to improving students' conceptual understanding of plane figures, particularly in inclusive classroom settings.

Table 4. Description of student learning outcome test

Information	School A	School B	School C
	Trial I	Trial II	Trial I
Highest Score	88	90	90
Lowest Score	55	66	40
Average	79,12	81,96	75,38

3.3. The Improvement of Student Response Using HistoMath

This section presents the analysis of students' responses toward the use of the HistoMath application during the learning process. Student responses were collected using questionnaires administered during Trial I and Trial II. The purpose of this analysis was to evaluate changes in students' engagement and perceptions toward the learning media. As presented in Table 5, student responses showed consistent improvement across all participating schools. The average response score in School A increased from 73.5 in Trial I to 80.9 in Trial II. Similarly, School B demonstrated an increase from 70.5 to 82.7, while School C showed improvement from 76.5 to 86.7.

In addition, the lowest response scores in each school increased significantly, indicating that students who initially showed low engagement became more actively involved in the learning process. Meanwhile, the highest scores remained consistently at the maximum level, reflecting sustained positive perceptions among highly engaged students. Overall, these findings indicate that the HistoMath application effectively enhances student engagement and fosters positive attitudes toward learning, particularly in inclusive classroom environments.

Table 5. Description of the result of the student questionnaire for trial I and II

Information	School A	School B	School C
	Trial I	Trial II	Trial I
Highest Scores	100	100	100
Lowest Rate	20	63,6	16,5
Average	73,5	80,9	70,5

3.4. The Impact of the HistoMath Application on Learning Outcomes

The impact of the HistoMath application on student learning outcomes will be analyzed using simple linear regression and the coefficient of determination. This analysis utilizes data from the independent variable X (student responses using the HistoMath application) and the dependent variable Y (student learning outcomes). The primary objective of this analysis is to assess the extent of HistoMath's impact expressed in percentage terms.

This analysis specifically focuses on special needs students (SNS) who require specialized instruction in learning geometric shapes. By evaluating the responses from student questionnaires and their subsequent learning outcomes, the analysis aims to determine how effectively HistoMath influences their academic performance. The results from this analysis are detailed in the following Table 6, providing insights into the efficacy of the application in improving educational experiences for students with special needs (SNS).

Table 6. Difference in questionnaire data and student learning outcomes

School	Student	Classical Completion	X (Student Response)
School A	S1 (SNS)	60	25
	S2 (SNS)	60	28
	S3 (SNS)	65	25
School B	S1 (SNS)	78.2	42
	S2 (SNS)	81.8	45
	S3 (SNS)	76.4	48
	S4 (SNS)	80	45
School C	S1 (SNS)	76.4	45
	S2 (SNS)	76.4	35
	S3 (SNS)	60	35
	S4 (SNS)	60	35

The X score was calculated by measuring the difference in responses of special needs students (SNS) between the second and first trials, while the Y score was determined based on their learning outcomes across these trials. This method allows for a comparison of changes in student engagement and performance over time. To explore the relationship between these variables, a simple linear regression analysis was conducted. This statistical approach helps in understanding the correlation between the independent variable (X) and the dependent variable (Y), offering insights into how variations in student responses may influence their learning outcomes.

The primary objective of this analysis is to elucidate the impact of the X variable on the Y variable. By examining the linear relationship between these two variables, the analysis aims to determine the degree to which changes in student responses affect their academic performance.

This investigation provides valuable information on the effectiveness of the interventions and can guide further adjustments to improve educational strategies for special needs students (Y).

3.5. Coefficient Determination

This section presents the coefficient of determination analysis to examine the proportion of variance in students' learning outcomes that can be explained by the use of the HistoMath application. The results provide insight into the magnitude of the relationship between student responses toward the application and their learning performance. The results of the coefficient of determination analysis are presented in Table 7, which shows the proportion of variance in students' learning outcomes explained by the use of the HistoMath application.

Table 7. Determinant coefficient test

Model Summary				
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.809a	.655	.617	5.247

a. Predictors: (Constant), Learning Outcomes

The correlation coefficient, denoted as R, is 0.655. When applying the SPSS results for the coefficient of determination, which involves using the learning outcomes of students with special needs (SNS) as the dependent variable (Y) and the aggregate student activity during the learning process with HistoMath as the independent variable (X), the coefficient of determination, represented as R-squared, is 0.655 or 65.5%. This value indicates that HistoMath accounts for 65.5% of the variance in the learning outcomes of SNS students. Therefore, it can be concluded that the HistoMath application has a significant impact on student learning outcomes, demonstrating an influence of 65.5% on the academic performance of students with special needs.

3.6. Significant Value Test

This section presents the results of the significance test of the regression model used to examine the relationship between the use of the HistoMath application and students' learning outcomes. The significance test aims to determine whether the regression model is statistically valid for explaining the influence of the independent variable on the dependent variable. The results of the significance test are presented in Table 8.

Table 8. Significant value test

ANOVA						
Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	471.091	1	471.091	17.109	.003b
	Residual	247.819	9	27.535		
	Total	718.909	10			

a. Dependent Variable: HistoMath Response
b. Predictors: (Constant), Learning Outcomes

Table 8 presents the results of the significance test for the linear regression model. The ANOVA table indicates the following values: the Sum of Squares for Regression is 471.091 with 1 degree of freedom, yielding a Mean Square of 471.091.

The F-value is 17.109 with a significance level (Sig.) of 0.003. The Sum of Squares for Residual is 247.819 with 9 degrees of freedom, resulting in a Mean Square of 27.535. The Total Sum of Squares is 718.909 with 10 degrees of freedom.

This significance test assesses the linearity and significance of the regression model. A significance level (Sig.) of 0.003, which is below the threshold of 0.05, indicates that the regression model is statistically significant. This result confirms that the model meets the criteria for being a valid predictor, meaning that the learning outcomes significantly impact the HistoMath response. Therefore, the regression model is appropriate and effective for predicting the effects of HistoMath on student performance.

3.7. Linear Regression Test

This section presents the results of the linear regression analysis used to examine the influence of the HistoMath application on students' learning outcomes. The regression analysis aims to determine the direction and magnitude of the relationship between student responses toward the application and their learning performance. The results of the regression coefficient analysis are presented in Table 9.

Table 9. Linear regression test

Coefficients						
Model		Unstandardized Coefficients		Standardized Coefficients	t	Mr.
		B	Std. Error	Beta		
1	(Constant)	15.221 (a)	12.746		1.194	.263
	Learning Outcomes	.743 (b)	.180	.809	4.136	.003

a. Dependent Variable: HistoMath Response

Table 9 provides the results of the linear regression analysis, detailing the coefficients for the model. The constant term, with a value of 15.221 and a standard error of 12.746, represents the baseline learning outcomes of students when the HistoMath application is not utilized. This constant indicates that without the application, students' learning outcomes start at 15.221. The coefficient for the independent variable, which is 0.743 with a standard error of 0.180, reflects the change in learning outcomes associated with each unit increase in the use of HistoMath. The regression equation derived from the regression analysis is presented in Equation (1).

$$Y = 15.221 + 0.743X \quad (1)$$

This equation indicates that every one-unit increase in the use of the HistoMath application is associated with an increase of 0.743 units in students' learning outcomes. The positive regression coefficient suggests that the application has a positive influence on students' understanding of geometric concepts.

4. Research Findings

The findings of this study highlight that 35.5% of the factors influencing students' learning outcomes in Medan, particularly inclusive students, stem from both internal and external factors. Internally, health conditions significantly impact students' ability to focus on their studies. For example, students experiencing health issues, such as fever, often struggle with concentration, negatively affecting their learning process [49]. Similarly, sensory limitations, such as visual impairments, are particularly challenging for students seated at the back of the classroom, as inadequate visibility impedes their ability to follow lessons effectively [50].

Research has confirmed that optimal health and sensory function are critical contributors to academic performance [51].

Motivation also emerges as a crucial internal factor. Students with high intrinsic motivation tend to actively engage in learning activities, regardless of personal challenges [52]. Emotional intelligence plays a key role here, enabling students to manage stress and maintain focus during academic tasks [53]. Furthermore, learning styles whether visual, auditory, or kinesthetic significantly influence the effectiveness of students' comprehension. A mismatch between teaching methods and students' preferred learning styles can result in diminished understanding and reduced academic outcomes.

Externally, the lack of engaging educational media has been identified as a significant barrier to student learning. Schools in Medan primarily rely on traditional tools like blackboards, which fail to capture students' interest in a technology-driven era [54]. Digital learning tools have been shown to enhance engagement and comprehension by up to 40% compared to traditional methods [55]. However, the poor condition of blackboards in some schools exacerbates this issue, further discouraging students from active participation [56].

Family support is another critical external factor influencing students' learning outcomes. The study indicates that students receiving emotional and academic support from their families display higher motivation and better academic performance. Prior research corroborates that parental involvement in education boosts academic achievement by approximately 30% [57]. Conversely, students lacking familial support often face reduced motivation and struggle to meet academic expectations.

The classroom environment also plays a pivotal role, especially for inclusive students. These students require adaptive learning environments with appropriate facilities such as accessible seating arrangements and assistive learning devices. Inadequate classroom setups not only hinder learning but also affect the self-confidence of inclusive students. Thus, investing in inclusive infrastructure is vital for fostering equitable education.

Policy interventions are equally important. Government initiatives to allocate funds for digital learning tools and teacher training can significantly improve the quality of inclusive education. Programs designed to equip educators with strategies for addressing the diverse needs of inclusive students are imperative. Furthermore, policies promoting inclusive education should emphasize collaborative efforts among schools, families, and local communities to create a supportive learning ecosystem [58].

A synergistic approach involving teachers, families, and policymakers is essential to address these challenges. Teachers must innovate with technology-driven teaching methods tailored to students' diverse needs, while families should actively participate in their children's education. Policymakers should prioritize resource allocation for inclusive education and provide ongoing professional development for teachers to enhance their ability to manage diverse classrooms effectively [59].

Overall, internal factors such as health, motivation, emotional intelligence, and learning styles, combined with external factors like educational media and family support, form an interconnected web influencing students' academic performance. Addressing these issues through a holistic, multi-stakeholder approach can significantly enhance the quality of inclusive education in Medan.

5. Discussion

The improvement in student learning outcomes observed in this study aligns with existing research that underscores the effectiveness of digital learning tools in enhancing comprehension and academic achievement. For instance, the integration of digital media in learning environments has been shown to improve student comprehension by up to 40% [55], which is consistent with the notable increases in post-test scores across the three schools in this study. The positive changes, such as the average score increase of 6.58 points at SDN 064007 Medan, reflect HistoMath's capacity to engage students more effectively compared to traditional teaching methods. Similarly, previous studies have emphasized the role of health and motivation in influencing learning outcomes [49], [50], [51], [52], [53], which this study corroborates by demonstrating how interactive and engaging content addresses these factors.

Futhermore, the significant improvement in student engagement, as evidenced by the rise in questionnaire scores from Trial I to Trial II, highlights the effectiveness of HistoMath in fostering active learning. Previous studies have also identified the critical role of engagement in academic success. Students' interest and participation increased significantly with the use of interactive educational media [60], paralleling the findings from SDN 067261 Medan, where questionnaire scores improved by 7.4 points [60]. Furthermore, outdated tools, such as poorly maintained blackboards, have been shown to hinder learning engagement [61], a challenge effectively mitigated by the introduction of applications like HistoMath.

This study's focus on special needs students (SNS) provides important insights into the role of adaptive digital tools in inclusive education. The finding that HistoMath accounts for 65.5% of the variance in SNS learning outcomes (R-squared = 0.655) is particularly noteworthy. Previous studies have emphasized the importance of tailored learning environments and tools for inclusive students, highlighting that appropriate adaptations can significantly enhance academic performance and self-confidence [62]. The regression equation obtained in this study ("$Y = 15.221 + 0.743X$") demonstrates a direct positive correlation between the use of HistoMath and learning outcomes, thereby supporting previous findings that highlight the importance of technology integration [63].

The findings contribute to the broader discourse on the integration of technology in education by highlighting the dual benefits of HistoMath: enhancing cognitive outcomes and fostering socio-emotional engagement. Students with high intrinsic motivation excel academically, a phenomenon this study reinforces by demonstrating how interactive tools can boost both motivation and performance. Additionally, the significant F-value (17.109, $p < 0.05$) validates the regression model, supporting the assertion that HistoMath's interactive features create a conducive learning environment for diverse student populations.

These results underscore the necessity of adopting digital tools like HistoMath to address both internal and external barriers to learning. The observed improvements in student outcomes across all schools suggest that HistoMath effectively bridges the gap between traditional teaching methods and the needs of 21st-century learners. Collaboration between educators, families, and policymakers is essential for the successful implementation of such tools. This study's findings support recommendations for increased funding for digital learning tools and teacher training to maximize their potential impact.

While this study highlights HistoMath's efficacy, certain limitations must be acknowledged. For instance, the analysis was limited to three schools in Medan, and the sample size of special needs students was relatively small. Future research should expand the scope to include diverse educational settings and larger sample sizes to enhance generalizability. Additionally, longitudinal studies could explore the long-term impact of HistoMath on student learning trajectories.

6. Conclusion

In conclusion, the findings of this study underscore the significant impact of the HistoMath application in enhancing mathematics education within Medan City's inclusive schools. By integrating Discovery Learning strategies with an ethnomathematics-based approach and utilizing advanced technologies such as Augmented Reality and 3D 360° visualizations, HistoMath offers a culturally relevant and interactive learning experience. Its features, including 3D representations of local landmarks and interactive quizzes, demonstrate high validity (90.63%) and practicality (85%), contributing to notable improvements in student learning outcomes. The application accounted for 65.5% of the variation in student performance ($p = 0.003$), emphasizing its potential to elevate educational quality in inclusive settings. These results not only highlight the app's efficacy in engaging students but also align with the broader goal of leveraging digital tools to meet 21st-century educational needs.

Moreover, this study identifies critical internal and external factors influencing student learning outcomes, including health issues, sensory abilities, motivation, emotional intelligence, learning styles, the use of learning media, and family support. Interviews with students and teachers revealed that challenges such as limited classroom resources, damaged teaching tools, and inadequate digital integration hinder engagement and learning efficacy. Addressing these barriers by investing in educational resources, enhancing family-school collaboration, and expanding digital access could amplify the positive effects of tools like HistoMath. While this study demonstrates the app's transformative potential, further research should examine its long-term impact across diverse educational environments, ensuring its scalability and adaptability for broader application in inclusive education.

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