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Exploring the Utilization of Collaboration Scripts to Enhance Mathematical Argumentation of Grade 8 Students

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Abstract

This study explored the effectiveness of collaboration scripts in enhancing the mathematical argumentation skills of Grade 8 students at Bacoor National High School - Main. A heterogeneous class of 35 students participated in a three-week intervention using structured collaboration scripts. Employing a mixed-methods explanatory sequential design, quantitative data were gathered through a pre-test and post-test that measured four components of mathematical argumentation. Qualitative data from student interviews captured their learning experiences. Results revealed significant improvements in all post-test components. Students reported increased confidence, improved reasoning, and enhanced communication skills, which they attributed to the collaboration scripts. These findings suggest that collaboration scripts are effective tools for promoting engagement, deepening conceptual understanding, and developing mathematical argumentation in secondary mathematics classrooms.

Keywords: Collaboration scripts, Mathematical argumentation, Mixed-method research, Secondary mathematics, Student engagement

1. Introduction

The importance of mathematical literacy has been consistently emphasized in PISA assessments, including from PISA 2003 to PISA 2022. PISA defines mathematical literacy as the ability to reason mathematically, develop and apply mathematics, and understand and solve problems in various situations. It helps individuals recognize the importance of mathematics in everyday life. It equips them to make thoughtful and informed decisions, essential qualities for active, responsible, and reflective citizens in the 21st century (OECD, 2022).

Mathematical literacy is the skill that supports the application of mathematics in dealing with lives. This allows students to develop the skills and confidence to think numerically and spatially, interpret and critically analyze daily situations, and solve problems (Zarzua & Pasia, 2024). Mathematical literacy encompasses competencies such as mathematical thinking and reasoning, mathematical argumentation, mathematical communication, modeling, problem posing and solving, representation, use of symbols, and application of tools and technology (Rizki et al., 2019).

Argumentation skills need to be developed to enhance students' critical thinking (Campbell et al., 2021). The process of argumentation helps improve students' reasoning skills, communication, social behavior, and information-gathering abilities. Argumentation is a

crucial skill for high school students to develop, construct, and communicate mathematical knowledge (Stylianides, 2018).

According to Kollar et al. (2014), the complexity of mathematical argumentation may necessitate the use of scaffolds for developing a strategy to acquire it. Collaboration scripts are among the scaffolding strategies that can be deployed to enhance mathematical argumentation skills (Schwaighofer et al.,2017).

This study aims to improve the mathematical argumentation skills of Grade 8 students by using collaboration scripts. Unlike the research conducted by Kollar et al. (2014), which focused only on high-achieving students, this study explores the impact of collaboration scripts on students across all achievement levels—low, average, and high. Furthermore, unlike Schwaighofer et al. (2017), who emphasized the benefits of combining multiple scaffolds for higher-achieving students while cautioning against using them with low-achieving students, this study acknowledges the potential challenges of integrating multiple scaffolds. To address these difficulties and prevent overloading learners, this study only focuses on collaboration scripts as a single scaffold to simplify the learning process.

2. Methods

2.1 Research Design

This study employed a mixed-methods explanatory sequential design to investigate the mathematical argumentation skills of Grade 8 students at Bacoor National High School Main. Mixed-method research was used in the study because it integrated both quantitative and qualitative data to provide a comprehensive understanding of the research problem (Creswell & Plano Clark, 2017). This design was used because it effectively connected the results of the quantitative to those of the qualitative study.

2.2 Respondents of the Study

The researcher included thirty-five (35) Grade 8 students enrolled at Bacoor National High School - Main for the 2024-2025 school year.

2.3 Sampling Procedure

The researcher used cluster sampling to select one heterogeneously grouped Grade 8 Mathematics class with 35 students from Bacoor National High School - Main. This method was chosen due to the large population size, making other sampling techniques less feasible. The selected class was treated using collaboration scripts.

2.4 Research Instrument

In the quantitative phase, the researcher developed a pre-test and post-test with questions categorized according to the elements of mathematical argumentation, including quality of arguments, student engagement, mathematical understanding, and communication skills. The two instruments, the pre-test and the post-test, were parallel to each other, targeting the same mathematical competency. In the qualitative phase, a questionnaire with three interview questions was developed to explore how students described their experiences using collaboration scripts to enhance their mathematical argumentation.

2.5 Data Gathering Procedure

Before the study, the researcher obtained approval from the school head and division office, followed by parental consent for 35 Grade 8 students. Mathematics experts validated the research instrument.

The quantitative phase began with a pre-test to assess students' initial performance. Based on the results, students were grouped into teams of five: two low scorers, two average scorers, and one high scorer. After a brief introduction to collaboration scripts, lessons were conducted using this strategy to enhance mathematical argumentation.

After three weeks of teaching with collaboration scripts, a post-test was administered to compare students' performance before and after the intervention.

The qualitative phase followed the quantitative analysis. Five students were interviewed to explore their experiences with collaboration scripts. The interview data were coded and thematically analyzed to provide deeper insights into the quantitative results and a comprehensive understanding of students' experiences.

2.6 Statistical Treatment and Data Analysis

Frequency and percentage were used to describe students' mathematical argumentation pre-test and post-test scores. A paired t-test was conducted to determine whether there was a significant change between the pre-test and post-test scores, while thematic analysis was used to identify and interpret key themes and patterns in students' responses regarding their experiences with collaboration scripts.

3. Results

3.1 Quantitative Phase of the Study

Table 1. Pre-test and Post-test Scores of Students in Mathematical Argumentation in Terms of Quality of Arguments

Quality of Arguments				
Score	**Pre-test Performance**		**Post-test Performance**	
	Frequency	**Percentage**	**Frequency**	**Percentage**
2.67 – 4.00	-	-	23	65.71%
1.34 – 2.66	5	14.30%	9	25.71%
0.00 – 1.33	30	85.70%	3	8.58%
Total	**35**	**100.00%**	**35**	**100.00%**

Table 1 shows the students' performance in the quality of their mathematical arguments during the pre-test and post-test. In the pre-test, 85.70% (30 out of 35) were at a low achievement level, and only 14.30% reached at least the average level. It can be seen that none of the students attained high-level performance. Most students struggled to develop clear, logical, and well-supported arguments. Their responses often contained false statements, poor evidence, and unclear explanations, which suggest issues with understanding mathematical concepts, articulating ideas, and using appropriate mathematical language and symbols. These challenges are corroborated by the findings of Tristani and Nusuntra (2022), who observed that students are poorly prepared in mathematical argumentation because classroom teaching places more emphasis on finding correct answers than explaining why. Likewise, Indrawatiningsih et al.

(2020) emphasized that conceptual knowledge scarcity hinders the development of valid and coherent arguments by students.

On the other hand, following the implementation of collaboration scripts, the post-test results showed a notable improvement. Only a small percentage of students continued to fall into the low-achievement category, while the majority attained the high-achievement level. Students' arguments became more thorough and cohesive, and they were able to make assertions that were more clearly backed up by pertinent examples or counterexamples. Additionally, they demonstrated gains in clarity of representation, mathematical language usage, and logical sequencing. These advancements demonstrate improvements in both reasoning and mathematical communication skills. Overall, the findings suggest that collaboration scripts were crucial in enhancing students' performance in argumentation and conceptual understanding.

Table 2. Pre-test and Post-test Scores of Students in Mathematical Argumentation in Terms of Students' Engagement

Students' Engagement				
Score	**Pre-test Performance**		**Post-test Performance**	
	Frequency	**Percentage**	**Frequency**	**Percentage**
2.67 – 4.00	-	-	20	57.14%
1.34 – 2.66	3	8.60%	12	34.29%
0.00 – 1.33	32	91.40%	3	8.58%
Total	**35**	**100.00%**	**35**	**100.00%**

Table 2 shows students' engagement in mathematical argumentation during the pre-test and post-test. In the pre-test, most students demonstrated low engagement, characterized by minimal participation and limited critical thinking. Many responses lacked justification, reflecting low confidence, limited experience, and gaps in understanding. This aligns with Manalaysa (2024), who emphasized that engagement influences learning and comprehension, and Roche et al. (2021), who noted its impact on motivation. Feelings of inadequacy and low self-efficacy often hinder participation in reasoning tasks.

Post-test results showed a significant increase in engagement after the use of collaboration scripts. Over half of the students reached the high achievement level, actively applying reasoning, organizing thoughts, and justifying conclusions with evidence. Students demonstrated thoughtful analysis, considered alternative options, and supported their claims.

The data suggest that collaboration scripts improved engagement by providing structure and promoting collaborative interaction. Iwuanyanwu (2022) highlighted that argumentation enhances critical thinking, supports multiple solution paths, and builds communication skills. Through collaboration, students gained confidence and became more active, reflective, and engaged in mathematical argumentation (Ederon & Aliazas, 2024).

Table 3. Pre-test and Post-test Scores of Students in Mathematical Argumentation in Terms of Students' Mathematical Understanding

Mathematical Understanding		
Score	**Pre-test Performance**	**Post-test Performance**

	Frequency	Percentage	Frequency	Percentage
2.67 – 4.00	-	-	16	45.71%
1.34 – 2.66	-	-	15	42.86%
0.00 – 1.33	35	100.00%	4	11.43%
Total	**35**	**100.00%**	**35**	**100.00%**

Table 3 presents students' understanding of mathematical concepts as measured by the pre-test and post-test. In the pre-test, all students demonstrated a low achievement level, indicating difficulty in applying theorems and postulates, particularly in problems involving triangle congruence and angle relationships. Their responses lacked accurate calculations, clear reasoning, and proper use of concepts, reflecting limited conceptual understanding. This aligns with Kartika et al. (2021), who emphasized that conceptual knowledge is essential for constructing valid and coherent arguments.

In contrast, post-test results revealed notable improvement. Most students moved to average or high achievement levels, with only a few remaining at low levels. Many demonstrated clearer reasoning, correct identification and application of postulates, and improved communication of mathematical concepts. While some errors persisted, they were mostly procedural rather than conceptual. This suggests that collaboration scripts helped students better understand and apply key mathematical concepts, enhancing their ability to construct meaningful and valid arguments.

Table 4. Pre-test and Post-test Scores of Students in Mathematical Argumentation in Terms of Students' Communication Skills

Communication Skills				
Score	**Pre-test Performance**		**Post-test Performance**	
	Frequency	**Percentage**	**Frequency**	**Percentage**
2.67 – 4.00	-	-	12	34.29%
1.34 – 2.66	-	-	12	34.29%
0.00 – 1.33	35	100.00%	11	31.43%
Total	**35**	**100.00%**	**35**	**100.00%**

Table 4 presents the students' performance in both the pre-test and post-test in terms of their communication skills in mathematical argumentation. During the pre-test, all students were classified at the low achievement level, indicating significant difficulty in expressing mathematical reasoning clearly and effectively. Their responses were often unclear, unstructured, or missing logical explanations altogether. This lack of clarity and organization suggests not only a limited understanding of mathematical content but also an inability to communicate their reasoning coherently and logically. Rohid (2019) emphasized that effective mathematical communication involves the ability to organize, connect, and express mathematical ideas using appropriate language. Without this skill, students are unable to construct sound arguments, which rely heavily on both content knowledge and clear expression (Osorio & Aliazas, 2022).

The post-test results, also shown in Table 4, demonstrate substantial improvement. A majority of students moved into the average and high achievement levels, indicating an enhanced ability to communicate mathematical ideas. Students who reached the high level were able to construct well-organized explanations, use appropriate terminology, such as congruence postulates and

geometric definitions, and guide the reader clearly through their reasoning. Those at the average level demonstrated a general understanding of the content but still struggled with precision, logical flow, and complete justification. Overall, the results suggest that the use of collaboration scripts helped students not only understand mathematical concepts more deeply but also express their thinking more clearly and systematically, leading to stronger and more coherent mathematical arguments

Table 5. Test of Significance in the Pre-test and Post-test Scores before and After Implementing Collaboration Scripts

Mathematical Argumentation Skills	Mean	SD	t	df	Sig. (2-tailed)	Interpretation
Quality of Argument	1.86 5.77	1.19 1.96	-14.021	34	0.000	Significant
Student's Engagement	1.00 5.54	0.97 1.95	-12.520	34	0.000	Significant
Mathematical Understanding	0.97 4.29	1.96 2.20	-13.66	34	0.000	Significant
Communication Skills	0.69 4.29	0.76 2.20	-9.51	34	0.000	Significant

Results reveal a significant improvement in all four components of mathematical argumentation quality, student engagement, mathematical understanding, and communication skills, after the implementation of collaboration scripts (all $p < 0.000$). These findings indicate that collaboration scripts effectively enhance students' argumentation skills.

The scripts notably improved the quality of arguments by encouraging the use of counterexamples, enabling students to test claims and reject faulty reasoning. Student engagement increased through structured interactions that required active participation, explanation, and justification during group discussions. Mathematical understanding deepened as students were guided to apply concepts accurately and articulate their reasoning clearly. Communication skills also improved, with students demonstrating more coherent, precise, and logically structured arguments in both written and oral forms.

Overall, collaboration scripts provided a structured framework that promoted critical thinking, equal participation, and evidence-based reasoning, leading to significant gains in students' mathematical argumentation.

3.2 Qualitative Phase of the Study

The thematic analysis revealed four key benefits of using collaboration scripts: enhanced participation and engagement, effective idea sharing and comparison, improved understanding and reasoning, and stronger group collaboration. Students became more actively involved in class discussions and group tasks, showing greater confidence and willingness to contribute.

The structured format of the scripts created a safe environment for exchanging ideas, encouraging all members to participate meaningfully.

Collaboration scripts also supported the development of mathematical reasoning. Students reported a clearer understanding of concepts and improved ability to construct logical, well-supported mathematical arguments. The process of justifying solutions, comparing reasoning, and refining ideas through dialogue helped deepen their conceptual knowledge and reasoning skills.

In terms of group collaboration, the scripts brought structure and balance, guiding students on how to listen, respond, and contribute effectively within their groups. This improved both individual accountability and group efficiency.

Overall, the themes strongly align with observed improvements in the quality of students' arguments, engagement, mathematical understanding, and communication skills. Collaboration scripts provided a structured and supportive framework that facilitated meaningful learning and strengthened the elements of mathematical argumentation.

4. Discussion

The researcher implemented collaboration scripts to examine their effect on the mathematical argumentation skills of Grade 8 students, using a mixed-methods explanatory sequential design. Pre-test results showed that 85.71% of students were at a low achievement level in argument quality, 91.43% in engagement, and 100% in both mathematical understanding and communication skills.

After the intervention, post-test results showed significant improvements: 65.71% reached high achievement in argument quality, 57.14% in engagement, 45.71% in mathematical understanding, and 34.29% in communication skills. Only 14.29% to 31.42% of students remained in the low achievement level across these components.

Paired t-tests revealed statistically significant differences between pre-test and post-test scores across all components ($p = 0.000$).

Following this, five students were interviewed to explore their experiences. Thematic analysis revealed four key themes: Enhanced Individual Participation and Engagement, Effective Idea Sharing and Comparison, Improved Mathematical Argumentation and Reasoning, and Support for Group Collaboration. Students reported that collaboration scripts made activities more engaging and supported the expression of ideas despite initial challenges.

5. Conclusion

This study concludes that the implementation of collaboration scripts significantly improved students' mathematical argumentation skills, as evidenced by the increase in their post-test scores. The results highlight that structured peer interaction can be an effective strategy in mathematics education, especially in fostering students' reasoning and communication skills.

A notable advantage of using collaboration scripts is that they provide all students with the opportunity to participate and exchange ideas, making classroom discussions more interactive and inclusive. However, since the study was limited to a single Grade 8 class over a short three-week period, the generalizability of the findings is limited.

To build on these results, future research may consider applying collaboration scripts across different grade levels, subject areas or over extended periods. Such investigations could offer deeper insights into the broader applicability and long-term impact of this strategy in enhancing students' mathematical understanding and argumentation skills.

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