

Mathematics Performance and Collaborative Skills of Grade 7 Students Participating in Math Circles

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ABSTRACT

This study examined mathematics performance and self-reported collaborative skills among Grade 7 students participating in the Math Circles Program at Dagatan Integrated National High School, including group differences and the association between the two outcomes. A quantitative descriptive-correlational design was employed. From 68 Math Circles participants, 58 learners were selected through simple random sampling. Data were collected using a validated 25-item Mathematics Performance Test and a 32-item Student Collaborative Skills Survey. Frequency, percentage, means, standard deviations, independent-samples *t* tests, and Pearson correlation were used at the .05 significance level. Learners achieved an overall mathematics mean of 19.62 out of 25, classified as Proficient; conceptual understanding ranked highest (80.08%), followed by application of mathematical

skills (78.23%) and problem-solving (76.94%). Collaborative skills were rated to a Very Great Extent ($M = 3.60$, $SD = 0.20$), with positive interdependence and social interaction receiving the highest rating ($M = 3.64$). Neither mathematics performance nor collaborative skills differed significantly by sex, age, or academic standing. Their correlation was very weak and statistically non-significant ($r = .057$, $p = .670$). On this basis, an Integrated Math Circles Enhancement Framework was proposed using a Prepare–Explore–Express–Examine–Apply–Reflect learning cycle. The findings identify independent mathematical problem-solving and selected communication behaviors as priorities for program improvement; they do not establish the causal effect of Math Circles.

Keywords: *Math Circles; mathematics performance; collaborative skills; Grade 7 students; mathematical problem-solving; enrichment framework*

INTRODUCTION

Mathematics education is expected to develop conceptual fluency, flexible problem-solving, and the capacity to communicate ideas with others. Yet many Filipino learners continue to experience difficulty with mathematical understanding and application. In the 2022 Programme for International Student Assessment, Philippine performance in mathematics remained below the OECD average (Organisation for Economic Co-operation and Development [OECD], 2023). This challenge underscores the importance of enrichment experiences that complement regular instruction rather than merely repeat procedural drills.

Math Circles are structured but informal opportunities for learners to explore non-routine problems through inquiry, explanation, and peer interaction. Unlike assessment-driven remediation, they encourage mathematical curiosity and collective reasoning. International descriptions of the model emphasize open tasks, shared facilitation, and participation without excessive performance pressure (Cushman et al., 2023; Peck et al., 2023; Rech et al., 2021). These qualities align with learner-centered mathematical instruction and may offer opportunities to strengthen reasoning and collaboration among early adolescents.

In the Philippine context, differentiated instruction and inquiry-based practices have been explored to address mathematics learning gaps, but implementation may be uneven and locally adapted enrichment remains

comparatively limited (Aguhayon et al., 2023; Cabrera, 2024). The Math Circle initiative documented by Pangasinan State University–Lingayen Campus (2022) demonstrates local interest, but empirical descriptions of participating Grade 7 learners in public basic-education settings remain valuable. At Dagatan Integrated National High School, existing Math Circles sessions provided the setting for examining learners' mathematics performance and collaborative skills rather than implementing a new experimental treatment.

This study assessed three domains of mathematics performance—conceptual understanding, application of mathematical skills, and problem-solving—and four domains of collaborative skills: communication and shared understanding, collaborative problem-solving, group participation and responsibility, and positive interdependence and social interaction. It further examined differences according to sex, age, and academic standing, tested the relationship between the principal variables, and used the results to propose an Integrated Math Circles Enhancement Framework. The descriptive-correlational approach allows these outcomes and associations to be characterized without implying that Math Circles caused changes in achievement.

Literature Review

Math Circles, Inquiry, and the Social Construction of Mathematical Knowledge

Math Circles offer a setting in which learners' reason about unfamiliar problems, compare approaches, and construct meaning through discussion. Social constructivism explains how interaction with peers and facilitators supports learning within the zone of proximal development (Arduini-Van Hoose, 2020). Inquiry-oriented activity likewise shifts attention from reproducing answers to making conjectures, representing relationships, testing solutions, and refining reasoning. Examples from Math Circles describe adaptable facilitation and collective mathematical exploration (Cushman et al., 2023; Peck et al., 2023).

Mathematical enrichment is most educationally meaningful when challenging tasks are accompanied by accessible questions, appropriate support, and opportunities for reflection. The escape-room activities described by Rech et al. (2021), for instance, illustrate how collaborative problem solving can be embedded in an engaging enrichment format. Research on inquiry-based teaching also connects guided exploration with higher-order thinking, although the magnitude and direction of outcomes depend on learning conditions and the measures employed (Antonio & Prudente, 2024; Lumabit & Sagge, 2023).

These perspectives support the Math Circles context of the present study but do not predetermine its statistical results. Learning may be socially supported even when individual test scores and collaboration ratings are not strongly correlated. The distinction is important because a learner can participate constructively in a group yet still require practice selecting strategies, executing procedures, and justifying answers independently.

Mathematics Performance: Understanding, Application, and Problem-Solving

Conceptual understanding concerns mathematical relationships and the meaning underlying procedures. Contextualized and problem-based instruction offers opportunities to connect abstract concepts with realistic mathematical situations (Amistoso, 2024). Assessment should nevertheless differentiate conceptual understanding from the ability to perform operations or solve non-routine problems. Cabuquin and Abocejo (2023) examined mathematics achievement in a Philippine public-school setting, underscoring the importance of understanding school-specific patterns of performance.

Application of mathematical skills requires learners to identify relevant information, select appropriate operations, and transfer knowledge to a particular problem. Enrichment and peer-supported activities can provide additional opportunities for such transfer (Pasion & Marcelo, 2024). The development of inquiry-based modules for general mathematics similarly illustrates how students can work with mathematical ideas through structured activities rather than isolated practice (Lumabit & Sagge, 2023).

Problem-solving adds a strategic dimension: understanding a task, devising a plan, implementing it, and evaluating the solution. Studies on secondary learners' mathematical problem-solving report the importance of reasoning, planning, and productive activity when students face challenging tasks (Ermac & Tan, 2023; Larenio

& Futralan, 2025). These works inform the present study's separation of problem-solving from conceptual and application scores and motivate targeted practice with multi-step, non-routine mathematical tasks.

Collaborative Skills and Mathematical Discourse

Effective collaboration requires more than placing learners together. It includes clear communication, listening, perspective taking, appropriate role distribution, and shared understanding. Chopra and Kauts (2023) and Jaswal and Behera (2024) treated collaborative competencies as multidimensional constructs that can be examined through student-facing scales. In mathematics, such skills are expressed when learners ask for clarification, explain an approach, verify shared understanding, and take responsibility for contributions to a solution.

Collaborative problem-solving involves coordinating ideas as well as testing solution strategies. A systematic review by He et al. (2023) examined how students' roles in collaborative learning relate to collaborative problem-solving competence. Work on cooperative mathematical problem-solving similarly emphasizes peer acceptance and relationships as relevant conditions for productive participation (Klang et al., 2021). Thus, interpersonal support may help sustain group activity even when strategic flexibility and individual mathematical reasoning need additional reinforcement.

Research on collaborative learning in junior high schools associates structured group work with engagement and learning-related capacities (Dimatacot & Parangat, 2022; Sappaile et al., 2025). However, task design, measurement, prior knowledge, and group participation can differ across studies. Positive interactions should therefore be evaluated alongside, not treated as substitutes for, independent demonstrations of mathematical competence.

Learner Characteristics and the Performance–Collaboration Relationship

Demographic and academic profiles provide useful context for interpreting mathematics and collaboration outcomes. Philippine and regional studies have examined achievement and collaborative participation across learners with differing backgrounds and readiness (Berrame, 2024; Delos Reyes et al., 2024; Flores et al., 2024). Research on group discussion also indicates that communication patterns can vary with participants and instructional settings (Ngath et al., 2024). Such evidence justifies examining sex, age, and academic standing without assuming that these characteristics necessarily create statistically significant differences.

The relation between collaboration and performance is conceptually plausible but empirically variable. Studies of students' collaborative problem-solving dispositions and group roles demonstrate that collaboration includes heterogeneous competencies rather than a single uniform trait (He et al., 2023; Li et al., 2023). A learner may be supportive, communicative, and responsible without necessarily showing equivalent strength on an individual, time-limited mathematics test. Differences in instrument format and outcome definitions further complicate direct comparison.

Accordingly, the present study treated mathematics performance and collaborative skills as distinct outcomes and tested their observed linear association among Math Circles participants. The resulting evidence was intended to guide an enhancement framework focused on both individual mathematical problem-solving and selected group-learning processes, not to establish the causal impact of one variable on the other.

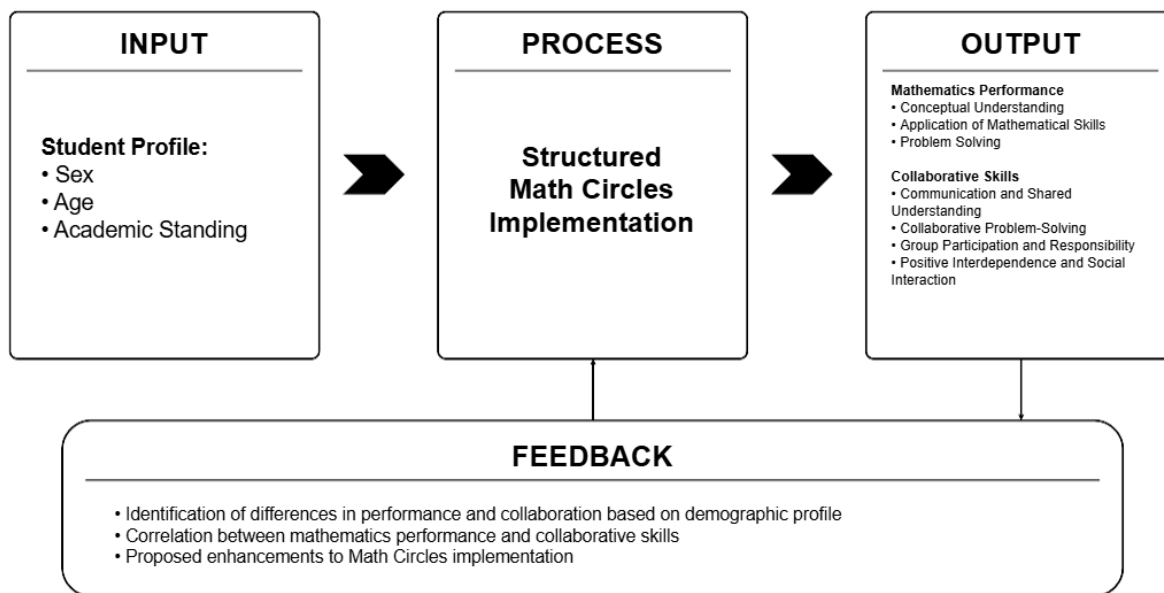


Figure 1. *Conceptual Paradigm of the Study*

METHODS

Research Design

The study employed a quantitative, descriptive-correlational design. It described mathematics performance and self-reported collaborative skills of existing Math Circles participants, compared outcomes across demographic and academic groups, and tested the linear relationship between the main variables. The researcher did not manipulate the variables or introduce an experimental treatment.

Research Locale

The study was conducted at Dagatan Integrated National High School during school year 2025–2026, using the school’s existing Grade 7 Math Circles Program as the research setting. Data collection occurred after the Quarter 2 Math Circles sessions.

Participants and Sampling Technique

The Grade 7 population included 412 learners. Of these, 295 were identified as average (mathematics grades of 80–84) or struggling (79 and below), and 68 voluntarily participated in Math Circles. A sample size of 58 from these 68 participants was calculated using Raosoft with a 95% confidence level and 5% margin of error. The researcher selected the 58 respondents through simple random sampling. Consequently, the findings describe the sampled Math Circles participants rather than the entire Grade 7 population.

Research Instrument

The researcher used a demographic profile form, a 25-item Mathematics Performance Test, and a 32-item Student Collaborative Skills Survey. The test measured conceptual understanding (9 items), application of mathematical skills (8 items), and problem-solving (8 items), with topics aligned to the Grade 7 Revised K to 10 Curriculum and Math Circles learning competencies. Performance levels were defined as Highly Proficient (85–100%), Proficient (70–84%), Moderately Proficient (50–69%), and Low Proficiency (below 50%).

The collaborative-skills questionnaire used a four-point response scale covering communication and shared understanding, collaborative problem-solving, group participation and responsibility, and positive interdependence and social interaction, with eight items per domain. Domain means were interpreted as No Extent (1.00–1.49), Moderate Extent (1.50–2.49), Great Extent (2.50–3.49), and Very Great Extent (3.50–4.00). The two instruments underwent expert review and piloting among 40 other Grade 7 learners; following revisions and item screening, Cronbach’s alpha was .803 for the final mathematics test and .893 for the collaborative-skills survey.

Data Gathering Procedure

After obtaining authorization from the Schools Division Office and school head, the researcher secured parental or guardian consent and learner assent. Administration was coordinated with Grade 7 mathematics teachers. The test and survey were completed after the Quarter 2 Math Circles sessions; responses were subsequently collected, scored, coded, and organized for statistical analysis. No additional Math Circles intervention was introduced for the research.

Data Analysis

Frequencies and percentages described respondent characteristics and mathematics results. Means and standard deviations summarized performance and collaborative-skills ratings. Independent-samples *t* tests evaluated differences in mathematics performance and collaborative skills for sex, age, and academic-standing groups. Pearson product–moment correlation tested the linear association between the main variables. Inferential tests used an alpha level of .05.

Ethical Consideration

The researcher obtained institutional permission, parental or guardian consent, and written student assent. Participation was voluntary, and respondents were informed of the purpose and procedures and their right to withdraw without penalty. Identifying information was replaced by codes, individually identifiable data were restricted to the researcher, and results were reported in aggregate to protect the participants’ privacy.

RESULTS AND DISCUSSION

Respondent Characteristics

Fifty-eight Grade 7 learners participated in the study. The sample included both sexes and both age groups, with a modest majority of female learners and 12-year-olds. In academic standing, 36 learners (62.10%) were classified as average and 22 (37.90%) as struggling. The profile represents varying levels of prior mathematics achievement within one existing enrichment program.

Table 1. *Profile of the 58 Grade 7 Math Circles Respondents*

Characteristic	Category	n	%
Sex	Male	26	44.8
	Female	32	55.2
Age	12 years	31	53.45
	13 years	27	46.55
Academic standing	Average	36	62.10
	Struggling	22	37.90

The inclusion of both average and struggling learners is relevant to mixed-ability interactions in Math Circles, but the descriptive data do not establish that profile groups experienced different benefits. Group comparisons are presented below. Findings from cooperative learning settings suggest that shared activity can engage students with differing characteristics when participation and support are intentionally organized (Delos Reyes et al., 2024; Berrame, 2024).

Mathematics Performance

The learners recorded an overall mean test score of 19.62 out of 25 and were classified as Proficient. Conceptual understanding was the strongest domain (80.08%), followed by application of mathematical skills (78.23%) and problem-solving (76.94%). All three domains were within the proficiency classification; the ordering indicates a relative rather than categorical weakness in mathematical problem-solving.

Table 2. *Mathematics Performance by Domain*

Domain	Items	Mean score	Reported %
Conceptual understanding	9	7.21	80.08
Application of mathematical skills	8	6.26	78.23
Problem-solving	8	6.16	76.94
Overall	25	19.62	78.98

Relatively stronger conceptual understanding suggests that students could recognize and interpret mathematical relationships; applying those relationships in novel contexts and choosing independent solution methods were somewhat more demanding. This distinction is consistent with descriptions of conceptual, procedural, and strategic mathematical competence in contextualized instruction (Amistoso, 2024; Lumabit & Sage, 2023). It should not be read as proof that the Math Circles sessions produced these scores, because the study did not compare outcomes with a baseline or untreated group.

The comparatively lower problem-solving percentage points to a practical improvement priority: constructing plans, comparing alternatives, checking reasonableness, and explaining answers without relying entirely on group assistance. Ermac and Tan (2023) and Larenio and Futralan (2025) describe the importance of systematic problem-solving activity. The study therefore supports strengthening problem-solving within the existing enrichment structure while retaining opportunities for conceptual exploration.

Extent of Collaborative Skills

Students rated their overall collaborative skills to a Very Great Extent ($M = 3.60$, $SD = 0.20$). Positive interdependence and social interaction ranked highest ($M = 3.64$), followed by group participation and responsibility ($M = 3.61$), collaborative problem-solving ($M = 3.59$), and communication and shared understanding ($M = 3.57$). All domain means fell within the Very Great Extent category.

Table 3. *Overall Collaborative-Skills Ratings*

Collaborative-skills domain	Mean	SD	Interpretation
Communication and shared understanding	3.57	0.21	Very Great Extent
Collaborative problem-solving	3.59	0.24	Very Great Extent
Group participation and responsibility	3.61	0.29	Very Great Extent
Positive interdependence and social interaction	3.64	0.25	Very Great Extent
Overall	3.60	0.20	Very Great Extent

The item-level results add important nuance to the high overall ratings. Asking questions when uncertain was rated strongly ($M = 3.83$), while clearly explaining mathematical ideas was lower ($M = 3.31$). Encouraging alternative approaches ($M = 3.41$) and suggesting a new method after an unsuccessful solution ($M = 3.40$) were comparatively less evident than listening and staying involved. These differences suggest that participation and encouragement were not always accompanied by equally strong mathematical explanation or strategic flexibility.

Similarly, maintaining focus and avoiding distractions ($M = 3.48$) ranked below other participation behaviors, and confidence in sharing ideas was the lowest indicator in the positive-interdependence domain ($M = 3.22$). The ratings imply that respectful peer relations coexisted with some hesitation in articulating reasoning. These specific needs align with multidimensional approaches to assessing student collaboration (Chopra & Kauts,

2023; Jaswal & Behera, 2024) and research distinguishing supportive relationships from the strategic behaviors involved in solving problems together (He et al., 2023; Klang et al., 2021).

Because the survey captured students' self-reports, the high means describe perceived collaborative behaviors and should not be interpreted as independent observation of every behavior in each session. Nevertheless, they provide a useful basis for adding explanation routines, strategy comparison, rotating roles, and explicit opportunities for quieter learners to contribute. Studies of collaborative learning similarly emphasize meaningful participation and well-structured tasks (Sappaile et al., 2025; Dimatacot & Parangat, 2022).

Differences in Outcomes by Sex, Age, and Academic Standing

Independent-samples comparisons found no statistically significant differences in mathematics performance by sex ($p = .466$), age ($p = .714$), or academic standing ($p = .197$). Female learners scored slightly higher on average than males (19.88 versus 19.31); 13-year-olds scored 19.78 compared with 19.48 among 12-year-olds; and average learners scored 20.00 compared with 19.00 for struggling learners. None of these observed differences reached the specified .05 significance level.

Table 4. *Group Comparisons for Mathematics Performance*

Grouping	Group means	t	p
Sex	Male 19.31; female 19.88	-0.735	.466
Age	12 y 19.48; 13 y 19.78	-0.368	.714
Academic standing	Average 20.00; struggling 19.00	1.306	.197

Collaborative skills were also not significantly different by sex ($p = .697$), age ($p = .856$), or academic standing ($p = .742$). In all three comparisons, group ratings were closely clustered around 3.59–3.61. These results describe insufficient evidence of differences for this sample, not proof that the respective populations or individual learners were identical in capacity.

Table 5. *Group Comparisons for Collaborative Skills*

Grouping	Group means	t	p
Sex	Male 3.59; female 3.61	-0.392	.697
Age	12 y 3.59; 13 y 3.61	-0.182	.856
Academic standing	Average 3.61; struggling 3.59	0.332	.742

The non-significant profile comparisons may be considered alongside studies of cooperative learning and demographic participation, which underscore the potential importance of instructional context and learner characteristics without establishing uniform effects across settings (Delos Reyes et al., 2024; Ngath et al., 2024; Flores et al., 2024; Macagba & Daza, 2025). The present findings support making Math Circles accessible across these groups while preserving responsive facilitation for individual students.

Relationship Between Mathematics Performance and Collaborative Skills

Pearson correlation revealed a very weak positive but statistically non-significant relationship between mathematics performance and self-reported collaborative skills ($r = .057$, $p = .670$). Stronger ratings of communication, shared responsibility, and positive peer interaction did not reliably coincide with higher individual mathematics test scores in the study sample. This result does not demonstrate that collaboration has no educational value; it establishes only that a linear association was not supported by the observed data.

Table 6. *Pearson Correlation of the Principal Study Variables*

Variable pair	Pearson r	p	Result
Mathematics performance × collaborative skills	0.057	.670	Not statistically significant

Group engagement and individual test performance represent different forms of learning evidence. Social support may help students remain involved and persist, whereas individual scores also depend on subject knowledge, solution planning, accuracy, and independently demonstrated reasoning. Studies of collaborative dispositions and problem-solving roles illustrate the complexity of these constructs (Li et al., 2023; He et al., 2023). The present design cannot test whether collaboration moderates or mediates learning over time or whether other unmeasured factors explain performance variation.

Proposed Integrated Math Circles Enhancement Framework

Based on the domain scores and item-level needs, the thesis proposed an Integrated Math Circles Enhancement Framework to maintain the strengths of positive group interaction while strengthening independent mathematical problem-solving. Its six-stage learning cycle—Prepare, Explore, Express, Examine, Apply, and Reflect—moves from problem orientation and individual thought to group explanation, strategic evaluation, independent application, and reflection. The framework prioritizes clear mathematical communication, shared understanding, alternative solution methods, sustained engagement, and individual accountability.

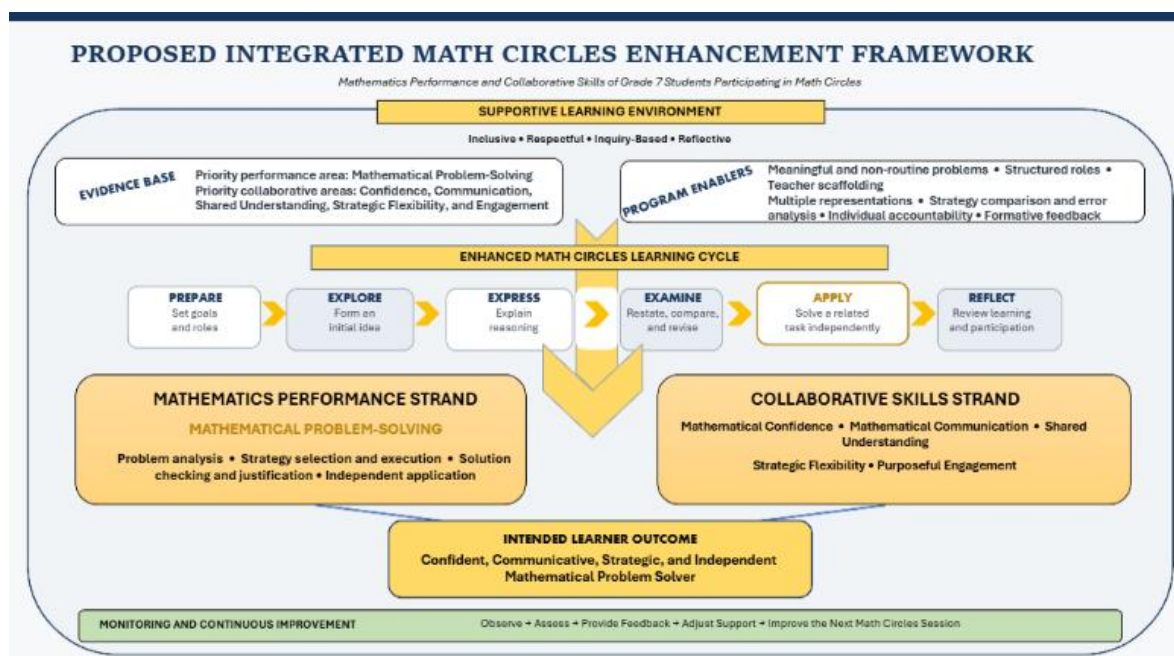


Figure 2. *Proposed Integrated Math Circles Enhancement Framework*

The framework also proposes a cycle of observation, assessment, feedback, and improvement across successive sessions. Such implementation would require manageable non-routine tasks, supportive facilitation, explicit group roles, and short individual checks after collective work. Because the framework is a proposed output rather than an experimentally evaluated intervention, its effectiveness and feasibility remain to be tested in subsequent school implementation and research.

CONCLUSION

Grade 7 Math Circles participants demonstrated Proficient mathematics performance and self-reported collaborative skills to a Very Great Extent. Conceptual understanding was their comparatively strongest mathematical domain, while problem-solving showed the greatest need for attention. Positive interdependence and social interaction were strongly rated, but some mathematical explanation, alternative strategy selection, and confident contribution behaviors were less evident. Neither mathematics performance nor collaborative skills differed significantly by sex, age, or academic standing, and the correlation between the two variables was very weak and statistically non-significant. The study contributes context-specific evidence for improving an existing enrichment program, particularly by linking group mathematical dialogue to independently demonstrated problem-solving. As a descriptive-correlational investigation in one school, it cannot establish causal benefits of Math Circles or determine the effectiveness of the proposed framework.

Recommendation

Mathematics teachers and Math Circles facilitators may prioritize non-routine and multi-step tasks that require learners to interpret information, select and compare strategies, justify reasoning, and check solutions. Guided mathematical discussion should include opportunities for students to explain an approach, restate a peer's idea, represent a solution in more than one way, and revise an unsuccessful method. Rotating group responsibilities and brief independent application tasks can support both equitable participation and individual accountability.

School administrators may support a pilot of the proposed Prepare–Explore–Express–Examine–Apply–Reflect cycle by providing appropriate materials, collaborative planning time, and feedback mechanisms. Future researchers may evaluate the framework using pretest–posttest or comparison-group designs, larger and more varied school populations, observational indicators of collaborative behavior, and additional variables such as prior achievement, motivation, engagement, and mathematical self-efficacy. The results of such studies would provide evidence that the present descriptive-correlational investigation was not designed to establish.

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