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RESEARCH ARTICLE

Increasing Students' Higher Order Thinking Skills: The Power of Project-Based STEM in Ethnomathematics Learning

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ABSTRACT

This research aims to test the effectiveness of integrating STEM into project-based ethnomathematics learning to improve students' higher-order thinking skills (HOTS). A quantitative experimental design was used, involving 124 students from four junior high schools in Grobogan Regency. Data were collected using a test instrument based on HOTS indicators and processed using ANOVA after meeting prerequisites. The results show that STEM integration in project-based ethnomathematics significantly enhances students' HOTS. There was a significant difference in HOTS achievement among the four research groups after the intervention. Post Hoc tests with Tukey's HSD revealed that students exposed to project-oriented STEM had the highest average HOTS achievement compared to other groups. These students completed all HOTS stages, including analyzing (C4), evaluating (C5), and creating (C6). In contrast, students taught with conventional methods generally reached only the analysis stage (C4) and did not progress further. This condition shows that project-based STEM has the power to increase students' HOTS in ethnomathematics learning.

INTRODUCTION

The Industrial Revolution 4.0 has rapidly transformed world civilization, creating significant uncertainty. People globally must develop strategies to respond. Governments are responsible for preparing citizens with strategies to compete globally. To fulfill this responsibility, countries have adapted their educational curricula (Ishartono et al., 2021). One of Indonesia's education policies is the Merdeka Mengajar Platform (Platform Merdeka Mengajar/PMM). This platform encourages teachers to innovate and create quality learning that meets current demands. 21st century learning requires a realistic, collaborative approach, emphasizing problem-solving, critical thinking, technological proficiency, and effective information processing (Sutama et al., 2020; Jan, 2017; Nong et al., 2022). Despite advancements, many mathematics lessons still fall short of developing students' critical thinking abilities (Hidayat et al., 2023). Such learning has not met the demands and challenges of the educational revolution (Hendriana et al., 2022). Therefore, mathematics education must encourage students to be critical, innovative, creative, and engaged, fostering their desire to learn (Bergmark & Westman, 2018).

Modern learning is characterized by access to information resources, the availability of learning materials, the convenience of completing assignments, and accessibility from anywhere at any time. This accessibility is a result of the rapid development of technology. However, technology alone is not enough to prepare students with the competencies needed for the 21st century; a more effective learning approach is still required (Fauziah et al., 2023). One effective approach is STEM, which integrates science, technology, engineering, and mathematics. STEM is believed to train students to face 21st century problems (Richardo et al., 2023). Integrating STEM in learning equips students with skills in problem-solving, critical and creative thinking (Kuenzi & Gonzales, 2012; Baharin et al., 2018; Richardo et al., 2023), and scientific thinking to improve high-level thinking skills (Stohlmann et al., 2012), ultimately making them more marketable in the workforce (White, 2014).

Various countries, including Australia, China, France, South Korea, Taiwan, and England, have integrated STEM into their education systems (Freeman et al., 2019). The Ministry of Education and Culture in Indonesia has launched the Kihajar STEM program (Kita Harus Belajar STEM). Kihajar STEM is an exploration platform for students at all educational levels. Kihajar STEM aims to equip students with critical, creative, collaborative, and communication skills for problem-solving. These skills can be achieved through a STEM-based learning approach (Stehle & Peters-Burton, 2019). STEM is a pedagogical philosophy which aims to draw the interrelationship between science, technology, engineering and mathematics to solve complex problems in real life situations (Changtong et al., 2020). Teachers, as the front line in education, must implement STEM to achieve learning goals for their students effectively (Deehan et al., 2024). Insights into progressive STEM learning can be used to analyze teacher needs and further improve the quality of education (Ramli et al., 2022).

Project-based learning (PjBL) is a teaching model that integrates various subjects and focuses on real-world problems (Wall, 2016). In PjBL, students learn by investigating, recording, and reporting their projects in response to complex problems assigned by the teacher. By solving these problems through scientifically designed projects, PjBL prepares students to face real-world challenges through practical experience in finding solutions, building collaboration, and communicating accurate ideas based on project data. PjBL enhances students' communication, collaboration, and problem-solving skills (Dias & Brantley-Dias, 2017). Combining PjBL with a STEM approach creates effective and challenging learning experiences (Dacumos, 2023). This integration improves students' learning outcomes and critical thinking abilities (Mundilarto & Ismoyo, 2017), creativity, inquisitiveness, problem-solving, logical reasoning, collaboration, and self-assurance (Allina, 2018; Irdalisa et al., 2024).

Mathematics is a crucial subject, and all students at all levels of education are required to study it (Sutama et al., 2020; Hidayat & Aripin, 2023). Bishop (2008) argued that mathematics plays a strategic role in developing human thinking power. Given the importance of mathematics for students, the material taught in schools must be delivered contextually and within a cultural environment. Despite the application of contextual learning in mathematics education, the integration of local cultural elements remains underutilized (Utami et al., 2019), even though mathematics cannot be separated from cultural development (Umbara et al., 2023).

A new paradigm is emerging that school mathematics needs to expand its parameters and become more inclusive by bringing mathematics to where students live (D'Ambrosio, 1985). Integrating mathematical concepts into a cultural context is called ethnomathematics. It aims to ensure that a cognitive assimilation process occurs, integrating new perceptions, concepts, and experiences into existing schemes in students' minds. With this concept, ethnomathematics-based learning involves teaching mathematics through topics packaged in local cultural contexts (Brandt & Chernoff, 2014).

When assessing learning, teachers must set high achievement targets to maximize students' skills. These skills, which include understanding ideas, developing, concluding, manipulating knowledge, and producing new knowledge, are known as higher order thinking skills (HOTS) (Muhibbuddin et al., 2023). The HOTS cognitive process encompasses conceptual knowledge, procedural understanding, and metacognitive abilities (Sutarni et al., 2024). HOTS is categorized into three levels in the revised Bloom's taxonomy: Level 4 (problem-solving and reasoning abilities), Level 5 (critical thinking skills), and Level 6 (creative thinking skills) (Krathwohl, 2002; Anggraini et al., 2019).

HOTS aims to 1) organize learned knowledge into long-term memory, 2) develop adaptability, and 3) foster the creation of quality individuals as competitive resources (Utami et al., 2019). HOTS was developed based on three main ideas about learning and thinking (Wulan et al., 2017; Yanuarto et al., 2023). Miterianifa et al. (2021) explain that the first idea involves interrelated and interdependent thoughts. The second idea focuses on improving thinking skills both inside and outside the classroom. The third idea emphasizes tasks that require high mental processes. These concepts are implemented through a STEM approach and learning models to support HOTS achievement. In Indonesia, the STEM approach is combined with the PjBL model (Khotimah et al., 2021).

Several researchers have revealed the effectiveness of integrating STEM in learning. STEM improves learning outcomes, HOTS, and critical thinking skills (Wahono et al., 2020) while also fostering HOTS (Agussuryani et al., 2020). Integrating STEM with the PjBL model enhances HOTS (Harun, 2020), as well as creativity, critical thinking, collaboration, and communication (4C) (Triana et al., 2020). STEM is also linked to improved information analysis, decision-making, and the cultivation of creativity and innovation among students (Iwuanyanwu, 2021). Moreover, STEM is recognized as a key factor in increasing productivity and global competitiveness, helping to address current and future socio-political and economic challenges (Bryan & Guzey, 2020).

Several researchers have conducted research on integrating STEM and PjBL, as explained earlier. These studies contribute to efforts to improve the quality of students' HOTS achievements. However, these studies were not specifically focused on ethnomathematics learning. The effectiveness of integrating STEM and PjBL, as carried out by previous researchers, cannot be generalized to mathematics learning because mathematics has unique characteristics, especially when taught using a cultural approach. No research has been found that integrates STEM and PjBL in ethnomathematics learning to increase students' HOTS. To evaluate the effectiveness of these research variables, this study aims to integrate STEM through the PjBL model in ethnomathematics learning, which is expected to increase students' HOTS.

METHODOLOGY

Research Design

This quantitative research used an experimental design over eight sessions: a pretest, six treatment sessions, and a posttest. The study focused on the "Opportunity" theme, using the traditional game of engklek/hopscotch as a cultural context. Four research groups received different treatments. Experimental group I was taught using a project-based STEM approach. Experimental group II was taught using a STEM approach without projects. Experimental group III was taught using a project-based approach without STEM. The control group was taught using neither STEM nor project-based methods. These treatments aimed to assess the effectiveness of project-based STEM integration in increasing students' HOTS. The research design is as follows:

Table 1. Research Design

Research Group	Pretest	Treatment	Postes
Experiment group I	O1	X1	O2
Experiment group II	O1	X2	O2
Experiment group III	O1	X3	O2
Control group	O1	X4	O2

Description:
X1 : ethnomathematics learning by integrating STEM and project-based
X2 : ethnomathematics learning by integrating STEM but not project-based
X3 : ethnomathematics learning does not integrate STEM but project-based
X4 : ethnomathematics learning does not integrate STEM and is not project-based

Sample and Data Collection

The sample for this research consisted of junior high school students from four different schools: two state junior high schools and two private junior high schools in Grobogan Regency, Indonesia. These schools have mathematics teachers with the same qualifications and "A" accreditation. The sample selection used a cluster random sampling technique because grouping occurs naturally through the classes available in each school. One class VIII from each school was randomly selected to participate in the research. The total sample size was 124 students, all aged 13–15 years.

Research data was collected using test techniques. The test consisted of five descriptive questions on the topic of Opportunity. The test instrument included HOTS question indicators: analyzing/C4, evaluating/C5, and creating/C6 (Krathwohl, 2002). The selected derivative indicators of analytical competence/C4 are examining, differentiating, and separating. The evaluating indicator/C5 involves providing arguments and assessments, while the creating indicator/C6 includes designing, formulating, and writing solutions. Before using the instrument, an expert test was conducted to determine the validity and consistency of the content (Anggraini et al., 2020). The expert judgment results were analyzed using the Gregory (2015) formula as follows:

$$\mathbf{CVI} = \frac{\mathbf{D}}{\mathbf{A}+\mathbf{B}+\mathbf{C}+\mathbf{D}} \quad (\mathbf{1})$$

Description:
CVI : content validity index
A : cells indicating disagreement between the two raters
B, C : cells indicating differences in views between raters
D : cells indicating valid agreement between the two raters

If the CVI calculation index is ≥ 0.78, the items are considered to have good content validity (Polit et al., 2007). In this research, the expert test involved two mathematics education lecturers with doctoral degrees. During the expert judgment analysis of the five questions on the research instrument, they assessed one item differently. However, the overall CVI for the instrument was 0.8, indicating that the HOTS question instrument is valid and can be used to collect research data.

Analyzing of Data

The pretest data homogeneity test was conducted via One-Way ANOVA to determine whether the research groups came from a homogeneous population with balanced abilities (Sawyer, 2009). After confirming that the four research groups had equal abilities, each group received an intervention according to the research design. The intervention ended with a posttest. Normality and homogeneity tests were carried out on posttest data before hypothesis testing. Hypothesis testing was conducted using two-way ANOVA. All quantitative data testing in this research used SPSS 27.0.

FINDINGS/RESULTS

Pre-Experiment Process

The pretest was conducted on four research groups using the same question instrument. The pretest was administered simultaneously at different school locations and supervised by the mathematics teacher of the relevant class, who had previously signed an honesty integrity pact. The pretest results were then analyzed to assess the normality of the data distribution and homogeneity to ensure that the data came from groups with the same variance. The normality test was carried out using the Kolmogorov-Smirnov test, the results of which can be seen in Table 2.

Table 2. Normality Test in the Pretest Data

Group	Kolmogorov-Smirnov Test		
	Statistics	N	Sig.
Experiment-I Class (STEM+Project)	0.130	31	0.192
Experiment-II Class (STEM+ Non Project)	0.144	30	0.105
Experiment-III Class (Non STEM+Project)	0.134	31	0.160
Control Class (Non STEM+ Non Project)	0.135	32	0.137

Table 2 shows that in experimental group I, the Sig value = 0.192; in experimental group II, the Sig value = 0.105; in experimental group III, the Sig value = 0.160; and in the control group, the Sig value = 0.137. In all research groups, the Sig. > 0.05, indicating that all pretest data in the four research groups are normally distributed. Ensuring the data is normally distributed is very important for the hypothesis testing process with parametric statistics in this research. The next prerequisite test is data homogeneity. This test ensures that the variances of the four research groups are the same. The results of the homogeneity test with Levene's Statistics are presented in Table 3.

Table 3. Homogeneity Test in the Pretest Data

Levene Statistic	df 1	df 2	Sig.
0.915	3	120	0.436

Table 3 shows that the Sig. = 0.436, which is greater than 0.05, illustrating that the four research groups came from populations with the same or homogeneous variances. Based on the results of the normality and homogeneity tests of the pretest data in Table 2 and Table 3, a mean difference test was then carried out to assess the initial abilities of the research subjects before the research intervention. The statistical test chosen is ANOVA because it can compare the averages of more than two research groups simultaneously. The ANOVA test results for pretest data are shown in Table 4. The table shows the Sig. = 0.655, which means it is greater than 0.05. This result proves that the four research groups had the same abilities before the research intervention.

Table 4. ANOVA Test in the Pretest Data

	Sum of Squares	df	Mean of Squares	F	Sig.
Between Groups	107.452	3	35.817	0.542	0.655
Within Groups	7931.645	120	66.097		
Total	8039.097	123			

Post-Experiment Process

The research intervention followed the research design and lasted for six sessions, in addition to the pretest and posttest. Mathematics teachers in each school implemented the learning with specific treatments. These four teachers were trained to deliver learning using predetermined approaches and methods. The intervention concluded with a posttest. The posttest results were analyzed to assess data normality, data homogeneity, and differences in the abilities of each research group. An overview of the posttest results is shown in Table 5.

Table 5. Description of Posttest Data

Group	N	Mean	Std. Deviation	Min	Max
Experiment-I Class (STEM+Project)	31	80.06	10.386	60	98
Experiment-II Class (STEM+ Non Project)	30	77.27	8.921	60	92
Experiment-III Class (Non STEM+Project)	31	68.97	12.317	46	88
Control Class (Non STEM+ Non Project)	32	62.56	12.763	38	88

Table 5 shows the average HOTS achievement posttest data: experimental group I scored 80.06, experimental group II scored 77.27, experimental group III scored 68.97, and the control group scored 62.56. The difference in average HOTS achievement needs to be tested statistically for significance. As with pretest data, prerequisite tests are also needed for posttest data processing. The statistical technique used to measure data normality is the Kolmogorov-Smirnov test. The results of the posttest data normality test are presented in Table 6.

Table 6. Normality Test in the Posttest Data

Group	Kolmogorov-Smirnov Test		
	Statistics	**N**	**Sig.**
Experiment-I Class (STEM+Project)	0.127	31	0.215
Experiment-II Class (STEM+ Non Project)	0.113	30	0.417
Experiment-III Class (Non STEM+Project)	0.118	31	0.325
Control Class (Non STEM+ Non Project)	0.111	32	0.391

Based on Table 6, the Sig. values are 0.215 for experimental group I, 0.417 for experimental group II, 0.325 for experimental group III, and 0.391 for the control group. These values indicate that all research groups have a Sig. value > 0.05, showing that the posttest data in the four research groups is normally distributed. The next step is to test the homogeneity of research data variants using the Levene Statistics test. The homogeneity test results are presented in Table 7.

Table 7. Homogeneity Test in the Posttest Data

Levene Statistic	df 1	df 2	Sig.
1.200	3	120	0.313

Table 7 shows a Sig. value of 0.313, which is greater than 0.05, indicating that the research data comes from populations with the same or homogeneous variances. With the posttest data being normally distributed and homogeneous, the next step is to test the difference in average posttest results. This test assesses the effect of the intervention on each research group. The analysis technique used is ANOVA. The two-way ANOVA test will indicate how effective the project-based STEM approach is in improving the HOTS abilities of students in each research group. The criterion used is if the Sig. value < 0.05, then there is a significant difference in the average HOTS achievement of students in each research group due to the intervention. Otherwise, the opposite applies. The results of the statistical analysis of posttest data are presented in Table 8.

Table 8. ANOVA Test in the Postest Data

	Sum of Squares	df	Mean of Squares	F	Sig.
Between Groups	5982.258	3	1994.086	15.800	<0.001
Within Groups	15144.580	120	126.206		
Total	21126.839	123			

Table 8 shows a Sig. value < 0.001, which is less than 0.05, indicating that the average HOTS achievement of students in each research group is significantly different after the intervention. The very small Sig. value (< 0.001) results from an F value of 15.800. The F value is the ratio between the variance between groups and the variance within groups. A large F value indicates that the variance between groups is greater than the variance within groups, meaning there is a significant difference between group means. However, the ANOVA test results only provide information on differences in average HOTS achievement between research groups and do not specify which groups are significantly different. Further analysis of the research interventions in each group is needed to determine the most effective integration model for increasing students' HOTS.

The most suitable statistical analysis to determine the effectiveness of integrating learning approaches and models is the Post Hoc Test with Tukey's HSD. This model was chosen because Tukey's HSD can detect differences in pairs of study group means that have significant differences. Tukey's HSD is a statistical tool for analyzing post-experimental mean comparisons to identify differences between tested groups. It provides consistent results on data testing that meets ANOVA assumptions, ensuring reliable conclusions from data analysis. This model can also detect differences in each pair of groups with high accuracy, allowing for a more in-depth analysis of differences between groups. The Tukey HSD calculation is presented in an easy-to-interpret table, helping researchers quickly understand significant differences between the groups tested. The results of statistical calculations with Tukey's HSD are presented in Table 9:

Table 9. Post-Hoc Test by Using Tukey's HSD

(I) Research Group	(J) Research Group	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
Experiment-1 (STEM+Project)	STEM+Non-Project	2.798	2.877	0.765	-4.70	10.29
	Non-STEM+Project	11.097*	2.853	0.001	3.66	18.53
	Non-STEM+Non-Project	17.502*	2.831	0.000	10.13	24.88
Experiment-2 (STEM+Non-Project)	STEM+Project	-2.798	2.877	0.765	-10.29	4.70
	Non-STEM+Project	8.299*	2.877	0.024	.80	15.80
	Non-STEM+Non-Project	14.704*	2.855	0.000	7.27	22.14
Experiment-3 (Non-STEM+Project)	STEM+Project	-11.097*	2.853	0.001	-18.53	-3.66
	STEM+Non-Project	-8.299*	2.877	0.024	-15.80	-.80
	Non-STEM+Non-Project	6.405	2.831	0.113	-.97	13.78
Control (NonSTEM+Non-Project)	STEM+Project	-17.502*	2.831	0.000	-24.88	-10.13
	STEM+Non-Project	-14.704*	2.855	0.000	-22.14	-7.27
	Non-STEM+Project	-6.405	2.831	0.113	-13.78	.97

Table 9 shows that experimental group I, with a learning intervention using a project-based STEM approach, achieved the highest average increase in HOTS competency compared to the other three groups. The next highest average HOTS achievement was in experimental group II, followed by experimental group III, with the control group having the lowest. Although there is a difference in the average between experimental group I and experimental group II, this difference is not significant (Sig. 0.765 > 0.05). These results suggest that the project method does not significantly impact increasing students' HOTS. This finding is reasonable because the only difference between experimental group I and experimental group II is the type of intervention (project vs. non-project methods). There was a significant difference between the HOTS achievements of the control group and the other groups. The HOTS achievements of students in the control group are less encouraging, indicating that learning that does not integrate STEM and is not project-based is highly discouraged, as it is less effective in increasing students' HOTS.

DISCUSSION

This research examines the effectiveness of STEM in project-based ethnomathematics learning to increase students' HOTS. Improvement in HOTS is measured by students' ability to analyze, evaluate, and design solutions to problems related to opportunities. Statistical analysis indicates that integrating STEM in project-based ethnomathematics learning was most effective in enhancing students' HOTS compared to the other three research groups.

Another aspect discussed in this research is the interaction between predictor variables that contribute to increasing HOTS. Figure 1 is a mean plot showing the interaction between the STEM approach variables and the project-based learning model. The mean plot shows parallel or almost parallel lines for both variables, indicating no significant interaction between the two predictor variables. The influence of the STEM approach on HOTS achievement in each research group did not change systematically with the project-based learning approach variable or vice versa. This plot confirms previous findings that experimental group I and experimental group II, whose students were taught using a STEM approach, were able to increase HOTS significantly regardless of the learning model, project-based or not. However, integrating STEM with project-based learning is still recommended because it has a slight positive influence on students' HOTS achievement (comparison of HOTS achievement of experimental group I with the results of experimental group II).

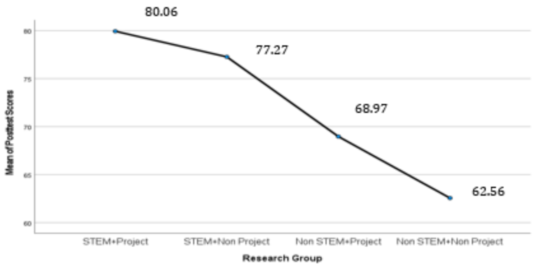

Figure 1. Means Plots

The findings of this study corroborate several similar studies. The STEM approach integrated with PjBL can improve creative thinking abilities (Wahono et al., 2020; Rahayu et al., 2023), critical thinking abilities (Priatna et al., 2020), problem-solving abilities (Rochim et al., 2022), and HOTS (Harun, 2020). STEM even facilitates the development of ethnomathematics, mathematical modeling, and a detailed understanding of mathematical concepts. Ethnomathematics involves ways of thinking, reasoning, and expanding mathematical knowledge in different sociocultural contexts (Rosa & Orey, 2021). This research builds on existing studies by adding and integrating several variables that influence the increase in students' HOTS. Ultimately, this research serves as an additional scientific reference, especially in ethnomathematics learning, to increase the HOTS of junior high school students. Practically, this research can guide mathematics teachers in applying the STEM approach and the PjBL model in ethnomathematics learning in the classroom.

Further assessment of the research findings was carried out on the adequacy of fulfilling the HOTS indicators. For this purpose, an analysis of students' posttest answers was conducted. One of the indicators measured in HOTS competency is the ability to create/C6. This ability is demonstrated by students in designing, modifying, and discovering new concepts from the initial concepts taught by the teacher. Students are tested on designing problem-solving models in the engklek game. The concept being measured is the probability of an event and the complement of that probability, where $P(A) + P(A^c) = 1$. Mastering this concept requires mathematical logic skills in analyzing the given problem. HOTS thinking skills in this concept help students think critically about an event and its complementary opportunities. The habit of HOTS thinking in this material will train them to face life's challenges that require analysis and problem-solving. This concept also prepares students to handle life situations involving uncertainty and risk, enabling them to make more appropriate decisions.

The analysis of students' answers shows that their HOTS achievements vary greatly in each research group. These answers reflect their learning achievements. Mathematics learning achievement can be seen through how they work on and solve the given problems (Hendriana et al., 2018). Learning achievement manifested in answer papers is authentic evidence of performance after learning. Mathematics performance can be seen from the stages of using concepts, facts, and procedures in mathematics (Umbara et al., 2023). The variations in answers illustrate their different abilities to absorb this material. It is claimed that the diversity of understanding of this material results from applying the STEM approach and the PjBL model. This statement is reasonable because the students' abilities before the intervention were the same or homogeneous based on the analysis of pretest scores.

Below are the results of students' answers from experimental group I, which was taught using a project-based STEM approach, and the control group, which was taught conventionally (non-STEM and non-project). The analysis of students' answers in experimental group I showed that 83.87% were able to identify the problem correctly. They also answered and designed solutions to problems coherently and structuredly. One example of a student's answer with the initials NE is shown in Figure 2.

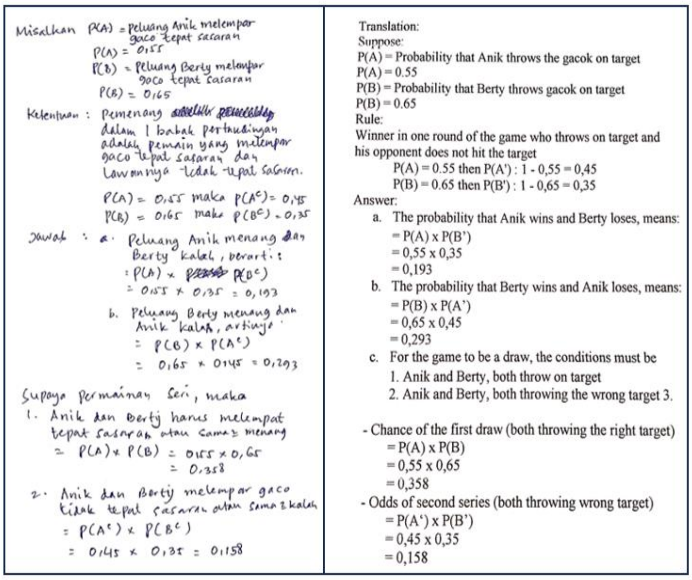

Figure 2. Answers of respondents from experiment-I group (integrated STEM, project-based)

Figure 2 shows that NE begins by representing the outcomes of the identified problem. Using the fundamental concept of probability learned previously, NE determines the complement. NE then analyzes the conditions required by the question, such as "Anik wins and Berty loses" or "Berty wins and Anik loses," and calculates the probability. NE can also plan the engklek game so that Anik and Berty achieve a draw and determine the corresponding probability. NE's workflow demonstrates mastery of the probability concept, enabling coherent and accurate problem-solving. The results of NE's answers indicate that the project-based STEM approach can enhance thinking skills in analysis, evaluation, and creation (Rosidin et al., 2019), and foster a learning environment conducive to HOTS development (Agussuryani et al., 2020;Tyas & Naibaho, 2021).

NE's answers differed slightly from those of students in experimental group II. Most students in this group could identify problems, determine complementary probabilities, and analyze conditions. Still, only a few could calculate probabilities and design engklek match sessions for a draw between Anik and Berty. The results are very different when comparing NE's answers with those of control group students. Figure 3 shows the answers of a control group student, NK, who was taught using a conventional (non-STEM+non-project) approach.

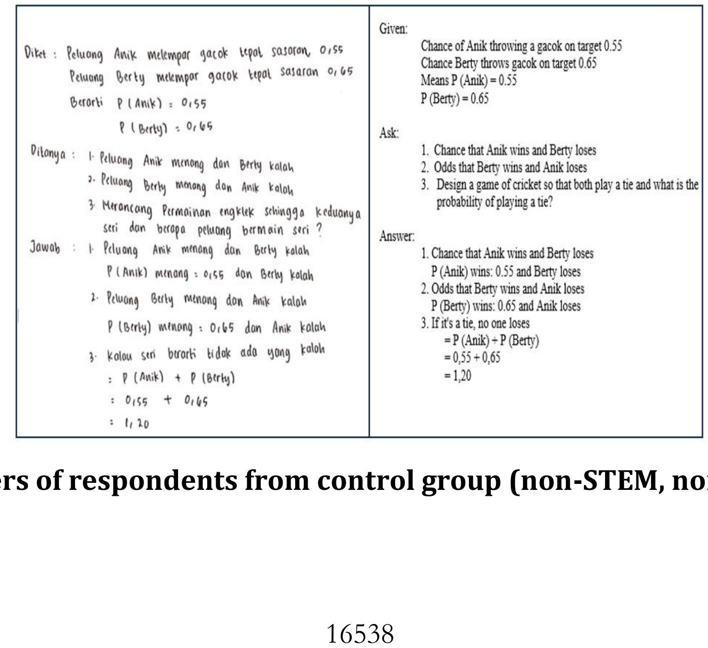

Figure 3. Answers of respondents from control group (non-STEM, non-project-based)

Figure 3 shows that while NK could identify the problem, they could not progress through subsequent problem-solving stages. NK's thinking is simple and stops at the analysis stage. NK cannot analyze the chances of one player winning and another losing or their complements. Analysis of NK's answers shows a lack of understanding of probability. Comparing NE and NK's answers provides evidence that project-oriented STEM helps improve HOTS. This analysis strengthens the research findings discussed earlier.

Given the disparity in learning outcomes between NE and NK, teachers must use engaging and effective teaching strategies to foster student enjoyment (Sheridan et al., 2009). Innovative teaching approaches are needed to stimulate HOTS thinking. One approach is STEM combined with the project method. Project-based STEM empowers students to become problem solvers, innovators, inventors, and independent thinkers (Maryani et al., 2021). Through projects, students develop ideas and generate new knowledge in solving problems. Frequent involvement in project-oriented STEM learning fosters a STEM mindset and scientific problem management intuitively, improving students' HOTS abilities, which are essential for thriving in the global era.

CONCLUSION

The integration of STEM in project-based ethnomathematics learning improves students' HOTS abilities. An F value of 15.800 and a Sig. value < 0.001 indicate a significant difference in HOTS competency achievement among the four research groups after the intervention. Post Hoc calculations with Tukey's HSD support this conclusion. The performance of students taught with a project-oriented STEM approach is very encouraging. They fulfill all stages of HOTS-based problem solving: analyzing/C4, evaluating/C5, and creating/C6. In contrast, students taught using conventional approaches mostly only identified problems/C4 and failed to complete subsequent stages. This student's performance proves that project-based STEM has the power to increase students' HOTS in ethnomathematics learning.

Recommendations

Based on the research findings, it is recommended that teachers continue to innovate their teaching methods. One innovation is integrating project-based STEM to enhance students' HOTS competency. Through this approach, students will become accustomed to solving problems scientifically, using technology, thinking technically with mature mathematical calculations, and collaborating responsibly. These skills are essential for thriving in the current competitive era. Further research should enrich the variables in ethnomathematics learning, considering urban/rural areas, gender perspectives, or other factors. Integrating project-based STEM in ethnomathematics learning for diverse students will enrich mathematics learning literature and provide a more accurate understanding of students' HOTS achievements.

Limitations

This research is limited to the variables of STEM and PjBL in enhancing students' HOTS in ethnomathematics learning. It does not compare implementation in ethnomathematics and non-ethnomathematics classes, local ethnicity, gender, or other complex variables. Another limitation is the predominantly quantitative research design. Combining quantitative and qualitative methods would provide a more comprehensive study, exploring students' hard and soft skill competencies from project-based STEM implementation.

Ethics Statements

The PPD Muhammadiyah University of Surakarta, Jln. Ahmad Yani No.157, Tromol Pos I, Pabelan, Sukoharjo, Indonesia has approved this research. Students who participated as research respondents received permission from their mathematics teachers and school principals, ensuring the study did not disrupt their mathematics lesson schedule.

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Conflict of Interest

The authors declare no conflict of interest.

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