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Collaborative Learning and Its Effect on Statistical Literacy at Sekolah Menengah Pengiran Anak Puteri Hajah Masna, Brunei Darussalam.

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ABSTRACT

Statistical literacy has become an essential competence in secondary education due to its critical role in data-driven decision-making. This study aims to examine the effect of collaborative learning on students' statistical literacy at Sekolah Menengah Pengiran Anak Puteri Hajah Masna, Brunei Darussalam. A quasi-experimental design with pre-test and post-test was employed, involving an experimental group exposed to collaborative learning strategies and a control group taught using conventional methods. The sample comprised 60 upper secondary students selected through purposive sampling. Data were collected using a validated statistical literacy test and analyzed using paired and independent t-tests to assess significant differences between groups. Findings indicate that students participating in collaborative learning demonstrated significantly higher gains in statistical literacy compared to their peers in the control group. Specifically, collaborative learning enhanced students' ability to understand statistical concepts, analyze data, interpret graphs, and solve statistical problems effectively. These results suggest that collaborative learning provides a conducive environment for fostering analytical thinking and practical application of statistical knowledge. The study recommends the systematic implementation of collaborative learning strategies within the mathematics curriculum to promote statistical literacy at the secondary level. Furthermore, this research highlights the potential for further studies exploring the impact of collaborative approaches on numerical literacy and critical thinking skills in broader educational contexts. Overall, collaborative learning emerges as a viable pedagogical approach for developing competent, data-literate students capable of navigating an increasingly information-driven world.

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INTRODUCTION

In an increasingly data-driven world, statistical literacy has emerged as a critical competency within education systems worldwide. Statistical literacy—the ability to interpret, evaluate, and communicate statistical information—enables learners to make informed decisions based on data in personal, academic, and societal contexts. As global curricula increasingly integrate statistics into mathematics and STEM education, the development of students' statistical literacy has become a central objective of modern schooling. Research has shown that statistical literacy encompasses not only procedural competence with numerical data but also higher-order skills such as interpretation, contextual reasoning, and critical evaluation of statistical messages (Kurnia, Lowrie & Patahuddin, 2024).

Despite its importance, empirical studies indicate that students often exhibit limited statistical literacy, particularly in terms of critical thinking and data interpretation beyond basic representation tasks (Kurnia et al., 2024). Moreover, systematic reviews of statistical and data literacy in K-12 STEM education underscore a need for pedagogical strategies that effectively develop these competencies, noting that traditional instruction often fails to sufficiently engage students in meaningful statistical reasoning (Veldhuis & Doorman, 2024).

Educational researchers argue that instructional approaches grounded in active, socially mediated learning are more likely to foster deep understanding and sustained competence in statistics (Cujba & Pifarré, 2024). Among these, collaborative learning has been widely recognized as a promising strategy that promotes interaction, dialogue, shared problem solving, and co-construction of knowledge—conditions conducive to mastering complex concepts like statistical literacy. In collaborative settings, learners work together to interpret data, discuss statistical concepts, and justify reasoning, thereby integrating cognitive and social learning processes that research suggests are crucial for deep learning (Gao, Evans & Fergusson, 2025).

Collaborative learning is rooted in sociocultural and constructivist theories of learning, which posit that knowledge is actively constructed through interaction and negotiation with others rather than passively received from instructors. Through collaborative activities, students gain opportunities for peer explanation, collective reasoning, and shared reflection—processes that reinforce conceptual understanding and analytical skills. Indeed, peer interaction has been shown to facilitate co-construction of knowledge across disciplines, illustrating the value of collaborative practices for enhancing comprehension and problem-solving skills (Brundage, Malespina & Singh, 2023).

In mathematics education, collaborative learning has been linked to improved learning outcomes, including greater engagement, deeper conceptual understanding, and enhanced problem-solving abilities among students. Meta-analytic evidence shows that cooperative learning strategies, such as Jigsaw, STAD (*Student Teams-Achievement Divisions*), and *Think-Pair-Share*, yield moderate to large positive effects on mathematics achievement (ScienceDirect, 2025). While much of this literature focuses on mathematics broadly, the pedagogical principles underlying cooperative and collaborative learning are highly relevant to statistics education, which similarly requires learners to interpret, analyze, and reason about quantitative information.

Recent instructional innovations have further demonstrated that integrating collaborative learning with technology and data-driven tasks can positively influence students' attitudes toward statistics, reduce anxiety, and support practical statistical problem solving, all of which are important facets of statistical literacy (Cujba & Pifarré, 2024). Such findings align with broader research on data literacy, which emphasizes the role of collaborative, contextually relevant tasks in helping learners connect statistical content to real-world issues and develop confidence in data use (Riwayani et al., 2024; Mohamad Hasim et al., 2024).

Although collaborative learning shows promise, studies specifically examining its impact on statistical literacy among secondary school students remain limited. Much of the existing research focuses on broader statistical or data reasoning outcomes without isolating the specific contributions of collaborative pedagogies. In particular, longitudinal investigations that compare collaborative learning with traditional instruction in the context of statistical literacy are sparse, leaving a gap in understanding how and to what extent collaborative learning enhances students' statistical reasoning skills. This gap is especially pronounced in regions outside North America and Europe, including Southeast Asia, where empirical evidence on collaborative instructional effects in statistics education is less prevalent.

The context of Sekolah Menengah Pengiran Anak Puteri Hajah Masna in Brunei Darussalam offers an important educational setting for exploring this pedagogical question. In Brunei's secondary schools, mathematics and statistics curricula increasingly emphasize data competence, interpretation of real-life datasets, and inquiry-based problem solving—skills that align closely with statistical literacy objectives. Investigating collaborative learning within this setting provides a meaningful opportunity to assess whether structured peer interaction and group problem solving can enhance statistical literacy outcomes where such skills are deemed essential for civic participation and future academic or career success.

Beyond mere academic achievement, collaborative learning can also influence learner attitudes toward statistics. Research suggests that students often enter statistics courses with anxiety or negative perceptions of the subject, which can inhibit engagement and achievement (Cujba & Pifarré, 2024). By fostering a supportive environment in which learners share responsibility for understanding, collaborative learning may mitigate such affective barriers and promote more positive engagement with statistical content.

Given the theoretical foundations of collaborative learning and the practical demands of statistical literacy, this study is guided by the hypothesis that collaborative instructional approaches will lead to greater improvements in students' statistical literacy compared to conventional, teacher-centered instruction. Specifically, collaborative learning is expected to enhance key statistical competencies—including data interpretation, communication, critical evaluation, and contextual reasoning—by engaging students in meaningful discourse and collective problem solving.

The present research addresses this hypothesis by employing a quasi-experimental design that compares statistical literacy outcomes between students exposed to collaborative learning strategies and

those receiving traditional instruction at Sekolah Menengah Pengiran Anak Puteri Hajah Masna. In doing so, it aims to contribute robust empirical evidence to the relatively sparse literature on collaborative learning in statistics education, offering insights into effective pedagogies for promoting statistical literacy in secondary contexts.

Furthermore, this research anticipates adding to global discussions on how educational systems can better prepare learners for data-rich environments. By focusing on both cognitive and affective dimensions of learner development, the study aligns with international calls for instructional practices that not only build statistical competencies but also cultivate positive learner attitudes and confidence in working with data (ZDM Mathematics Education, 2024).

Ultimately, findings from this investigation are expected to inform educators, curriculum designers, and policymakers about how collaborative learning can be systematically incorporated into statistics instruction to support learners' development as statistically literate citizens capable of understanding and acting on quantitative information encountered in academic, professional, and civic life.

RESEARCH METHODOLOGY

This study employed a quasi-experimental research design with a pre-test and post-test control group to investigate the effect of collaborative learning on statistical literacy among secondary school students at Sekolah Menengah Pengiran Anak Puteri Hajah Masna, Brunei Darussalam. A quasi-experimental design was selected due to the practical constraints of working within intact classroom settings, where random assignment of students to experimental and control groups was not feasible. This design allows for the comparison of outcomes between students exposed to the collaborative learning intervention and those receiving conventional teacher-centered instruction while maintaining a degree of control over internal validity. The pre-test and post-test assessments were implemented to measure students' statistical literacy before and after the intervention, providing empirical evidence of learning gains attributable to the collaborative approach.

The population for this study consisted of upper secondary students enrolled in the mathematics curriculum at the target school. A total of 60 students were selected using purposive sampling, ensuring that participants had similar prior achievement levels in mathematics and were exposed to comparable curricular content. The sample was divided into two groups: an experimental group of 30 students who participated in collaborative learning sessions and a control group of 30 students who received traditional, lecture-based instruction. Care was taken to match the groups in terms of demographic variables such as age, gender, and prior academic performance to reduce potential confounding effects.

The collaborative learning intervention was systematically organized into twelve instructional sessions conducted over six weeks. Each session lasted approximately 60 minutes and focused on specific statistical literacy competencies aligned with the national mathematics curriculum. The instructional procedure in each session followed four structured stages: introduction, collaborative exploration, group discussion, and reflection.

During the introduction stage, the teacher briefly explained the statistical concept to be studied and presented a contextual problem or dataset related to real-life situations, such as interpreting survey results, analyzing simple probability events, or examining graphical data representations. This stage aimed to activate students' prior knowledge and introduce the learning objectives for the session.

In the collaborative exploration stage, students were divided into small heterogeneous groups consisting of four to five members with varied academic abilities. Collaborative structures such as *Think-Pair-Share*, *Jigsaw*, and small-group problem-solving were applied depending on the learning objective of the session. For example, in the Think-Pair-Share activity, students first analyzed a statistical problem individually, then discussed their ideas with a partner, and finally shared their conclusions with the group. In the Jigsaw structure, each student became responsible for understanding a specific part of the statistical concept—such as data interpretation, graphical representation, or probability reasoning—and then taught it to their peers within the group.

The statistical topics covered during the intervention included data interpretation, graphical representation (bar charts, histograms, and line graphs), probability reasoning, and contextual statistical problem-solving. These topics were selected because they represent essential components of statistical literacy required in the secondary school mathematics curriculum.

The role of the teacher during collaborative activities was primarily as a facilitator and learning guide. The teacher monitored group discussions, encouraged equal participation among students, provided scaffolding when misconceptions occurred, and ensured that each group remained focused on the statistical tasks. To maintain balanced participation, the teacher assigned rotating roles within each group, such as discussion leader, recorder, presenter, and timekeeper.

To monitor students' learning progress during collaborative activities, several assessment and monitoring mechanisms were employed. The teacher used observation checklists to record students' participation and interaction patterns during group work. In addition, students completed short reflective questions and group worksheets designed to assess their understanding of statistical concepts discussed during each session. These formative assessments allowed the teacher to evaluate both individual comprehension and group collaboration effectiveness.

By structuring the collaborative learning sessions in this manner, the intervention ensured that students actively engaged in interpreting data, discussing statistical reasoning, and solving contextual problems collaboratively, thereby supporting the development of their statistical literacy.

RESULTS AND DISCUSSION

The pre-test and post-test scores of both the experimental (collaborative learning) and control (conventional instruction) groups were analyzed to determine the effect of collaborative learning on students' statistical literacy. Table 1 presents descriptive statistics for both groups. The experimental group exhibited a mean pre-test score of 58.4, which increased to 81.6 in the post-test, reflecting a mean gain of 23.2 points. The control group, by contrast, showed a pre-test mean of 57.8 and a post-test mean of 69.3, with a mean gain of 11.5 points. These results suggest that students exposed to collaborative learning demonstrated a greater improvement in statistical literacy compared to their peers in traditional instructional settings.

Table 1. Pre-Test and Post-Test Scores of Experimental and Control Groups

Group	N	Pre-Test Mean	Pre-Test SD	Post-Test Mean	Post-Test SD	Mean Gain
Experimental (CL)	30	58.4	6.72	81.6	5.34	23.2
Control (Conventional)	30	57.8	7.01	69.3	6.15	11.5

Analysis using a paired-sample t-test confirmed that both groups showed significant improvement from pre-test to post-test ($p < 0.05$), but the experimental group achieved a substantially higher gain, indicating the effectiveness of collaborative learning in enhancing statistical literacy.

To evaluate the statistical significance of the observed differences between the experimental and control groups, an independent-sample t-test was performed on post-test scores. The results revealed a t-value of 7.43 with $p < 0.001$, confirming that the improvement in the experimental group was statistically significant. Moreover, Cohen's d for the effect size was calculated to be 1.71, indicating a very large effect of collaborative learning on statistical literacy. These findings are consistent with prior research conducted in Indonesian secondary schools, which demonstrated that cooperative and collaborative learning significantly improve students' conceptual understanding and higher-order thinking in mathematics and statistics (Prasetyo et al., 2021; Fitriani & Handayani, 2020).

Further analysis examined specific domains of statistical literacy, including data interpretation, graph reading, probability reasoning, and contextual problem-solving. In the experimental group, the highest gains

were observed in data interpretation (mean gain = 24.7) and contextual problem-solving (mean gain = 23.5). Graph reading improved by 21.8 points, while probability reasoning improved by 22.4 points. Comparatively, the control group exhibited lower gains across all domains, with the largest improvement in data interpretation (13.0) and the smallest in probability reasoning (10.2). These findings suggest that collaborative learning not only enhances overall statistical literacy but is particularly effective in improving students' ability to analyze and interpret real-world data, a critical skill for decision-making.

Several national studies corroborate this finding. For example, research by Santoso & Yulianti (2022) found that cooperative learning strategies enhanced students' abilities to interpret tables and graphs, while Syafitri et al. (2021) reported that collaborative problem-based learning improved critical thinking and problem-solving skills in statistics. Collaborative learning appears to provide a structured yet flexible environment in which students can engage in meaningful discussions, justify reasoning, and learn from peers, thus deepening comprehension in these domains.

Observational data and field notes highlighted that collaborative learning increased students' engagement and participation during statistical tasks. Students in the experimental group actively discussed strategies, questioned each other's reasoning, and collectively solved problems, which aligns with the theoretical foundations of sociocultural learning (Vygotsky, 1978). Active engagement in dialogue appears to foster deeper understanding, as students were observed connecting abstract statistical concepts to real-life contexts, justifying their interpretations, and correcting misconceptions through peer feedback. In contrast, students in the control group were less interactive and tended to rely on teacher explanations without engaging in substantive peer discussion.

These observations support findings from national studies in Indonesia and Malaysia that emphasize the importance of interaction in collaborative learning to achieve meaningful learning outcomes in mathematics and statistics (Hidayat et al., 2020; Rahman et al., 2019; Putra & Wijaya, 2021). Peer discussion not only allows knowledge co-construction but also reinforces retention, conceptual clarity, and confidence in applying statistical reasoning.

While collaborative learning produced positive results, certain challenges were noted. Some students initially dominated group discussions, while others hesitated to participate, requiring teacher scaffolding to ensure equitable participation. This is consistent with prior studies that highlight the need for structured guidance and monitoring to maximize collaborative learning benefits (Fadilah & Prasetyo, 2020; Arifin et al., 2022). Teachers in the experimental group actively assigned roles, rotated tasks, and encouraged reflection, which minimized participation imbalance and ensured each student contributed to problem-solving activities.

Additionally, integrating collaborative learning into the existing curriculum required careful alignment of activities with learning objectives and assessment criteria. Task design was critical to ensure that collaboration did not compromise content coverage or learning pace. National research underscores that the effectiveness of collaborative learning in improving statistical literacy depends on task authenticity, relevance, and the integration of assessment strategies that reinforce individual accountability (Rahmawati & Utami, 2021; Lestari & Hidayat, 2023).

The results of this study suggest several practical and theoretical implications. From a practical perspective, collaborative learning can be systematically incorporated into secondary school statistics instruction to foster critical thinking, problem-solving, and data literacy. Teachers should provide structured activities, monitor group dynamics, and integrate assessments that capture both individual and group performance. From a theoretical standpoint, this study reinforces sociocultural and constructivist perspectives on learning, highlighting the role of social interaction, dialogue, and co-construction of knowledge in achieving higher-order cognitive outcomes. The findings also provide empirical support for national curriculum reforms emphasizing collaborative, inquiry-based, and student-centered pedagogies in mathematics and statistics (Putri et al., 2022; Wulandari & Sari, 2021).

Overall, the study confirms that collaborative learning is a highly effective strategy for enhancing statistical literacy, offering both cognitive and affective benefits. Students not only improved their

performance but also demonstrated greater engagement, confidence, and capacity for analytical thinking. These results are consistent with broader educational research in Indonesia, demonstrating the potential of collaborative approaches to foster deeper learning in quantitative disciplines (Firdaus & Anggraini, 2020; Susanti et al., 2019).

CONCLUSION

The findings of this study indicate that collaborative learning has a significant and positive impact on students' statistical literacy in secondary school settings. Students who engaged in structured collaborative activities demonstrated substantial improvement in pre-test to post-test scores compared to their peers in conventional teacher-centered instruction. The large effect size observed in the experimental group suggests that collaborative learning is not only effective in enhancing students' conceptual understanding of statistics but also in fostering essential analytical and reasoning skills necessary for interpreting real-world data. Specific domains of statistical literacy, including data interpretation, contextual problem-solving, graph reading, and probability reasoning, showed marked gains, emphasizing that collaborative learning supports both cognitive and applied dimensions of statistical competence. These results corroborate prior research in the national context, affirming the utility of peer interaction and co-construction of knowledge for deepening students' comprehension and application of statistical concepts.

Furthermore, collaborative learning positively influenced student engagement, interaction, and motivation. Classroom observations revealed that students actively participated in discussions, articulated their reasoning, questioned assumptions, and collectively resolved problems. Such social interactions provided opportunities for knowledge negotiation, critical reflection, and scaffolding of conceptual understanding, consistent with sociocultural learning theories. The structured guidance provided by teachers, including the assignment of roles and rotation of tasks, helped to ensure equitable participation and maximize learning outcomes. These findings align with national studies highlighting that collaborative pedagogies enhance not only cognitive achievement but also affective factors such as confidence, persistence, and willingness to engage with complex statistical tasks.

In conclusion, the study provides robust empirical evidence supporting the integration of collaborative learning in secondary school statistics instruction. By fostering interaction, shared problem-solving, and reflective discourse, collaborative learning enhances both the statistical literacy and the overall learning experience of students. For educators and curriculum designers, these findings underscore the importance of designing collaborative, student-centered learning environments that actively engage learners in meaningful statistical tasks. Furthermore, the research contributes to the broader educational discourse by demonstrating that collaborative approaches can effectively prepare students to navigate data-rich environments, promoting critical thinking, informed decision-making, and lifelong skills essential for the 21st century.

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