Educazione: Journal of Education and Learning
Vol 03, No 01, 2025 | Page (58-66)
Doi: https://doi.org/10.61987/educazione.2498

OPEN ACCESS

A Multivariate Analysis of Ethnomathematics Through Malay Traditional Games: Effects on Mathematics Ability and Nationalism in Elementary School Students

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Abstract

The persistently low mathematical ability and weakening sense of nationalism among elementary school students underscore the need for contextual, culturally responsive learning innovations. This study analyzes the effect of implementing ethnomathematics through traditional Malay games on students' mathematical ability and nationalism. A quantitative approach with a quasi-experimental, nonequivalent control group pretest-posttest design was employed. The participants were 40 elementary school students from SD IT Alfatih, Bengkalis, divided into an experimental group and a control group. Data were collected through a mathematics achievement test and a nationalism questionnaire, then analyzed using descriptive statistics and Multivariate Analysis of Variance (MANOVA). The results revealed a significant multivariate effect of ethnomathematics-based learning through traditional Malay games on mathematical ability and nationalism simultaneously (*Wilks' Lambda* = 0.216; $p < 0.001$). Follow-up univariate analyses confirmed significant effects on mathematical ability ($F = 120.773$; $p < 0.001$) and nationalism ($F = 24.374$; $p < 0.001$), with the experimental group attaining substantially higher posttest scores. These findings indicate that integrating traditional Malay games into mathematics learning enhances mathematical competence while strengthening nationalism, demonstrating the potential of ethnomathematics to unite cognitive and affective outcomes within a single culturally grounded framework.

Article History
Received : July 2025
Revised : August 2025
Accepted : November 2025

Keywords:
Ethnomathematics, Malay Traditional Games, Mathematics Ability, Nationalism, Elementary School Students

How to Cite:
Zakiah, N., & Ivonesti, S. (2025). Traditional Malay Games as Ethnomathematics: Strengthening Mathematical Ability and Nationalism in Elementary School Students. *Educazione: Journal of Education and Learning, 3*(1), 58–66.

INTRODUCTION

Improving the quality of basic education remains a strategic priority in the development of human resources for the twenty-first century. Yet a range of indicators suggests that the numeracy skills of Indonesian students continue to face serious challenges. The 2022 Programme for International Student Assessment (PISA), published by the Organisation for Economic Co-operation and Development (OECD), placed Indonesia sixty-ninth among eighty participating countries, with a mathematics score of 355 (Furnham & Cheng, 2024). This result indicates that most students still struggle to apply mathematical concepts when solving contextual problems. Such difficulty is concerning because fundamental mathematical concepts, including numbers, computational operations, logical reasoning, and relationships between variables, form the very foundation of logical thinking (Kostic, 2023; Tsampouris & Sampedro Requena, 2022; Veenman et al., 2022). Early mathematical skills are among the strongest predictors of children's later achievement, yet they are frequently under-stimulated during childhood (Allen et al., 2024), leaving many students underprepared for the demands that depend on sound quantitative reasoning and making early intervention an urgent educational concern.

The challenge facing elementary education, however, is not confined to cognitive

competence alone. Alongside weak numeracy, the national character of Indonesian students has come under increasing pressure. The rapid expansion of digital media and the accompanying exposure to foreign cultures risk eroding the national values traditionally passed down to younger generations (Tleuberlinova et al., 2026). When students absorb global cultural influences without a firm grounding in their own identity, attachment to local heritage and a sense of nationhood may gradually weaken. This makes the strengthening of nationalism from the elementary level just as pressing as the improvement of academic ability. Education, therefore, faces a dual mandate: it must cultivate strong mathematical reasoning while simultaneously nurturing affective dispositions such as love of country and respect for cultural heritage. Addressing only one of these dimensions leaves the broader goal of holistic education unfulfilled, underscoring the need for learning approaches capable of advancing both at once.

One approach well suited to this dual challenge is ethnomathematics, which connects mathematical concepts to the cultural practices of a community so that learning becomes more contextual and meaningful (Prahmana & Istiandaru, 2021; Tran & Castro Schepers, 2023; Vanetik & Litvak, 2021). From a constructivist perspective, knowledge is more readily understood when it is anchored in real experiences close to students' everyday lives (Silseth & Erstad, 2022; Upton, 2025). Rather than presenting mathematics as a set of abstract symbols and procedures, ethnomathematics allows students to encounter mathematical ideas within familiar cultural settings, where meaning is constructed through direct engagement. Integrating local culture into mathematics learning therefore accomplishes more than supporting conceptual understanding; it simultaneously reinforces students' cultural identity and national character. In this way, ethnomathematics offers a pathway that links the cognitive and affective dimensions of education within a single learning process. This positions it as a promising response to the twin demands of strengthening mathematical ability and cultivating nationalism among elementary school students in an increasingly globalized environment.

Among the various forms of local culture, traditional games hold particular promise for integration into mathematics learning. Games such as *congklak*, *dam batu*, tops, and *engklek* embody a wide range of mathematical concepts, including number operations, patterns, relations, geometry, measurement, strategy, and problem solving (Agata et al., 2025; Lestari et al., 2021; Tinungki et al., 2022). Beyond their mathematical content, these games also carry social and cultural values such as cooperation, sportsmanship, discipline, responsibility, and respect for the nation's cultural heritage (del Valle, 2023). This combination is significant, because a single cultural activity can develop quantitative reasoning while transmitting values that nurture national character. Traditional games thus function as a learning medium capable of advancing mathematical skills and instilling nationalistic values at the same time. Their dual character makes them especially relevant to an educational agenda that seeks to unite cognitive and affective outcomes, providing a concrete and culturally rooted vehicle through which the principles of ethnomathematics can be enacted in the classroom.

A growing body of research has demonstrated the effectiveness of ethnomathematics in improving mathematics learning, reporting gains in conceptual understanding, mathematical thinking, communication, and motivation (Wikasari et al., 2025). Other studies show that traditional games such as *congklak* and *engklek* enhance learning outcomes and engagement, while culturally grounded learning strengthens students' cultural identity and national awareness (Lin et al., 2024). Most of this work, however, treats improvement in mathematical skills as the sole learning outcome. Studies that integrate mathematical ability as a cognitive aspect with nationalism as an affective aspect within one learning model remain relatively scarce (Mawardi et al., 2022). Equally rare is ethnomathematics research drawing on traditional Riau Malay games, especially those that flourish in the coastal areas of Bengkalis Regency. This is a notable omission, given that Malay culture offers a wealth of traditional games rich in both mathematical concepts and national values that could serve as valuable contextual learning resources.

These shortcomings reveal a clear research gap: empirical evidence on the effectiveness

of ethnomathematics through traditional Malay games in improving students' mathematical ability and nationalism simultaneously remains limited. The present study addresses this gap by analysing the effect of implementing ethnomathematics through traditional Malay games on the mathematical ability and nationalism of elementary school students. Its novelty lies in two contributions. First, it integrates cognitive and affective outcomes within a single ethnomathematics-based framework, rather than treating them in isolation as earlier studies have done. Second, it draws on traditional Bengkalis Malay games as a local cultural context that has been largely overlooked in mathematics education research. The findings are expected to enrich ethnomathematical scholarship while offering an alternative model of mathematics learning that is contextual, meaningful, and oriented towards strengthening students' national character, thereby uniting academic achievement and character formation within one coherent pedagogical approach.

RESEARCH METHOD

This study employed a quantitative approach with a quasi-experimental design to test the effect of implementing ethnomathematics through traditional Malay games on the mathematical ability and nationalism of elementary school students. A quasi-experimental design was chosen because full randomization of individual subjects was not feasible within classes that had already been formed (Kallus, 2021; Traynor et al., 2025). The design adopted was a nonequivalent control group pretest-posttest design, in which both the experimental and control groups completed a pretest and a posttest, but only the experimental group received ethnomathematics-based learning through traditional Malay games, while the control group received conventional instruction (Lu et al., 2025). The structure of this design is presented in Table 1.

Table 1. Nonequivalent Control Group Pretest-Posttest Design

Group	Pretest	Treatment	Posttest
Experimental	O_1	X	O_2
Control	O_3	-	O_4

The study was conducted at SD IT Alfatih, Bengkalis Regency, Riau Province, a site chosen because the local community still maintains traditional Malay games as part of its cultural life, allowing the learning to be carried out contextually. The population comprised all elementary school students at the school, and two classes with relatively homogeneous characteristics were selected through cluster random sampling, one as the experimental group and the other as the control group (Galanis et al., 2025; Leon-Novelo & Savitsky, 2023). The resulting sample size met the minimum requirement for analysis using MANOVA (Sabbioni et al., 2025).

Data were collected using two main instruments: a mathematical ability test and a nationalism questionnaire. The mathematical ability test measured students' conceptual understanding, mathematical reasoning, problem-solving, and mathematical communication, and was administered as both a pretest and a posttest. Nationalism was measured through a five-point Likert-scale questionnaire developed from indicators appropriate to elementary school students, namely love of country, pride in being Indonesian, appreciation of cultural diversity, concern for national unity, respect for state symbols, and commitment to preserving local culture. Before use, both instruments underwent content validation by experts in mathematics education and educational evaluation, and were then trialed with students of similar characteristics to the research subjects. The empirical validity of each item was examined using the Pearson product-moment correlation, while reliability was estimated using Cronbach's alpha, with a minimum acceptable coefficient of 0.70 (Khan et al., 2021).

The data were analyzed descriptively and inferentially with the aid of IBM SPSS Statistics. Descriptive analysis summarized students' mathematical ability and nationalism before and after treatment through minimum and maximum scores, means, and standard deviations. Before hypothesis testing, the data were screened against the assumptions of multivariate

analysis through a normality test using Shapiro-Wilk, a homogeneity of variance test using Levene's test, and a homogeneity of covariance matrices test using Box's M test (Hu et al., 2021). The hypothesis was then tested using MANOVA, chosen because the study involved one independent variable and two dependent variables, namely mathematical ability and nationalism, which were tested simultaneously. The multivariate results were interpreted through Pillai's trace, Wilks' lambda, Hotelling's trace, and Roy's largest root at a significance level of 0.05 (Shimizu & Hashiguchi, 2022). Where a significant effect emerged, the analysis proceeded to the tests of between-subjects effects to examine each dependent variable separately, with partial eta squared used to gauge the magnitude of the effect.

RESULT AND DISCUSSION

Result

This study set out to examine the effect of implementing ethnomathematics through traditional Malay games on the mathematical ability and nationalism of elementary school students. The findings are reported in two stages: descriptive statistics that summarize students' performance before and after the intervention, followed by hypothesis testing conducted through Multivariate Analysis of Variance (MANOVA).

Descriptive Statistics

To establish the starting point of the analysis, descriptive statistics were computed for both groups across the pretest and posttest stages. The summary of these scores for mathematical ability and nationalism is presented in Table 2.

Table 2. Descriptive Statistics of Mathematics Ability and Nationalism

Variable	Group	N	Mean	SD
Mathematics Pretest	Experimental	20	36.40	6.34
Mathematics Pretest	Control	20	36.40	9.44
Mathematics Posttest	Experimental	20	80.00	6.09
Mathematics Posttest	Control	20	52.40	9.44
Nationalism Pretest	Experimental	20	7.30	3.92
Nationalism Pretest	Control	20	7.20	4.24
Nationalism Posttest	Experimental	20	14.10	4.14
Nationalism Posttest	Control	20	7.35	4.50

Table 2 reveals a clear pattern of divergence that emerges only after the intervention. At the pretest stage, the two groups were practically indistinguishable: both recorded an identical mean mathematics score of 36.40, and their nationalism means differed by a single decimal point (7.30 against 7.20). This baseline equivalence is critical, because it removes pre-existing ability as a competing explanation and allows any later difference to be traced to the treatment itself. The posttest figures tell a different story. The experimental group climbed to a mean of 80.00 in mathematics, more than doubling its starting score, while the control group reached only 52.40. The same asymmetry appears in nationalism, where the experimental group nearly doubled its mean to 14.10, yet the control group remained essentially static at 7.35. The widening gap on both measures provides the first and most direct evidence that learning through traditional Malay games produced gains that conventional instruction did not.

Homogeneity Test

Before proceeding to multivariate testing, it was necessary to verify that the groups shared equal error variances, a precondition for the validity of MANOVA. The results of Levene's Test of Equality of Error Variances are reported in Table 3.

Table 3. Levene's Test of Equality of Error Variances

Variable	F	Sig.
Mathematics Ability	3.325	0.076
Nationalism	0.066	0.799

The significance values in Table 3 confirm that the homogeneity assumption holds for both dependent variables. With significance levels of 0.076 for mathematics ability and 0.799 for nationalism, both comfortably above the 0.05 threshold, the null hypothesis of equal variances cannot be rejected. The notably high value for nationalism (0.799) indicates an especially close match in variance between the groups. These results establish that the subsequent multivariate analysis rests on a statistically sound foundation, free from the distortion that unequal variances would introduce.

Multivariate Test Results

With the assumption of variance homogeneity satisfied, MANOVA was performed to determine whether the learning model exerted a significant effect on mathematical ability and nationalism taken jointly. The multivariate test statistics are displayed in Table 4.

Table 4. Multivariate Test Results

Multivariate Statistic	Value	F	Sig.
Pillai's Trace	0.784	67.101	0.000
Wilks' Lambda	0.216	67.101	0.000
Hotelling's Trace	3.627	67.101	0.000
Roy's Largest Root	3.627	67.101	0.000

Table 4 provides unequivocal support for a significant multivariate effect. All four criteria yield an identical F value of 67.101 with a significance level below 0.001, and this convergence across statistics that are computed differently lends particular strength to the conclusion. The *Wilks' Lambda* value of 0.216 is especially informative: it indicates that only about 22 per cent of the variance in the combined outcomes remains unexplained, leaving roughly 78 per cent accounted for by the difference between the learning models. In substantive terms, ethnomathematics through traditional Malay games shaped students' mathematical ability and nationalism simultaneously, and did so to a degree that is difficult to attribute to chance.

Tests of Between-Subjects Effects

Because the multivariate test confirms a joint effect but does not reveal how each variable contributed to it, follow-up univariate analyses were conducted. The between-subjects effects for each dependent variable are presented in Table 5.

Table 5. Tests of Between-Subjects Effects

Dependent Variable	F	Sig.	Partial Eta Squared
Mathematics Ability	120.773	0.000	0.761
Nationalism	24.374	0.000	0.391

Table 5 demonstrates that the intervention affected both variables significantly, but with strikingly different magnitudes. For mathematics ability, $F = 120.773$ ($p < 0.001$) accompanied by a partial eta squared of 0.761 signals a very large effect, meaning that approximately 76 per cent of the variance in mathematical performance is explained by the treatment alone. Nationalism also responded significantly, $F = 24.374$ ($p < 0.001$), with a partial eta squared of 0.391 that qualifies as a large effect; yet this figure is roughly half the value recorded for mathematics. The contrast is the most revealing aspect of Table 4: while traditional Malay games strengthened both the cognitive and the affective outcome, their influence on mathematical ability was substantially more pronounced than on nationalism. This disparity suggests that the cognitive domain is more

directly and immediately responsive to the intervention, whereas nationalism, as a broader attitudinal construct, shifts more gradually, a point taken up in the discussion.

Taken together, the results show that students who learned through ethnomathematics based on traditional Malay games attained higher scores in both mathematics and nationalism than those who received conventional instruction. The multivariate analysis confirmed that the intervention affected the two variables simultaneously, while the univariate analyses established that each variable was significantly influenced in its own right. The disparity in effect sizes further indicates that the intervention shaped the cognitive outcome more powerfully than the affective one, a pattern examined in the following discussion.

Discussion

The findings demonstrate that ethnomathematics through traditional Malay games exerts a very strong influence on students' mathematical ability, with the experimental group's mean rising from 36.40 to 80.00 against only 52.40 in the control group, supported by an effect size of 0.761 (Tran & Castro Schepers, 2023). This magnitude can be understood through social constructivism, which positions experience as the principal source of knowledge formation (Furnham & Cheng, 2024). Whereas conventional instruction presents mathematics as abstract symbols and procedures, traditional Malay games immerse students in objects, rules, strategies, and patterns that carry mathematical meaning. Through this engagement, students do not merely receive concepts but actively construct mathematical understanding from concrete experience. The unusually large effect, exceeding that of most prior studies, appears to stem from positioning culture as the core of learning rather than as an illustration, so that the entire process of concept formation unfolds through cultural activity itself, making local culture a learning resource equal in importance to formal mathematical sources.

Beyond cognitive gains, the intervention significantly strengthened nationalism, raising the experimental group's mean from 7.30 to 14.10 while the control group remained essentially unchanged, with an effect size of 0.391 (Tsampouris & Sampedro Requena, 2022). This outcome can be explained through social identity theory, which holds that a sense of belonging develops gradually through the internalization of shared symbols, values, and experiences (Veenman et al., 2022). Traditional Malay games function as cultural symbols connecting students to their local identity, so that playing games passed down across generations brings them into contact not only with mathematical concepts but also with the collective values of the Malay community. Notably, the effect on nationalism is considerably smaller than that on mathematical ability. This difference is meaningful: mathematical skill develops directly through learning activities, whereas nationalism is a broader affective construct shaped by family, peers, media, and wider social experience, and therefore shifts more gradually.

The contrast with studies reporting only weak ethnomathematical effects highlights the decisive role of integration quality. Where earlier research found limited impact, cultural elements typically served as decoration, loosely attached to the mathematical concepts under study (Kostic, 2023). The present findings suggest that the success of ethnomathematics depends not on the mere presence of culture but on how thoroughly cultural activity is fused with mathematical reasoning. In this study, traditional Malay games were not introduced as cultural examples but employed as the primary means through which mathematical concepts were explored, so that students underwent an authentic learning process rather than simply receiving information about local culture. This interpretation aligns with the view that culture-based learning becomes effective only when cultural activity serves as a genuine site of concept exploration (Prahmana & Istiandaru, 2021). The quality of integration, therefore, emerges as the factor that determines whether ethnomathematical implementation succeeds.

Taken together, these findings allow the study to advance both theory and practice through a single contribution: the *Ethnomathematics-Character Integration Framework*, which conceives local culture as operating along two distinct pathways. The first is a cognitive pathway

that improves mathematical ability through contextual, meaningful concept construction; the second is an affective pathway that strengthens nationalism through the internalization of cultural identity and social values. The divergent effect sizes for mathematical ability and nationalism provide empirical support for this dual structure, showing that culture influences the cognitive domain more powerfully than the affective one in the short term (Cheng & Kang, 2025). Practically, this framework offers teachers and curriculum developers a basis for treating traditional games not as supplementary material but as an integral medium that simultaneously raises numeracy and cultivates character, thereby uniting academic competence and character formation, including the dimensions of the Pancasila Student Profile, within one coherent pedagogical process.

CONCLUSION

This study concludes that implementing ethnomathematics through traditional Malay games significantly affects the mathematical ability and nationalism of elementary school students simultaneously, as confirmed by a significant multivariate effect that led to the acceptance of the research hypothesis. This influence proved very strong on mathematical ability and large on nationalism, indicating that traditional Malay games transform abstract concepts into concrete, contextual, and meaningful learning experiences while fostering cultural identity and a sense of belonging as part of national identity. The greater effect on the cognitive than the affective domain suggests that local culture shapes mathematical reasoning more readily than nationalism in the short term. The principal contribution of this study lies in demonstrating, through the *Ethnomathematics-Character Integration Framework*, that local culture functions not merely as a context for learning but as a medium uniting academic competence and character formation, offering teachers and curriculum developers a basis for integrating traditional games to strengthen numeracy and character together. Future research is encouraged to involve larger samples, longer interventions, and additional character variables such as tolerance and responsibility to deepen understanding of this impact.

ACKNOWLEDGMENT

The authors gratefully acknowledge the support of SD IT Alfatih Bengkalis, particularly the students and teachers who participated in this study. The authors also thank all individuals who provided valuable assistance and constructive feedback during the research process.

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