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Design and evaluation of an ethnomathematics-based project-based learning model for enhancing students' numeracy literacy and mathematical problem-solving in the society 5.0 era

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Abstract

Background: The rapid advancement of digital technology in the Society 5.0 era requires university students to possess strong numeracy literacy and mathematical problem-solving skills to interpret data, solve contextual problems, and make informed decisions. However, many students still experience difficulties in applying abstract mathematical concepts to real-life situations. This condition highlights the need for innovative and contextual learning approaches. Integrating ethnomathematics with Project-Based Learning (PjBL) offers a meaningful strategy to connect mathematical concepts with students' cultural experiences.
Aims: This study aims to design and evaluate an ethnomathematics-based PjBL model to improve university students' numeracy literacy and mathematical problem-solving skills.
Method: A quasi-experimental design with a pretest–posttest approach was employed. The participants were undergraduate students enrolled in a mathematics-related course. Data were collected through numeracy literacy tests, observation sheets, and project-based assessments. Students developed projects integrating mathematical concepts with local cultural contexts. Data were analyzed using descriptive and inferential statistics.
Results: The findings indicated a significant improvement in students' numeracy literacy and problem-solving abilities. Students showed better skills in interpreting data, solving contextual problems, and communicating mathematical reasoning. Cultural integration also increased engagement and motivation.
Conclusion: The ethnomathematics-based PjBL model is effective in enhancing students' numeracy literacy and supports innovative learning in the Society 5.0 era.

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INTRODUCTION

The rapid advancement of digital technology in the Society 5.0 era has significantly transformed various aspects of human life, including the field of education. In this era, education is expected to prepare students with essential competencies such as critical thinking, problem-solving, creativity, and numeracy literacy. Numeracy literacy is a fundamental skill that enables individuals to understand, interpret, and apply mathematical concepts in everyday contexts (Díez-Palomar et al.,

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2023; Hoogland, 2023; Pratiwi et al., 2024; Sikko, 2023). It supports decision-making processes that are increasingly based on data and quantitative reasoning. As societies become more complex and technology-driven, the demand for strong numeracy skills continues to increase. Students are expected not only to master theoretical knowledge but also to apply it in practical and real-world situations (Altmeyer et al., 2020; Lowell & Moore, 2020). However, the reality shows that many students still struggle to translate mathematical knowledge into meaningful applications. This condition indicates that learning processes have not fully supported the development of higher-order thinking skills. The gap between theoretical understanding and practical application remains a significant challenge in mathematics education. Therefore, there is a pressing need to develop innovative learning approaches that can improve students' numeracy literacy in a meaningful and contextual manner.

Despite the recognized importance of numeracy literacy, many students continue to exhibit low proficiency in applying mathematical concepts to solve real-life problems. Traditional teaching approaches often emphasize procedural learning and memorization rather than conceptual understanding and application (Borji et al., 2021; De Lorenzis et al., 2023; Gerasimova et al., 2023). As a result, students tend to rely on formula-based thinking without fully understanding the underlying concepts. This limits their ability to analyze problems critically and apply mathematical reasoning effectively. In addition, students often experience difficulties in interpreting data and communicating quantitative information (Conrad et al., 2022; Kotronoulas et al., 2023). These challenges hinder their ability to function effectively in a data-driven society. Learning environments that do not provide meaningful contexts further reduce students' engagement and motivation (Cayubit, 2022; Ferrer et al., 2022; Hellín et al., 2023; Li et al., 2024). Consequently, students may perceive mathematics as abstract and disconnected from their daily experiences. This situation highlights the need for learning strategies that are more engaging, contextual, and relevant. Therefore, educators must adopt approaches that encourage active participation and real-world problem-solving.

One learning approach that has the potential to address these challenges is Project-Based Learning. This approach emphasizes active student involvement through the development of projects that are based on real-world problems. Through project activities, students are encouraged to explore, analyze, and apply knowledge collaboratively. Project-Based Learning promotes critical thinking, creativity, and problem-solving skills (Chang et al., 2022; S.-Y. Chen et al., 2022; Williamson, 2023). In addition, integrating ethnomathematics into learning provides a culturally responsive dimension to mathematics education (Batiibwe, 2025; Bonney et al., 2026). Ethnomathematics connects mathematical concepts with local cultural practices, traditions, and knowledge systems (Batiibwe, 2025; Kabuye Batiibwe, 2024; Rosa & Orey, 2021). This integration enables students to understand mathematics in a more meaningful and contextual way. It also enhances students' appreciation of cultural diversity while strengthening conceptual understanding. Combining ethnomathematics with Project-Based Learning creates a holistic learning environment that supports both cognitive and cultural development. However, existing learning practices rarely integrate these two approaches in a systematic manner.

Although previous studies have examined the effectiveness of Project-Based Learning (PjBL) and ethnomathematics in mathematics education, the integration of these two approaches remains limited, particularly in higher education contexts. Existing research generally treats PjBL as a strategy to enhance engagement, collaboration, and problem-solving skills, while ethnomathematics is primarily explored as a culturally responsive approach to improve conceptual understanding; however, both approaches are often implemented separately, resulting in fragmented pedagogical practices. Furthermore, most empirical studies are concentrated at the primary and secondary school levels, with relatively limited attention given to university students who are expected to demonstrate higher-order thinking and advanced numeracy competencies. In the Society 5.0 era, numeracy literacy extends beyond basic computational skills to include the ability to interpret complex data, solve real-world problems, and apply mathematical reasoning in interdisciplinary and technology-driven environments. Despite this growing demand, there is still a lack of research that systematically investigates how ethnomathematics-based PjBL can be designed and implemented to enhance numeracy literacy and mathematical problem-solving skills among university students. Therefore, further research is needed to explore the effectiveness of integrating ethnomathematics and PjBL within higher education settings to address the competencies required in the Society 5.0 era.

Based on the issues identified, this study aims to investigate the implementation of an ethnomathematics-based Project-Based Learning model in higher education. The study focuses on improving university students' numeracy literacy in the context of the Society 5.0 era. It seeks to examine how the integration of cultural elements into project-based learning activities influences students' understanding of mathematical concepts. The research also aims to evaluate the effectiveness of the learning model in enhancing students' ability to interpret numerical information. In addition, it explores students' competence in solving contextual mathematical problems using appropriate reasoning strategies. The study further examines how the model supports the development of higher-order thinking skills. Student engagement and motivation during the learning process are also considered as important aspects of the investigation. Furthermore, the research aims to identify how culturally relevant learning environments contribute to meaningful learning experiences. The findings are expected to provide empirical evidence regarding the effectiveness of the proposed learning model. Ultimately, this study aims to contribute to the development of innovative and contextual mathematics learning approaches that are aligned with the demands of the Society 5.0 era.

LITERATURE REVIEW

Numeracy literacy has become a central component of mathematics education in the twenty-first century due to its relevance in addressing real-world challenges. It is defined as the ability to understand, interpret, and apply mathematical concepts in various everyday contexts. This competence involves not only computational skills but also the capacity to analyze data, make decisions, and communicate quantitative information effectively (González-Salamanca et al., 2020; Nouri et al., 2020; Persaud, 2020). In modern society, individuals are frequently required to engage with numerical data in personal, academic, and professional settings (T. Chen & Lucock, 2022; Fischer et al., 2020; Taboas et al., 2023). Therefore, strong numeracy literacy is essential for functioning effectively in a data-driven environment. However, research indicates that many students still exhibit limited proficiency in applying mathematical concepts beyond routine tasks. This limitation often results from learning experiences that focus primarily on procedural knowledge. As a consequence, students may struggle to solve contextual problems that require higher-order thinking. Developing numeracy literacy requires learning environments that promote meaningful engagement with mathematical ideas (Bezuidenhout, 2020; Risdiyanti et al., 2024; Wardat & Alali, 2024). Thus, enhancing numeracy literacy remains a critical goal in contemporary mathematics education.

Project-Based Learning has been widely recognized as an effective instructional approach for promoting active and meaningful learning. This approach emphasizes student-centered learning through the completion of projects that are grounded in real-world problems. Through PjBL, students are encouraged to investigate, collaborate, and construct knowledge independently (Almulla, 2020; Hussein, 2021). The process of developing projects enables students to apply theoretical knowledge in practical situations (Afzal & Tumpa, 2025; Bell & Bell, 2020; Fantinelli et al., 2024; Lowell & Moore, 2020). Additionally, PjBL fosters essential skills such as critical thinking, creativity, communication, and collaboration (Williamson, 2023). Students become more engaged in learning as they take responsibility for their own learning processes (Kazlauskienė et al., 2021; Koralegedara, 2020; Sasson & Yehuda, 2023). This approach also supports the development of problem-solving skills by presenting authentic and complex challenges. Furthermore, PjBL allows for interdisciplinary learning by integrating knowledge from various fields (Chang et al., 2022; MacLeod & van der Veen, 2020; Malyuga & Petrosyan, 2022). As a result, students can develop a deeper understanding of concepts through contextual application. Therefore, Project-Based Learning is considered a suitable approach for enhancing numeracy literacy.

Ethnomathematics offers a culturally responsive perspective in mathematics education by connecting mathematical concepts with local cultural practices and knowledge systems. This approach recognizes that mathematical ideas are embedded in daily activities, traditions, and social practices. By incorporating cultural elements into learning, students can relate mathematical concepts to their own experiences (Abdulrahim & Orosco, 2020; Acharya et al., 2021; Kolovou, 2023). This connection enhances students' conceptual understanding and makes learning more meaningful. Ethnomathematics also promotes cultural awareness and appreciation among students (Asare, 2026; Batiibwe, 2025; Kabuye Batiibwe, 2024; Payadnya et al., 2024; Sari et al., 2023). It allows learners to explore the relevance of mathematics within their own cultural context. Furthermore, culturally contextualized learning can increase student motivation and engagement (Anyichie et al., 2023). Students are more likely to participate actively when learning materials reflect their lived experiences (Dieumegard et al., 2021; Hagenah & Thompson, 2021; Hsbollah & Hassan, 2022). This approach also supports inclusive education by valuing diverse cultural backgrounds. Consequently, ethnomathematics has significant potential to improve both cognitive and affective aspects of learning.

The integration of ethnomathematics and Project-Based Learning represents a promising strategy for enhancing mathematics education. Combining these approaches enables the creation of learning environments that are both contextual and inquiry-based. Students can engage in projects that incorporate cultural elements while applying mathematical concepts to solve real-world problems (Kohen & Orenstein, 2021; Rehman et al., 2024). This integration supports the development of higher-order thinking skills and deepens conceptual understanding. It also provides opportunities for students to explore mathematics in authentic and meaningful ways. Moreover, the use of culturally relevant contexts can increase student engagement and motivation. Integrative learning approaches encourage students to connect knowledge across disciplines and experiences (Berndtsson et al., 2020; Le et al., 2023; Nahon Crystal et al., 2024; Wu et al., 2025). However, existing studies often examine ethnomathematics and PjBL separately rather than as a unified model. This indicates a need for further research on their combined implementation. Therefore, integrating ethnomathematics with Project-Based Learning holds significant potential for improving learning outcomes.

In the context of the Society 5.0 era, the integration of technology and human-centered approaches in education has become increasingly important. Society 5.0 emphasizes the use of advanced technologies to solve societal problems while maintaining a focus on human well-being. In this environment, students are expected to possess competencies that enable them to adapt to rapid technological changes. Numeracy literacy plays a critical role in supporting these competencies by facilitating data interpretation and decision-making. Educational approaches must therefore align with the demands of technology-integrated learning environments. The integration of ethnomathematics-based PjBL can support this alignment by combining cultural relevance with innovative pedagogical strategies. It provides opportunities for students to develop both technical and contextual understanding. Furthermore, this approach encourages learners to become active participants in solving real-world problems. As a result, students are better prepared to meet the challenges of the Society 5.0 era. Consequently, the development of such integrative learning models is essential for advancing mathematics education.

METHOD

Research Design

This study employed a quasi-experimental research design using a pretest–posttest control group design to examine the effectiveness of an ethnomathematics-based Project-Based Learning (PjBL) model in improving students' numeracy literacy. The design enabled a systematic comparison between students who experienced the intervention and those who received conventional instruction. Two groups were involved, namely an experimental group and a control group, each receiving different instructional treatments. Both groups were administered a pretest prior to the intervention to determine their initial numeracy literacy levels. Following the intervention period, a posttest was conducted to assess the improvement in students' competencies. The use of a control group strengthened the internal validity of the study by allowing comparison of learning outcomes. The design also provided a structured framework to evaluate the causal effect of the learning model. The focus of the design was to measure changes in students' ability to interpret data, solve contextual problems, and apply mathematical reasoning. The duration of the intervention was aligned with the academic schedule to ensure consistency in learning exposure. Overall, this design was appropriate for evaluating the effectiveness of innovative instructional approaches in higher education settings.

Participant

The participants of this study were undergraduate students enrolled in a mathematics-related course within a teacher education program. The selection of participants was based on their relevance to the research objectives, particularly their engagement in learning mathematical concepts at the tertiary level. The participants were divided into two groups, namely the experimental group and the control group. Both groups were selected to have relatively similar academic backgrounds to minimize potential bias. The study was conducted in a natural classroom setting to maintain ecological validity. Students in the experimental group were exposed to the ethnomathematics-based PjBL model, while those in the control group received conventional instruction. Participation in the study was conducted ethically, with students being informed about the purpose of the research. All participants were expected to actively engage in the learning activities and complete all required assessments. The grouping of participants allowed for meaningful comparison of learning outcomes. The sample represented a typical cohort of university students in mathematics education.

Instrument

The primary instrument used in this study was a numeracy literacy test designed to measure students' ability to interpret numerical data, apply mathematical concepts, and solve contextual problems. The test consisted of essay-type and problem-solving questions that reflected real-life situations. Each test item was scored using an analytic rubric ranging from 0 to 4, based on accuracy, reasoning, and clarity of explanation. The instrument underwent a validation process through expert judgment to ensure its content validity. A pilot test was also conducted to evaluate the reliability of the instrument, which showed acceptable consistency for research use. In addition to the test, observation sheets were utilized to record students' learning activities during the implementation of the learning model. These observations focused on student engagement, participation, and collaboration. Project assessment rubrics were also employed to evaluate students' project outputs related to ethnomathematical contexts. Data collection was carried out in two stages, namely before and after the intervention. The use of multiple instruments allowed for data triangulation and increased the credibility of the findings.

Data Analysis

The data obtained from the pretest and posttest were analyzed using both descriptive and inferential statistical techniques. Descriptive statistics were used to calculate the mean and standard deviation of students' scores to provide an overview of their performance. Inferential statistical analysis was conducted to determine the significance of the differences between groups. A paired sample t-test was used to examine the improvement within each group between pretest and posttest results. In addition, an independent sample t-test was employed to compare the posttest scores between the experimental and control groups. All statistical analyses were conducted at a significance level of 0.05. The results of these analyses were used to evaluate the effectiveness of the ethnomathematics-based PjBL model. Qualitative data from observations were analyzed descriptively to support the quantitative findings. The combination of quantitative and qualitative data provided a comprehensive understanding of the learning outcomes. The analysis process was conducted systematically to ensure the validity and reliability of the results. The findings were interpreted in relation to the research objectives.

Procedure

The research procedure was conducted in several stages to ensure systematic implementation of the study. The first stage involved preparing research instruments, learning materials, and administrative requirements. In the second stage, a pretest was administered to both the experimental and control groups to measure their initial numeracy literacy levels. The third stage involved the implementation of the learning treatment. The experimental group participated in learning activities using the ethnomathematics-based PjBL model, which included identifying cultural contexts, designing projects, conducting investigations, and presenting results. Meanwhile, the control group received conventional instruction based on standard teaching methods. The learning activities were conducted over several weeks within one academic semester. During the implementation, observations were carried out to monitor students' engagement and participation. After the intervention, both groups were given a posttest to assess their learning outcomes. Students in the experimental group also completed project presentations as part of the assessment process. Finally, all collected data were analyzed to determine the effectiveness of the learning model in improving numeracy literacy.

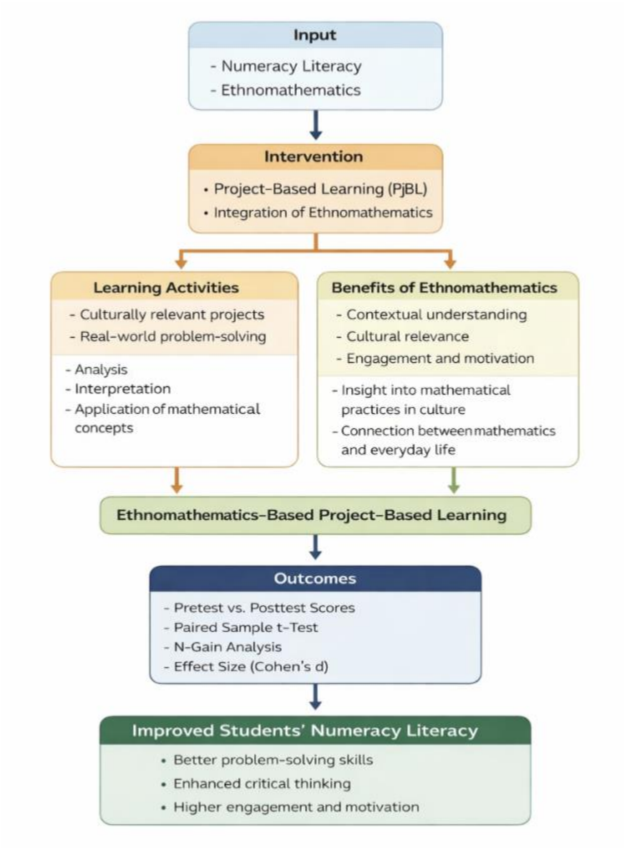

Figure 1. Research framework for improving students' numeracy literacy

RESULTS AND DISCUSSION

Results

Descriptive statistics

The descriptive statistics of students' numeracy literacy scores before and after the implementation of the ethnomathematics-based Project-Based Learning (PjBL) model are presented in Table 1.

Table 1. Descriptive statistics of pretest and posttest score

Variable	N	Mean	Std. Deviation
Pretest	30	62.17	14.78
Posttest	30	88.67	9.37

Based on Table 1, the average pretest score of students was 62.17, indicating that students' initial numeracy literacy levels were in the moderate category. The relatively high standard deviation (14.78) suggests that there was considerable variation in students' initial abilities. After the implementation of the ethnomathematics-based PjBL model, the average posttest score increased significantly to 88.67. This substantial increase reflects a marked improvement in students' numeracy literacy. In addition, the standard deviation decreased to 9.37, indicating that students' abilities became more homogeneous after the learning intervention. This suggests that the learning model not only improved overall performance but also reduced disparities among students. The increase in mean scores demonstrates that students were better able to interpret numerical information, solve contextual problems, and apply mathematical reasoning. The improvement also indicates that the learning activities successfully facilitated meaningful understanding. Overall, the descriptive results provide initial evidence of the effectiveness of the implemented learning model.

Normality test

Before conducting hypothesis testing, a normality test was performed using the Shapiro-Wilk test to determine whether the data met the assumptions for parametric analysis.

Table 2. Normality test

Variable	Sig.
Pretest	> 0.05
Posttest	> 0.05

The results presented in Table 2 show that the significance values for both pretest and posttest scores are greater than 0.05. This indicates that the data are normally distributed. The normality of data is an important prerequisite for conducting parametric statistical tests such as the paired sample t-test. Since the assumption of normality is satisfied, further analysis using parametric methods can be conducted with confidence. This ensures that the statistical results obtained are valid and reliable. The normal distribution of data also suggests that there are no extreme outliers that could significantly distort the analysis. Therefore, the data are considered suitable for further inferential statistical testing.

Paired sample t-test

A paired sample t-test was conducted to determine whether there was a statistically significant difference between students' pretest and posttest scores.

Table 3. Paired sample t-test

Variable	Mean Difference	t	Sig.
Pretest – Posttest	26.50	9.40	0.000

The results in Table 3 indicate that the mean difference between pretest and posttest scores is 26.50, showing a substantial increase in students' numeracy literacy. The calculated t-value of 9.40 further confirms the strength of this difference. The significance value obtained is 0.000, which is lower than the threshold of 0.05. This result indicates that there is a statistically significant difference between pretest and posttest scores. Therefore, it can be concluded that the implementation of the ethnomathematics-based PjBL model has a significant effect on improving students' numeracy literacy. The findings suggest that the learning intervention effectively enhanced students' ability to apply mathematical concepts in real-life contexts. This statistical evidence strengthens the argument that the applied learning model is effective. The results also indicate that the observed improvement is not due to chance.

N-Gain analysis

To determine the effectiveness level of the learning model, the normalized gain (N-Gain) was calculated using the following formula:

$$g = \frac{Posttest - Pretest}{100 - Pretest}$$

The average N-Gain score obtained was 0.68.

Table 4. N-Gain category

N-Gain	Category
g ≥ 0.7	High
0.3 ≤ g < 0.7	Moderate
g < 0.3	Low

Based on Table 4, the N-Gain value of 0.68 falls into the moderate category. This indicates that the learning model is effective in improving students' numeracy literacy, although there is still potential for further improvement. The moderate category suggests that the majority of students experienced meaningful learning gains. It also reflects that the intervention successfully bridged the gap between initial and final understanding. The N-Gain result complements the findings from the descriptive and inferential analyses. This indicates consistency across different measures of effectiveness. The use of N-Gain provides a more nuanced understanding of learning improvement. Overall, the results confirm that the implemented model is pedagogically effective.

Effect size (cohen's d)

To measure the magnitude of the learning improvement, Cohen's d effect size was calculated using the following formula:

$$d = \frac{Mean_{post} - Mean_{pre}}{SD_{pooled}}$$

The result obtained was: Cohen's d = 2.14

Table 5. Effect size interpretation

Cohen's d	Interpretation
0.2	Small
0.5	Medium
0.8	Large

The obtained effect size of 2.14 is categorized as a very large effect. This indicates that the ethnomathematics-based PjBL model has a very strong impact on improving students' numeracy literacy. The large effect size suggests that the observed improvement is not only statistically significant but also practically meaningful. It reflects a substantial change in students' learning outcomes as a result of the intervention. This finding further supports the effectiveness of the learning model. The combination of high mean improvement and large effect size strengthens the validity of the results. It also indicates that the model can be considered highly impactful in educational practice.

Overall, the results consistently indicate that the implementation of the ethnomathematics-based Project-Based Learning model significantly improves students' numeracy literacy. The increase in mean scores demonstrates substantial learning progress. The statistical significance from the paired sample t-test confirms that the improvement is meaningful. The N-Gain analysis indicates that the effectiveness of the model falls within the moderate category. Meanwhile, the very large effect size highlights the strong impact of the intervention. These findings suggest that integrating cultural contexts through ethnomathematics within project-based learning creates meaningful and engaging learning experiences. Students are better able to connect mathematical concepts with real-life situations. This integration enhances both cognitive understanding and practical application. Therefore, the learning model is highly recommended for improving numeracy literacy in higher education contexts.

Discussion

The findings of this study demonstrate that the implementation of the ethnomathematics-based Project-Based Learning (PjBL) model significantly improves students' numeracy literacy. This improvement is evidenced by the substantial increase in the mean score from 62.17 in the pretest to 88.67 in the posttest. The statistical analysis further confirms this enhancement, as the paired sample t-test indicates a significant difference between the two measurements. The significance level below 0.05 suggests that the observed improvement is not due to chance but is a result of the applied learning intervention (Naing et al., 2023; Outhwaite et al., 2020; J.-H. Zhang et al., 2020). In addition, the N-Gain score of 0.68 indicates that the effectiveness of the learning model falls within the moderate category. Although categorized as moderate, this value reflects a meaningful improvement in students' learning outcomes. Furthermore, the effect size of 2.14 indicates a very large practical impact of the intervention. This large effect size suggests that the learning model has strong educational significance beyond statistical results. The combination of these findings provides robust evidence of the effectiveness of the ethnomathematics-based PjBL model. Therefore, the results support the use of innovative and contextual learning strategies in mathematics education.

The observed improvement in numeracy literacy can be attributed to the core characteristics of Project-Based Learning. This model emphasizes student-centered learning, where students actively participate in constructing their own knowledge. Through project-based activities, students engage in solving real-world problems that require the application of mathematical concepts (Karan & Brown, 2022; Lazi et al., 2021; Rehman et al., 2023). This process encourages deeper cognitive engagement and facilitates meaningful learning experiences. Students are not only passive recipients of information but also active problem solvers. This finding is consistent with previous studies which report that PjBL enhances critical thinking and problem-solving skills (Karan & Brown, 2022; Loyens et al., 2023; W. Zhang et al., 2024). Compared to conventional instruction, PjBL provides more opportunities for students to apply knowledge in authentic contexts. The collaborative nature of PjBL also supports the development of communication and teamwork skills. These competencies are essential for addressing complex problems in modern society. Thus, the results confirm that PjBL is an effective approach for improving numeracy literacy.

In addition to the role of PjBL, the integration of ethnomathematics contributes significantly to the effectiveness of the learning model. Ethnomathematics provides a contextual framework that connects mathematical concepts with students' cultural experiences. This connection makes learning more relevant and meaningful for students. By incorporating cultural elements, students are able to see the practical applications of mathematics in daily life (Acharya et al., 2021; Lidinillah et al., 2022; Sari et al., 2023). This reduces the perception of mathematics as an abstract and difficult subject. Previous studies have shown that ethnomathematics-based learning enhances conceptual understanding and student motivation. The findings of this study support these results, as students demonstrated increased engagement during the learning process. The integration of culture also promotes a sense of identity and appreciation for local knowledge (Wijayanti et al., 2025; Zheng, 2024). This aligns with the principles of culturally responsive teaching. Therefore, ethnomathematics plays an important role in enriching the learning experience.

The moderate N-Gain result indicates that while the learning model is effective, there is still room for improvement in its implementation. This finding is consistent with previous research that reports moderate gains in similar instructional settings. One possible explanation for this result is the diversity in students' initial abilities and learning readiness. Some students may require additional support to fully benefit from the learning model (Cheon et al., 2020; Tullis & Goldstone, 2020). The complexity of project-based tasks may also present challenges for certain learners (Hussein, 2021). Previous studies have highlighted that the effectiveness of PjBL depends on factors such as instructional design, teacher facilitation, and student engagement (Sánchez-García & Reyes-de-Cózar, 2025; Tirado-Morueta et al., 2022; Umar & Ko, 2022; L. Zhang & Ma, 2023). In addition, the integration of ethnomathematics requires careful planning to ensure that cultural elements are meaningfully incorporated. Despite these challenges, the significant improvement observed in this study indicates that the model is effective overall. The reduction in variability among students suggests that the model helps create more equitable learning outcomes. This is an important consideration in educational practice. Therefore, further refinement of the model may enhance its effectiveness.

In the context of the Society 5.0 era, the findings of this study have important implications for mathematics education. Society 5.0 emphasizes the integration of technology and human-centered approaches to solve complex problems. In this context, numeracy literacy is a critical competency that supports data interpretation and decision-making. The ethnomathematics-based PjBL model aligns with these demands by providing a learning environment that integrates cognitive, cultural, and practical aspects. Students are encouraged to apply mathematical knowledge in real-life situations that reflect societal needs. This approach supports the development of analytical skills, creativity, and collaboration. Previous studies have emphasized the importance of integrating innovative learning strategies in preparing students for the future. The findings of this study extend this perspective by highlighting the role of cultural context in learning. The model also promotes meaningful engagement and lifelong learning skills. Therefore, the ethnomathematics-based PjBL model can be considered a relevant and effective approach for enhancing numeracy literacy in higher education.

Implications

The results of this study imply that integrating ethnomathematics into Project-Based Learning can serve as an effective instructional strategy for improving students' numeracy literacy. This approach not only strengthens students' conceptual understanding of mathematics but also situates learning within meaningful cultural contexts that enhance relevance and engagement. By connecting mathematical ideas with local knowledge and practices, students are able to perceive mathematics as a living discipline rather than an abstract body of knowledge. This contextualization supports deeper cognitive processing and facilitates the transfer of knowledge to real-life problem-solving situations. In addition, the project-based structure encourages active learning, collaboration, and independent inquiry, which are essential for developing higher-order thinking skills. The integration of ethnomathematics also promotes cultural awareness and appreciation, fostering a sense of identity and respect for local wisdom. These outcomes align with the educational demands of the Society 5.0 era, which emphasize the balance between technological advancement and human-centered values. From a pedagogical perspective, this study suggests that educators should adopt more contextual and culturally responsive teaching strategies in mathematics instruction. Curriculum developers can utilize this model to design learning frameworks that are adaptive, innovative, and relevant to students' social environments. Furthermore, the findings indicate that combining multiple pedagogical approaches can generate synergistic effects on student learning outcomes. This integration can also help reduce learning disparities by providing diverse entry points for understanding mathematical concepts. Therefore, ethnomathematics-based Project-Based Learning offers a promising direction for enhancing the quality and relevance of mathematics education in higher education.

Limitations and Suggestions for Future Research

This study has several limitations that should be considered when interpreting the findings and guiding future research. First, the study employed a quasi-experimental design with a limited sample size, which may affect the generalizability of the results to broader populations. The participants were drawn from a single institution, so the findings may not fully represent diverse educational contexts. In addition, the duration of the intervention was relatively short, which may not capture the long-term impact of the ethnomathematics-based Project-Based Learning model. The study also focused primarily on numeracy literacy, without examining other related competencies such as digital literacy or critical thinking in depth. Furthermore, the implementation of ethnomathematics depends heavily on the selection of relevant cultural contexts, which may vary across regions. Differences in students' prior knowledge and learning readiness were not fully controlled, potentially influencing the outcomes. The reliance on classroom-based assessments may also limit the ability to capture authentic real-world application of skills. Future research is recommended to involve larger and more diverse samples across multiple institutions to enhance external validity. Longitudinal studies are also needed to examine the sustainability of learning outcomes over time. Researchers may further explore the integration of technology with ethnomathematics-based PjBL to better align with the demands of the Society 5.0 era. Additionally, future studies could investigate the impact of this learning model on other competencies, such as critical thinking, creativity, and digital literacy, to provide a more comprehensive understanding of its effectiveness.

CONCLUSION

This study aimed to examine the implementation of an ethnomathematics-based Project-Based Learning (PjBL) model to improve university students' numeracy literacy in the era of Society 5.0. The findings indicate that the application of this learning model effectively enhances students' numeracy literacy skills. This improvement is reflected in students' increased ability to interpret numerical information accurately. In addition, students demonstrated better performance in solving contextual mathematical problems. Their ability to communicate quantitative reasoning also showed noticeable progress. These outcomes confirm that integrating innovative and contextual learning approaches can strengthen numeracy literacy in higher education. Furthermore, the incorporation of ethnomathematical elements within project-based learning provides meaningful and relevant learning experiences. Students are able to connect mathematical concepts with local cultural contexts, making learning more applicable to real-life situations. This approach also promotes cultural awareness and appreciation, which are important aspects of holistic education. The findings suggest that such integration aligns well with the demands of the Society 5.0 era, which emphasizes the balance between technological advancement and human-centered learning. Moreover, the ethnomathematics-based PjBL model demonstrates strong potential as an innovative instructional strategy in mathematics education. Therefore, its implementation is expected to contribute significantly to the development of contextual, culturally responsive, and future-oriented mathematics learning.

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