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Congklak-Based Ethnomathematics Learning: A MANOVA Analysis of Motivation and Mathematics Achievement

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Abstract

Many elementary students continue to struggle with mathematics and approach it with anxiety, which weakens both their motivation and their achievement. This study examines the effectiveness of *Congklak*-based ethnomathematics learning in improving elementary students' mathematics motivation and mathematics achievement through a multivariate approach. The research applied a quantitative method using a quasi-experimental pretest–posttest control group design involving 40 elementary school students, with 20 assigned to the experimental group and 20 to the control group. The experimental group learned mathematics through instruction built around the traditional game of *Congklak*, whereas the control group received conventional teaching. Mathematics motivation was measured using the Elementary Mathematics Motivation Inventory (EMMI), and mathematics achievement was assessed through a validated achievement test. After all assumptions were confirmed, the data were analyzed using descriptive statistics and multivariate analysis of variance (MANOVA). The findings showed meaningful gains in both motivation and achievement among students taught through *Congklak*-based ethnomathematics learning. The multivariate test confirmed a significant effect of the instructional approach on both dependent variables (Wilks' Lambda = 0.116; $F = 140.391$; $p < 0.001$). These results indicate that weaving a familiar traditional game into mathematics instruction builds a culturally meaningful environment that strengthens motivation and academic performance at once. Consequently, teachers are encouraged to draw on traditional games and local wisdom as practical resources for creating mathematics learning that is more engaging, contextual, and relevant to students' lives.

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INTRODUCTION

Mathematics occupies a decisive place in human life, yet a large share of students continue to struggle with it and carry a persistent unease toward the subject. Evidence from international assessments makes this concern difficult to ignore. The Program for International Student Assessment reported that a substantial proportion of participants failed to reach the baseline level of proficiency and performed poorly when asked to formulate mathematical situations from real contexts, even though they fared better at applying and interpreting results (Schleicher, 2019). The same body of evidence revealed that roughly 30 percent of students felt nervous or helpless when confronted with mathematical problems and consequently underperformed relative to expectations (OECD, 2013). Difficulties of this kind are not confined to adolescence. A population-based study found that a notable percentage of children and adolescents display low numeracy skills, and depending on the criteria applied, a smaller group is formally identified with mathematical learning difficulties (Barbaresi et al., 2005). Such figures signal a problem that reaches well beyond individual classrooms.

The stakes attached to this problem are considerable, since mathematical competence shapes how people manage everyday demands. Mathematics assists individuals in resolving personal, financial, and measurement-related matters, and its consistent character and principles are expected to cultivate learners who are truthful, consistent, and accountable (Siregar & Dewi, 2022). Improving mathematical ability, however, depends on more than cognitive drill alone. Emotion and motivation function as central forces in learning and achievement, and their role in mathematics has drawn growing scholarly attention (Schujaklow et al., 2023). Motivation, in particular, carries its own weight in determining whether a student succeeds at school (Utari & Putra, 2021). Mathematical motivation is therefore regarded as an essential dimension in the effort to understand and master mathematics (Nurkarim et al., 2023). Weak motivation, therefore, sits close to the heart of the achievement problem described above.

If motivation matters this much, the question becomes how teachers might strengthen it in ways that feel meaningful to learners. One promising route lies in ethnomathematics, the practice of grounding mathematical learning in the cultural life of the community. Ramopoly (2020) demonstrated that a culturally rooted approach raised the learning motivation of fifth-grade students, illustrating how mathematics framed through cultural nuance can contribute richly to instruction. Ethnomathematics rests on the understanding that mathematics is applied within the everyday practices of a community (Mayang, 2021), and culture-based learning simultaneously teaches students to preserve the heritage handed down across generations (Dwipayana et al., 2020). This orientation gains further justification from the recognition that mathematics is a body of knowledge embedded in daily activity and closely intertwined with culture (Martyanti & Suhartini, 2018). Existing work therefore points consistently toward the value of connecting mathematics to cultural experience.

Despite this encouraging direction, an important gap remains. Prior studies have largely confirmed the general benefit of culturally rooted instruction for motivation, yet few have subjected a specific traditional game to experimental testing that measures both motivational and cognitive gains at once. The traditional game of *Congklak*, in particular, has not been examined as a mathematics learning medium through a controlled experimental design at the elementary level. This absence marks the novelty of the present study. Rather than treating culture as a general backdrop, the research operationalizes a concrete cultural artifact into a structured intervention and evaluates its simultaneous effect on two distinct outcomes. In doing so, it moves the ethnomathematics conversation from broad advocacy toward measurable evidence, addressing a question earlier work has left largely untouched.

Building on this reasoning, the present study examines the effectiveness of *Congklak*-based ethnomathematics learning on elementary students' mathematics motivation and mathematics achievement using an experimental method. The choice of an experimental approach allows the study to establish whether the intervention produces genuine change rather than incidental improvement, thereby extending the ethnomathematics literature with empirical rather than merely conceptual support. Its relevance is twofold. Academically, it supplies evidence that a culturally responsive game can nurture cognitive and affective outcomes together, and practically, it offers teachers a low-cost, culturally familiar resource for enlivening mathematics instruction. The section that follows sets out the design, participants, instruments, and analytical procedures through which these effects were tested.

RESEARCH METHOD

This study employed a quantitative approach using a quasi-experimental design of the pretest–posttest control group type. Two sample groups were involved: an experimental group that received *Congklak*-based ethnomathematics learning and a control group that received conventional learning. The treatment was administered consistently across eight meetings, each lasting 2 × 35 minutes, in order to capture the changes that occurred after the intervention. The population comprised all students in one of the private elementary schools in Bengkalis Regency, and the sample was drawn through cluster sampling by selecting two classes with relatively equivalent characteristics. The final sample consisted of 40 elementary school students in grades V and VI aged 10–12 years, divided evenly into 20 students per group. This age range was chosen because the students are at the concrete operational stage of Jean Piaget's theory of cognitive development, the stage at which children begin to think logically about concrete objects, understand cause-and-effect relationships, and develop systematic problem-solving strategies (Imanualhaq & Ichsan, 2022). An equivalence test based on pretest scores was conducted before treatment to confirm the comparability of the two groups.

Data were collected through two instruments aligned with the study's dependent variables of mathematics motivation and mathematics learning outcomes. Mathematics motivation was measured using the Elementary Mathematics Motivation Inventory (EMMI) developed by Smart and Linder (2018), which encompasses three main constructs, namely mathematics anxiety, mathematics self-efficacy, and value of mathematics, with each item rated on a five-point Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree). Although the EMMI has demonstrated validity and reliability in previous studies, an adaptation and retesting process was carried out to ensure its suitability to the characteristics of the respondents; empirical validity was examined through item-total correlation, while reliability was assessed using Cronbach's alpha coefficient, a procedure consistent with instrument-development principles that emphasize revalidation across different usage contexts (DeVellis, 2017). Mathematics learning outcomes, in turn, were measured through a validated achievement test constructed from basic elementary school competencies. The independent variable, *Congklak*-based ethnomathematics learning, integrated local cultural elements into mathematics through traditional game activities involving counting operations, number patterns, counting strategies, and mathematical reasoning.

To clarify the sequence of these procedures, the three implementation stages of the study are summarized in Table 1 before the analytical techniques are described. This overview illustrates how preparation, treatment, and data collection were structured to ensure methodological rigor and consistency across both groups. The stages are outlined in **Table 1**.

Table 1. Stages of Research Implementation

Stage	Activities
Stage 1 — Preparation	Development of *Congklak*-based ethnomathematics learning tools, preparation of research instruments, expert validation, and instrument trials
Stage 2 — Implementation	Administration of the pretest, followed by eight learning sessions; the experimental class utilized *congklak* game activities integrated with mathematical concepts, while the control class received conventional instruction
Stage 3 — Data Collection	Administration of the posttest and collection of research data

Source: Processed research data (2024)

Table 1 demonstrates that the research followed a logical progression in which each stage prepared the conditions for the next, from instrument readiness through treatment delivery to final measurement. The data obtained were then analyzed using descriptive and inferential statistics with the assistance of SPSS. Before hypothesis testing, several prerequisite tests were conducted, comprising a multivariate normality test, a variance homogeneity test using Levene's Test, and a covariance matrix homogeneity test using Box's M Test. Hypothesis testing was subsequently performed using multivariate analysis of variance (MANOVA), which enabled the simultaneous examination of the treatment's effect on both dependent variables, offering a more comprehensive interpretation while reducing the risk of Type I errors. When significant results were obtained, the analysis proceeded to univariate tests to identify the dependent variables contributing to group differences, and the magnitude of the treatment effect was determined through the Partial Eta Squared value. This study was conducted after obtaining permission from the school, and all participants received an explanation of the research purpose and procedure, with the data used solely for academic purposes and kept confidential without disclosing individual identities.

RESULT AND DISCUSSION

Results

Descriptive Analysis

The initial analysis examined the descriptive statistics of both mathematics achievement and mathematics motivation across the experimental and control groups before and after the treatment. This descriptive examination was conducted to establish the baseline equivalence of the two groups and to observe the magnitude of change following the intervention. The pretest and posttest scores, along with their standard deviations, provide a preliminary overview of how *Congklak*-based ethnomathematics learning influenced student performance. A summary of these descriptive findings is presented in **Table 2**.

Table 2. Descriptive Statistics of Mathematics Achievement and Motivation

Groups	N	Mean Pretest	SD Pretest	Mean Posttest	SD Posttest
Achievement (Experimental)	20	54,50	4.90	83.25	5.04
Achievement (Control)	20	54.70	5.42	57.40	5.21
Motivation (Experimental)	20	35.65	2.27	52.80	4.62
Motivation (Control)	20	35.65	2.20	37.90	2.22

Source: Processed research data (2024)

Table 2 reveals that the two groups possessed nearly identical initial abilities, with the experimental group recording a pretest achievement mean of 54.50 and the control group 54.70. After the treatment, however, a substantial divergence emerged: the experimental group's achievement mean rose sharply to 83.25, while the control group reached only 57.40. A comparable pattern appeared in motivation, where both groups began at an identical baseline of 35.65, yet the experimental group climbed to 52.80 against the control group's modest 37.90. These figures indicate that the marked gains in the experimental group cannot be attributed to prior ability differences, since the groups started at equivalent levels. The considerable posttest gap therefore signals that the intervention produced a meaningful practical difference in both dependent variables.

To further clarify the contrast between the two groups, the comparison of posttest means for achievement and motivation is visualized. This visualization allows the magnitude of improvement in the experimental group to be observed at a glance relative to the control group. The chart consolidates the numerical results from Table 1 into a comparative form, making the disparity between the two instructional approaches more evident. The comparison of posttest performance is displayed in **Figure 1**.

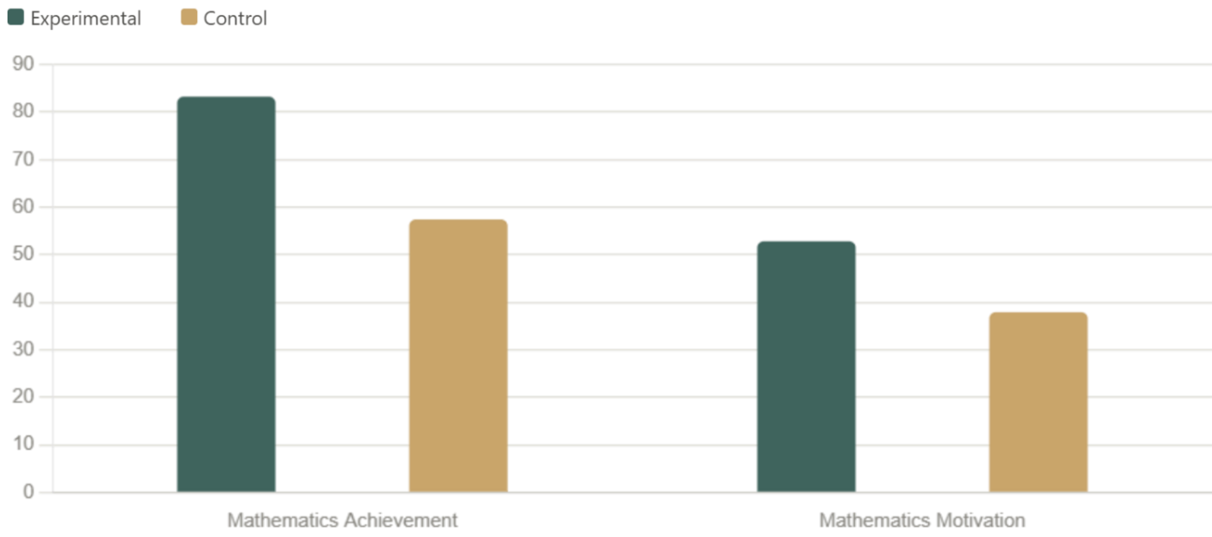

Figure 1. Comparison of Posttest Means for Mathematics Achievement and Motivation by Group
Source: Processed research data (2024)

Figure 1 makes the between-group disparity visually explicit, showing that the experimental group outperformed the control group on both measured outcomes by a wide margin. In mathematics achievement, the experimental bar reaches 83.25 against the control's 57.40, a gap of nearly 26 points that reflects the strong impact of the treatment. In mathematics motivation, the experimental group's score of 52.80 towers over the control group's 37.90, confirming that the affective benefit paralleled the cognitive one. Taken together, the visualization demonstrates that the improvement was not isolated to a single domain but occurred consistently across both dependent variables, reinforcing the practical significance of the descriptive findings before formal hypothesis testing.

MANOVA Prerequisite Tests

Before conducting the multivariate analysis of variance, several statistical assumptions were verified to ensure the appropriateness of the procedure. The first assumption examined was the normality of the data distribution for each variable within both groups, tested using the Kolmogorov–Smirnov statistic. This step was necessary because MANOVA requires that the dependent variables be normally distributed across the sampled groups. Meeting this condition provides confidence that subsequent multivariate results are not distorted by non-normal data. The results of the normality test are summarized in **Table 3**.

Table 3. Normality Test Results (Kolmogorov–Smirnov)

Variable	Group	K-S Statistic	Sig.
Learning Outcomes	Experimental	0.133	0.200
Learning Outcomes	Control	0.146	0.200
Motivation	Experimental	0.118	0.200
Motivation	Control	0.127	0.200

Source: Processed research data (2024)

Table 3 shows that every significance value exceeded the 0.05 threshold, with all four groups producing a Sig. value of 0.200 for both learning outcomes and motivation. This uniform result indicates that the data in each group did not deviate significantly from a normal distribution. Consequently, the normality assumption required for multivariate analysis was fully satisfied across both dependent variables and both experimental conditions. Because none of the distributions violated normality, the analysis could proceed to the subsequent homogeneity assumptions without the need for data transformation. This outcome establishes a sound statistical foundation for the multivariate testing that follows. The second assumption concerned the homogeneity of variance for each dependent variable, evaluated using Levene's Test. This test determines whether the variability of scores is equivalent between the experimental and control groups. Satisfying this condition ensures that any observed differences reflect the treatment rather than unequal error variances. The results of the variance homogeneity test are presented in **Table 4**.

Table 4. Variance Homogeneity Test (Levene's Test)

Variable	F	Sig.
Learning Outcomes	0.342	0.562
Motivation	0.721	0.401

Source: Processed research data (2024)

Table 4 confirms that the significance values for both variables exceeded the 0.05 criterion, recording 0.562 for learning outcomes and 0.401 for motivation. These results indicate that the variances of the two groups were statistically equivalent for each dependent variable. In practical terms, the spread of scores in the experimental group did not differ meaningfully from that of the control group, satisfying the homogeneity of variance assumption. This equivalence strengthens the validity of the group comparisons by ruling out unequal variances as a confounding factor. With this condition met, the analysis advanced to the examination of the covariance matrices. The final prerequisite examined the homogeneity of the variance–covariance matrices across groups using Box's M Test. This assumption verifies that the relationship between the dependent variables remains consistent between the experimental and control conditions. Confirming it is essential because MANOVA assumes equivalent covariance structures across the compared groups. The results of Box's M Test are displayed in **Table 5**.

Table 5. Equality of Covariance Matrices (Box's M Test)

Box's M	F	Sig.
4.217	1.284	0.281

Source: Processed research data (2024)

Table 5 indicates a significance value of 0.281, which comfortably exceeds the 0.05 threshold required for this assumption. This result demonstrates that the variance–covariance matrices of the dependent variables were homogeneous across the two groups. In other words, the pattern of relationships between mathematics achievement and motivation was statistically consistent in both the experimental and control conditions. With this final assumption satisfied alongside normality and variance homogeneity, all prerequisite conditions for MANOVA were fully met. The data therefore qualified for multivariate analysis, allowing the main hypothesis test to be conducted with statistical confidence.

MANOVA Results

Having satisfied all prerequisite assumptions, the multivariate analysis of variance was performed to determine whether the instructional approach produced a simultaneous effect on the two dependent variables. This analysis evaluated the combined difference between the experimental and control groups on mathematics achievement and motivation together. Four multivariate test statistics were computed to provide a comprehensive assessment of the treatment effect. Each of these statistics converges on a single interpretation of the group differences. The multivariate test results are reported in **Table 6**.

Table 6. Multivariate Test Results

Test	Value	F	Sig.
Pillai's Trace	0.884	140.391	0.000
Wilks' Lambda	0.116	140.391	0.000
Hotelling's Trace	7.589	140.391	0.000
Roy's Largest Root	7.589	140.391	0.000

Source: Processed research data (2024)

Table 6 presents a Wilks' Lambda value of 0.116 with an F value of 140.391 and a significance level of 0.000, which falls well below the 0.05 threshold. All four multivariate statistics produced the same F value and identical significance, reinforcing the robustness of the finding. This convergence indicates a significant simultaneous difference between the experimental and control groups across the combined dependent variables of motivation and mathematics achievement. The exceptionally low Wilks' Lambda value further signals that a large proportion of the variance in the outcomes is explained by the difference in instructional approach. These results provide strong multivariate evidence that the treatment condition distinguished the two groups on both measured constructs at once.

Hypothesis Testing

The hypothesis testing was structured around a null hypothesis (H_0) stating no simultaneous influence of *Congklak*-based ethnomathematics learning on students' motivation and mathematics achievement, and an alternative hypothesis (H_1) asserting such an influence. The decision rule rested on the multivariate significance value obtained from the MANOVA procedure. Because Wilks' Lambda produced a significance value of .000, which is smaller than the .05 criterion, the null hypothesis was rejected. This decision confirms a statistically significant simultaneous influence of the instructional approach on both dependent variables. The rejection of H_0 directly supports the acceptance of the alternative hypothesis.

The accepted alternative hypothesis establishes that students who received *Congklak*-based ethnomathematics learning attained higher motivation and mathematics achievement than those who received conventional instruction. This conclusion is supported by the combination of the multivariate result (Wilks' Lambda = 0.116; F = 140.391; $p < 0.05$) and the descriptive gains observed earlier. The magnitude of the F value indicates a particularly strong treatment effect on the combined outcomes. Taken together, the statistical evidence confirms that integrating the traditional *Congklak game* into mathematics instruction simultaneously strengthened students' learning motivation and improved their academic performance. These findings therefore provide a clear empirical answer to the research question.

Discussion

The findings of this study confirm that *Congklak*-based ethnomathematics learning exerts a significant influence on students' motivation and mathematics achievement. Empirically, the average achievement of the experimental group rose from 54.50 to 83.25, whereas the control group improved only marginally from 54.70 to 57.40. A parallel pattern emerged in mathematics motivation, where the experimental group advanced from 35.65 to 52.80 while the control group increased slightly from 35.65 to 37.90. The MANOVA results reinforced these descriptive gains, yielding a Wilks' Lambda value of 0.116 and a significance level of 0.000 ($p < 0.05$), which demonstrates a simultaneous effect of the instructional approach on both dependent variables. Taken together, these outcomes indicate that embedding a traditional game within mathematics instruction produces measurable benefits that conventional teaching does not achieve, thereby establishing a solid empirical basis for interpreting the mechanisms behind the observed improvement.

The improvement in students' motivation can be explained through the first indicator, namely the reduction of mathematics anxiety. *Congklak*-based ethnomathematics learning transforms counting activities into a more enjoyable experience that is not solely oriented toward right or wrong answers. Through gameplay, students accumulate successful experiences in calculating, strategizing, and solving problems, so that their fear of mathematics gradually diminishes. This interpretation aligns with the findings of Balt et al. (2022), who reported that mathematics interventions can reduce anxiety by helping students soften their anxious responses while replacing negative beliefs such as "I cannot learn mathematics" with a more positive confidence in their mathematical ability. The reduction of anxiety therefore functions as an initial gateway that allows students to engage with mathematical tasks more openly, creating the emotional conditions necessary for deeper participation and sustained motivation throughout the learning process.

The second indicator explaining the motivational gains is the enhancement of students' mathematics self-efficacy. The *Congklak game* provides repeated success experiences through calculating and strategizing activities, which lead students to feel more competent in completing mathematical tasks. According to Bandura (1997), such success experiences constitute the primary source from which self-efficacy is formed. In a complementary manner, Ryan and Deci (2020) explained that fulfilling the need for competence can heighten intrinsic motivation and strengthen student involvement in learning. Consequently, the sense of accomplishment obtained through the *Congklak game* reinforces mathematics self-efficacy and elevates students' willingness to engage with the subject. This mechanism suggests that motivation is not merely a byproduct of enjoyment but is actively constructed through mastery experiences, positioning the traditional game as a meaningful vehicle for building students' belief in their own mathematical capabilities.

The third indicator concerns the increased value that students attach to mathematics. The *Congklak game* connects mathematical concepts with local culture, enabling students to perceive mathematics as more meaningful and applicable to their daily lives. This finding is consistent with Rosa and Orey (2023), who explained that the ethnomathematical approach increases the relevance of learning to students' cultural experiences and thereby encourages a more positive attitude toward mathematics. When students recognize the practical and cultural worth of what they study, their engagement shifts from obligation toward genuine interest. The perceived value of mathematics thus completes the motivational picture alongside reduced anxiety and strengthened self-efficacy. Together, these three indicators form an integrated affective foundation that explains why the experimental group demonstrated substantially higher motivation than the control group after the intervention was implemented across the eight learning sessions.

Beyond its motivational effects, *Congklak*-based ethnomathematics learning also improved students' mathematics achievement. This improvement indicates that integrating local culture into instruction helps students grasp mathematical concepts in a more contextual and meaningful manner. This finding corresponds with Rosa and Orey (2023), who noted that ethnomathematics supports the development of cognitive skills, educational abilities, and positive attitudes, making the overall learning progression more effective. The cognitive gains observed in this study therefore appear closely linked to the affective improvements discussed earlier, as heightened motivation and reduced anxiety created favorable conditions for conceptual understanding. In practical terms, students who felt more confident and saw mathematics as relevant were better positioned to internalize the counting operations, number patterns, and reasoning strategies embedded in the game, which ultimately translated into markedly higher achievement scores compared with their peers in the control group.

Overall, the results confirm that *Congklak*-based ethnomathematics learning constitutes an effective strategy for enhancing both the motivation and the mathematics achievement of elementary school students. The integration of local culture into instruction not only deepens the understanding of mathematical concepts but also strengthens motivation through contextual, active, and enjoyable learning experiences. The principal contribution of this study lies in providing empirical evidence, through a multivariate statistical approach, that a culturally responsive game can simultaneously foster cognitive and affective educational outcomes within a single intervention. These findings imply that mathematics teachers should optimize the use of traditional games and local wisdom as learning resources to create instruction that is more meaningful and relevant to students' lives. By demonstrating this dual impact, the present research enriches the literature on ethnomathematics and offers a practical, culturally grounded model that can inform future efforts to improve mathematics education at the elementary level.

CONCLUSION

For too long, elementary mathematics has been taught as a subject detached from the cultural worlds children already inhabit, leaving many students anxious, disengaged, and convinced that the discipline holds little meaning for their lives. This study set out to test whether a familiar traditional game could close that gap, and the evidence gathered here answers firmly in the affirmative. Students who learned mathematics through *Congklak*-based ethnomathematics instruction achieved substantially higher posttest scores in both achievement and motivation than their peers under conventional teaching, and the multivariate analysis confirmed that this dual gain was statistically significant rather than incidental (Wilks' Lambda = 0.116, F = 140.391, $p < 0.001$). What these numbers ultimately reveal is that culture is not a decorative addition to mathematics but a genuine lever for learning: when counting becomes play and abstract operations acquire local meaning, children grow more confident, less fearful, and more willing to see mathematics as worth their effort. The broader lesson for the field is that cognitive and affective growth need not be pursued separately, since a single culturally grounded intervention can nurture both at once. Teachers, then, have good reason to draw on traditional games and local wisdom as serious pedagogical resources rather than occasional diversions, and researchers are invited to carry this work further by tracing its long-term effects across wider age ranges, additional mathematical topics, larger samples, and the many cultural settings where such games still thrive.

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