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Development of a think-pair-share instructional material in statistics

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ABSTRACT

This study examines the development of think-pair-share (TPS) instructional material in Statistics, using the analysis, design, development, implementation, and evaluation (ADDIE) model, for the grade 11 science, technology, engineering, and mathematics (STEM) students in a parallel learning setup. It addresses the limited availability of structured TPS materials and the lack of evidence in such environments. A quasi-experimental design involving 173 students across four classes was employed. Expert-validated instruments, including an achievement test, formative assessment, and problem-solving test, measured learning outcomes. Results showed significant improvements in achievement (47.67% to 72.33%), formative scores (92.4% to 97.6%), and problem-solving ability (79.19%, closely approximating mastery). Regression analysis revealed formative scores and prior math performance as significant predictors. Qualitative feedback indicated increased engagement, clearer understanding, and improved reasoning. TPS integration enhanced learning, supporting its adoption in parallel settings.

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1. INTRODUCTION

Statistics is often considered a difficult subject for senior high school students because it demands both conceptual understanding and strong analytical skills. Many learners experience difficulty in interpreting data and applying statistical concepts to solve problems. Although traditional lecture-based instruction is effective for delivering content, it frequently limits student participation and engagement, which may hinder the development of critical thinking and problem-solving skills [1]. These concerns emphasize the need for more interactive and learner centered approaches in teaching statistics.

One approach that has shown potential in addressing these challenges is the think-pair-share (TPS) strategy. This cooperative learning method encourages students to think independently, collaborate with peers, and share their ideas with the class. Research indicates that TPS can improve students' academic performance, engagement, and conceptual understanding in mathematics related subjects [2]–[5]. When integrated with the analysis, design, development, implementation, and evaluation (ADDIE) model, an instructional design framework that includes analysis, design, development, implementation, and evaluation offers a systematic way of developing structured and interactive instructional materials [6]. In addition, employing a mixed methods approach allows for a more comprehensive evaluation of learning outcomes, while formative assessment supports continuous improvement by providing timely feedback that enhances students' problem-solving abilities [7], [8].

Collaborative learning strategies have consistently been associated with improved student engagement and academic performance across different educational settings [9]–[11]. However, there is still limited research on the development of TPS based instructional materials using the ADDIE framework, particularly in the context of statistics education and parallel class learning environments. At PHINMA-Cagayan de Oro College, where multiple class sections are conducted simultaneously, ensuring consistent student engagement remains a challenge. In response, this study focuses on developing and evaluating TPS based instructional materials in statistics for grade 11 science, technology, engineering, and mathematics (STEM) students using the ADDIE model within a parallel learning setup, with the goal of enhancing students' achievement, engagement, and problem-solving skills. Specifically, the study seeks to address the following questions: i) what instruments do learners need to support their learning? ii) how is the TPS instructional material designed and developed? iii) how will the TPS instructional material be implemented in a parallel class? iv) what is the academic performance of students taught statistics using the TPS instructional material in terms of: academic achievement; problem-solving test; and formative assessment? and v) which of the predictors, namely; formative assessment, academic achievement, and junior high school mathematics grade, have a significant relationship with students' problem-solving ability?

This study is grounded in instructional theories that underscore the relevance of TPS strategy in enhancing learning. Vygotsky's social constructivist theory highlights knowledge construction through social interaction, while Bandura's social learning theory emphasizes learning through observation and peer engagement, both supporting the collaborative nature of TPS [12]. Piaget's cognitive development theory further reinforces the role of active participation and peer discussion in cognitive growth, aligning with TPS as a structured interaction strategy. Additionally, problem-solving theories stress systematic reasoning, which TPS facilitates by prompting students to articulate, evaluate, and refine their thinking [7]. Empirical evidence also indicates that collaborative learning approaches improve student engagement and academic performance [9]–[11] with TPS serving as an effective active learning strategy that can complement traditional instruction [1], [13]. Collectively, these perspectives establish TPS as a theoretically supported approach for enhancing students' problem-solving skills and academic achievement across learning contexts.

2. METHOD

2.1. Research design

This study used a quasi-experimental design with qualitative support. The one-group pretest-posttest design measured students' achievement and formative assessment performance. The problem-solving test was analyzed using mean scores, standard deviations, and mastery levels to describe learners' proficiency in statistical problem-solving after the intervention. This is also a developmental study following the ADDIE model to create the TPS based instructional materials. Figure 1 illustrates the overall research design, showing how the pretest, TPS intervention, and posttest were systematically arranged to assess the instructional material developed through the ADDIE model.

O1 ——— X ——— O2

Figure 1. Design paradigm of the study

Where: O1 refers to the pretest administered for both the academic achievement test and formative assessment before utilization of TPS. X denotes the intervention or treatment, which involved instructional materials based on the TPS strategy and ADDIE model. O2 refers to the posttest administered for the academic achievement test, problem-solving test, and formative assessment after the utilization of TPS.

2.2. Participants

The 173 grade 11 STEM students from PHINMA-Cagayan de Oro College participated in the study. Since the students have already been matched in classes, it was not possible to randomly assign individual participants. Cluster sampling was therefore adopted with every section of the classes considered as a sample unit due to the intact parallel-class system.

2.3. Research procedure

The study utilized the ADDIE framework to design and develop TPS instructional materials. During the analysis phase, student needs and challenges were identified. In the design and development phases, lesson plans, activities, and assessments were created. The implementation phase involved applying the TPS materials to four parallel-class sections, incorporating collaborative learning strategies. The evaluation phase included pretests and posttests to measure learning outcomes, aligning with ADDIE's iterative assessment practices. A quasi-experimental one-group pretest-posttest design was used to evaluate the effectiveness of the materials in enhancing students' academic performance, problem-solving abilities, and formative assessment results.

2.4. Research instruments

This study employed validated researcher-developed instruments to assess student performance and the effectiveness of the TPS strategy. Students' instructional needs were identified using open-ended questions and a Likert-scale questionnaire [14], examining material suitability, clarity, collaborative learning experiences, and group activity preferences [2], [15]. Students' perceptions of TPS were measured through a 10-item evaluation tool focusing on reflection, collaboration, comprehension, retention, and participation, providing indicators of engagement and learning outcomes [13], consistent with prior findings [3], [16]. A teacher-made achievement test, refined from 60 to 30 items after expert validation, assessed statistical understanding across cognitive levels. It demonstrated strong reliability (Cronbach's α=0.847) [6].

Five expert-validated lesson plans supported TPS implementation, ensuring alignment with learning objectives and instructional standards [6]. A total of 15 problem-solving tests evaluated application of statistical concepts, with an item-level content validity index (I-CVI) of 1.00 confirming item validity [3]. A six-point problem-solving rubric assessed reasoning, process, and accuracy, providing a consistent measure of students' problem-solving performance [7].

2.5. Data analysis

The study applied a mixed methods approach, combining descriptive statistics and nonparametric tests to examine factors affecting problem solving ability at a 0.05 level of significance, alongside thematic analysis of student responses to identify patterns in engagement and learning challenges. The integrated findings guided the refinement of instructional materials and supported the use of collaborative learning approaches [8].

2.6. Ethical considerations

The study complied with ethical standards, securing approval from the Mindanao State University Human Ethics Subcommittee. Participation was voluntary, with informed and parental consent obtained, and confidentiality ensured through coded data and secure storage. Data will be retained for three years and reported in aggregate form. The study adhered to the transparent reporting of evaluations with nonrandomized designs (TREND) guidelines, with no conflicts of interest declared.

2.7. AI usage and assistance

The authors acknowledge the use of AI tools in preparing this manuscript. ChatGPT and QuillBot assisted with writing tasks such as grammar enhancement, sentence restructuring, and paraphrasing. Elicit and Scribbr were used for literature searches, information extraction, and citation management. These tools helped improve the text's clarity and structure but did not replace the authors' intellectual contributions, data analysis, or interpretation. All ideas, findings, and conclusions presented in the manuscript are the original work of the authors.

2.8. Limitations

This study demonstrates the effectiveness of the TPS strategy integrated with the ADDIE model but has several limitations. The one-group pretest-posttest design limits causal conclusions, as improvements may be influenced by factors like maturation, test familiarity, or teacher effects. The absence of a control group makes it difficult to fully attribute the improvements to the intervention. Future research should include a control group or randomized controlled trial (RCT). Variability in facilitator involvement across parallel classes suggests a need for more standardized teacher engagement. Additionally, the 8-session duration may have been too brief to achieve full mastery, as few students reached the "Mastered" category. Extending the intervention period may lead to greater learning outcomes. Despite these limitations, the study provides valuable insights into the TPS-ADDIE model's effectiveness and its potential applications in various educational contexts.

3. RESULTS AND DISCUSSION

3.1. The instruments needed by the learners

The study shows that combining cognitive strategies, peer collaboration, and structured instructional approaches improves students' understanding of statistics. The TPS method, which promotes idea sharing and confidence building through peer interaction, was found to be particularly effective. These findings are consistent with previous studies highlighting the role of collaborative learning and active engagement in improving students' academic performance and problem-solving skills [4], [15], [17]–[22].

The findings indicate that learners' understanding of statistics is supported by three key instruments: cognitive strategies, peer collaboration, and the use of technology, all of which are reinforced through structured approaches such as TPS. As shown in Table 1, active reading and recall, knowledge sharing through peer discussion, and the use of multimedia tools were all rated highly, indicating that learners employ a combination of metacognitive, social, and digital strategies to support comprehension. These results suggest that students are actively engaged in processing information, interacting with peers, and utilizing technology to enhance their learning. Peer collaboration, particularly through knowledge sharing and discussion, emerged as a central mechanism in enhancing problem solving and conceptual understanding. This aligns with the principles of TPS, where structured interaction enables students to articulate ideas and refine their thinking. The high-rating for-partner discussion further confirms that paired engagement is effective in clarifying complex statistical concepts. However, while participation was also rated high, its relatively lower mean suggests that ensuring equitable involvement remains a concern, highlighting the need for more structured facilitation. Overall, the results suggest that the integration of cognitive, collaborative, and technological instruments, as reflected in Table 1 and supported by structured strategies such as TPS, significantly enhances students' comprehension, engagement, and confidence in learning statistics [3], [4], [9]–[11] [15], [18], [23]–[28].

Table 1. Key learning instruments and TPS indicators

Category	Indicators	Description	Measure	Interpretation
Cognitive strategies	Active reading and recall	Use of note taking, recall, and self-assessment to support understanding	Score=4	Highly insightful
Collaboration	Knowledge sharing and peer discussion	Exchange of ideas and peer interaction to improve problem solving	Score=4	Highly insightful
Technology	Use of multimedia tools	Application of videos and apps to clarify concepts	Score=4	Highly insightful
TPS	Partner discussion	Help clarify complex concepts through paired interaction	M=3.95	High
TPS	Equal participation	Promote involvement among learners	M=3.61	High

3.2. Designing and developing of TPS instructional material following the ADDIE model

The study utilized an ADDIE based lesson plan integrating TPS to ensure a structured and collaborative approach to teaching grade 11 statistics. The framework addressed learner needs, content organization, and performance gaps, with TPS embedded in the design to promote active engagement and peer interaction. Instructional materials were developed and validated to ensure clarity and alignment with objectives, while implementation in a classroom setting enhanced participation and learning outcomes. Evaluation through assessments and expert feedback confirmed the effectiveness of the approach in supporting student understanding and aligning with curriculum standards [5], [18], [24], [28]–[31].

3.3. Implementing the TPS in a parallel class setting

The TPS method at PHINMA-Cagayan de Oro College is implemented in a parallel-class system, with one teacher rotating between four classrooms. The rotation follows 20-minute intervals, with the teacher spending time in each room while students engage in TPS activities under the guidance of facilitators. The session starts with a 5-minute preparation period at 7:30 a.m., followed by a 20-minute lecture in room 1 from 7:35 to 7:55 a.m., while students in the other rooms participate in TPS. The teacher then moves to room 2, and the cycle continues through rooms 3 and 4, with the longest tps session occurring in room 4 from 8:35 to 8:55 a.m. The session concludes at 9:00 a.m. with students having engaged in structured, collaborative learning.

3.4. Academic performance of students taught statistics using TPS on academic achievement and inferential analysis of academic achievement test

The results in Tables 2 and 3 show a statistically significant improvement in students' performance after the implementation of TPS, with mean scores increasing from 47.67% to 72.33% ($p<0.001$) and reduced variability indicating more consistent understanding [32]. These findings support prior research on the effectiveness of cooperative learning in improving achievement and retention [2], [5], [18]. While performance improved from average to moving towards mastery, the results suggest that increased use of the strategy may further enhance learning outcomes, including in other STEM areas [5].

Table 2. Pretest and posttest results in the academic achievement test

Test	Mean	SD	Mean percentage score (%)	Mastery level (DM No. 160, s. 2012)
Pretest	14.3	7.90	47.67%	Average
Posttest	21.7	5.79	72.33%	Moving towards mastery

Table 3. Wilcoxon signed-rank test results for pretest and posttest scores in academic achievement

Pretest	Posttest	Statistic (Wilcoxon W)	p	Interpretation
14.3	21.7	867[a]	<.001	Statistically significant improvement

Note.: H_a: μ (measure 1-measure 2) ≠ 0. [a] Five pairs of values were tied.

3.5. Academic performance of students taught statistics using TPS on problem-solving test and relationship of the predictors: formative assessment, academic achievement, and junior high school mathematics grade to students' problem-solving ability

The TPS strategy demonstrated a significant positive impact on student performance, as shown in Table 4, where 75.72% of learners reached the closely approximating mastery level and 3.47% attained full mastery. This reflects substantial gains in problem-solving skills while indicating that full mastery remains a challenge, requiring additional reinforcement and targeted feedback. Further analysis in Table 5 reveals that formative assessment scores (B=0.6932, p<0.001) and prior junior high school (JHS) mathematics grades (B=0.1295, p<0.001) are significant predictors of improved problem-solving ability, whereas posttest-based academic achievement was not significant (p=0.616). These findings highlight the critical role of continuous feedback in enhancing learning outcomes beyond traditional achievement measures [15], [31]. Overall, the results affirm the effectiveness of TPS as a collaborative learning strategy that strengthens engagement and problem-solving skills, offering a flexible and scalable approach applicable across diverse educational contexts, consistent with research on collaborative learning benefits [21].

Table 4. Students' performance levels in the problem-solving test during the TPS implementation

Mastery level	Frequency	Percentage	Interpretation
Moving towards mastery	36	20.81%	Requires reinforcement
Closely approximating mastery	131	75.72%	Nearing mastery, needs guidance
Mastered	6	3.47%	Fully mastered

Table 5. Ordinal logistic regression results on predictors of problem-solving ability

Predictor	Estimate (B)	SE	Z	p	Interpretation
Formative posttest	0.6932	0.1746	3.971	<.001	Significant-higher formative scores increase likelihood of higher problem-solving ability
Achievement posttest	-0.0167	0.0334	-0.501	0.616	Not significant
JHS grade	0.1295	0.0386	3.356	<.001	Significant-higher JHS math grade predicts higher problem-solving category

3.6. Academic performance of students taught statistics using TPS on formative assessment and inferential analysis of formative assessment scores

The results in Table 6 indicate a significant improvement in students' formative assessment performance, with the mean percentage score increasing from 92.4% to 97.6% and the standard deviation decreasing from 1.38 to 1.05, reflecting both enhanced understanding and greater consistency in performance. This progression from moving towards mastery to mastered underscores the effectiveness of the TPS strategy in deepening comprehension and strengthening problem-solving skills. Supporting this, the Wilcoxon signed rank test results in Table 7 confirm that the improvement is statistically significant (p<0.001), reinforcing the role of TPS in promoting active engagement, reflection, and collaborative learning. These findings are consistent with prior research on the benefits of peer interaction and active learning in improving conceptual understanding [18], [23] and collectively demonstrate that TPS effectively enhances academic achievement, collaboration, and problem-solving skills in statistics.

Table 6. Pretest and posttest results for the formative assessment

Test	N	Mean score	SD	Highest possible score	Mean percentage score (%)	Mastery level (DM 160, s. 2012)
Pretest	173	23.1	1.38	25	92.4%	Moving towards mastery
Posttest	173	24.4	1.05	25	97.6%	Mastered

Table 7. Wilcoxon signed-rank test results for pretest and posttest scores in formative assessment

Pretest	Posttest	Statistic (Wilcoxon W)	p	Interpretation
23.1	24.4	475[a]	<.001	Statistically significant improvement

Note. H_a: μ (measure 1-measure 2) $\neq 0$. [a] Five pairs of values were tied.

4. CONCLUSION

This study demonstrates the effectiveness of integrating TPS with the ADDIE model to enhance academic achievement, problem-solving skills, and engagement in STEM education. It emphasizes the importance of formative assessments in driving continuous improvement. While tested in Statistics, the model is applicable to other STEM fields such as physics, chemistry, and engineering, addressing global challenges in student engagement and problem-solving. This instructional framework offers valuable insights into improving STEM outcomes and can be adapted across diverse educational settings worldwide.

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C : **C**onceptualization
M : **M**ethodology
So : **So**ftware
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Fo : **Fo**rmal analysis
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R : **R**esources
D : **D**ata Curation
O : Writing - **O**riginal Draft
E : Writing - Review & **E**diting
Vi : **Vi**sualization
Su : **Su**pervision
P : **P**roject administration
Fu : **Fu**nding acquisition

CONFLICT OF INTEREST STATEMENT

No conflicts of interest declared.

INFORMED CONSENT

Informed consent and ethics approval were obtained.

DATA AVAILABILITY

The information underlying this study’s results can be obtained from the corresponding author, [LJDS], upon request.

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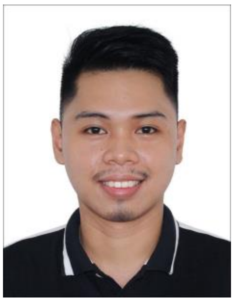

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