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# Square Root Maze with a Twist: Effects on Grade 9 Learners' Achievement Levels in Radicals

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## ABSTRACT

*This study investigated the effects of the Square Root Maze with a Twist (SRMT), a collaborative, game-based intervention, on the achievement levels and learning experiences of Grade 9 learners with low mathematics performance. The study employed a quasi-experimental nonequivalent control-group design. An experimental group engaged in SRMT for two weeks, while a control group received traditional remedial instruction. Quantitative analysis revealed no statistically significant differences in radicals achievement scores, either within or between groups. This finding is contextualized by the study's low statistical power due to small sample sizes. In contrast, qualitative data from learner journals and interviews showed that SRMT was highly effective in the affective domain. Thematic analysis revealed prominent themes of enhanced engagement, motivation, and the value of peer collaboration. Learners reported increased confidence and a strong preference for the game-based approach over traditional methods. The study concludes that while SRMT did not produce statistically significant achievement gains in this context, it holds considerable promise for improving learner motivation and engagement. The findings highlight the importance of considering affective outcomes alongside achievement scores when evaluating innovative pedagogical tools.*

**Key Words:** Game-based Learning, Collaborative Learning, Mathematics Education, Remedial Instruction, Student Engagement.

## 1. INTRODUCTION

Low mathematics proficiency among Filipino learners continues to be a pressing concern at both national and local levels. In the 2019 Trends in International Mathematics and Science Study (TIMSS), the Philippines ranked last among 58 participating countries in Grade 4 mathematics (Mullis, Martin, Foy, & Hooper, 2020), reflecting deep and systemic challenges in learners' numeracy. National assessments likewise report mathematics as one of the weakest learning areas, particularly in public schools and rural communities (Department of Education, 2019). These outcomes signal persistent gaps in conceptual understanding, problem-solving, and higher-order thinking skills.

Pantao Ragat Agro-Industrial High School (PRAIHS) in Lanao del Norte reflects this broader situation. Over the past five years, Grade 9 students have consistently performed below expected proficiency levels in mathematics, with around 55% of learners struggling with key competencies such as basic operations, problem solving, and critical thinking. Informal teacher reports and classroom assessments indicate that radicals are among the most difficult topics in the Grade 9 curriculum. Learners frequently confuse the properties of radicals, forget procedures, and struggle to connect symbolic manipulation with meaning. Recent research similarly shows that students often exhibit fragmented and unstable understanding of radical expressions, having difficulty coordinating conceptual knowledge of roots with procedural rules for simplification and operations (Katsioti, Pitta-Pantazi, & Christou, 2021). Parallel findings for exponents reveal persistent misconceptions about exponent rules, negative and zero exponents, and the relationship between radicals and fractional powers (Shongwe, 2020).

More broadly, work on cognitive load in algebra suggests that topics requiring the coordination of several subskills—such as factorization, exponent rules, and equivalence of numerical forms—place heavy demands on working memory, especially for learners with fragile prior knowledge (Özkan & Ünlü, 2022). As a result, low-

achieving students are particularly vulnerable to errors, misconceptions, and mathematics anxiety when working with radicals and related algebraic procedures (Ersoy & Oksuz, 2015; Soriano, 2014). The problem has been exacerbated by disruptions brought about by the COVID-19 pandemic, which limited opportunities for interactive, teacher-guided practice. In PRAIHS, many Grade 9 students from low-income families experienced reduced access to learning resources and inconsistent home support, widening existing achievement gaps. As a result, a substantial number of Grade 9 learners enter the second quarter with low achievement levels in mathematics, typically receiving quarterly grades between 75 and 79—barely meeting passing standards and requiring remedial instruction.

Traditional remedial approaches at PRAIHS have relied heavily on teacher-led review and additional worksheets. While these methods increase practice time, teachers report that they do not necessarily translate into improved engagement or confidence. Learners often perceive remedial work as repetitive and discouraging, and they rarely have opportunities to discuss solution strategies with peers or receive immediate, formative feedback. These conditions highlight the need for innovative remedial strategies that are not only aligned with curriculum standards but also responsive to learners' motivational and socio-emotional needs.

A growing body of literature suggests that game-based learning can enhance students' motivation, time-on-task, and conceptual understanding in mathematics by embedding practice within meaningful and enjoyable activities (Dalidig, 2019; Goos, 2010; Mayer, 2005). Game-based tasks can create a state of "flow," where students experience sustained focus, clear goals, and immediate feedback, all of which are associated with deeper learning. Similarly, collaborative learning approaches have been shown to support mathematical understanding by allowing learners to explain their reasoning, confront misconceptions, and jointly construct strategies (Anthony & Walshaw, 2007; Ornstein, 2005). When combined, game-based and collaborative structures may be particularly promising for low-achieving students, as they provide social support, reduce anxiety, and normalize error as part of learning.

However, despite the increasing interest in game-based and collaborative learning in mathematics, few studies have examined their use specifically for teaching radicals in Grade 9 remedial contexts in Philippine public schools. Existing game-based interventions often focus on whole-number operations, fractions, or general problem-solving skills, and are typically implemented as individual seatwork rather than structured, team-based activities. This leaves a gap in understanding how a collaborative, game-like remedial tool might influence the achievement and learning experiences of students who are already identified as struggling in algebra.

To respond to this gap, the present study explores the use of a Square Root Maze with a Twist (SRMT) as a remedial intervention for Grade 9 learners at PRAIHS who have low achievement levels in mathematics. The SRMT is an adaptation of the familiar "square root maze" worksheet, in which learners must correctly evaluate or simplify radical expressions to navigate from a starting point to an exit. In this study, the activity was redesigned as a team-based game with structured rules, limited "powers" (hints, answer checks, and passes), and a scoring system. The intervention aimed to (a) provide intensive practice on simplifying and operating on radical expressions, (b) promote collaborative problem solving and peer explanation, and (c) increase learners' engagement and confidence in working with radicals.

Theoretically, the study is grounded in Bruner's constructivism and Gardner's theory of multiple intelligences. From a constructivist perspective, learning occurs as learners actively build new knowledge through experience, reflection, and social interaction (Cunningham & Duffy, 1996). The SRMT creates opportunities for students to explore different solution paths, test their ideas, and receive immediate feedback through game outcomes. Gardner's framework suggests that learners possess varied profiles of intelligences, including logical-mathematical, spatial, and interpersonal intelligences. The SRMT leverages these dimensions by requiring logical reasoning with radicals, visual navigation through the maze, and cooperative decision-making within teams.

Within this context, the study focuses on Grade 9 students with quarterly mathematics grades between 75 and 79—identified by their teacher as struggling learners in need of remediation. It seeks to determine whether exposure to SRMT in remedial sessions is associated with changes in their achievement levels in radicals, and to document how learners perceive and experience this intervention. By integrating a collaborative, game-based remedial activity into a real classroom setting, this study contributes evidence on the potential and limitations of SRMT for supporting low-achieving Grade 9 learners' understanding of radicals in a Philippine public school context.



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The primary objective of this action research is to examine the effects of the Square Root Maze with a Twist (SRMT) on the achievement levels of Grade 9 learners who require additional support in understanding radicals. Specifically, this study sought to: (1) determine the pretest and posttest achievement levels in radicals of Grade 9 learners exposed to SRMT and those who received traditional remedial instruction; (2) determine and compare the gain scores in radicals of Grade 9 learners in the SRMT group and the control group; and (3) draw insights from Grade 9 learners' journals and interviews regarding their experiences and perceptions of the SRMT intervention.

## 2. METHODOLOGY

### 2.1 Research Design

This study employed a quasi-experimental nonequivalent control-group design with mixed methods. Two intact Grade 9 classes at Pantao Ragat Agro-Industrial High School (PRAIHS) were assigned as the experimental and control groups. Both groups completed a researcher-made achievement test on radicals as a pretest and posttest, while only the experimental group received the Square Root Maze with a Twist (SRMT) intervention.

The design was chosen because random assignment of individual learners to groups was not feasible in the school setting. However, a pretest–posttest structure allowed for comparison of changes in achievement between groups while partially controlling for initial differences. As with any nonequivalent control-group design, potential threats to internal validity—such as pre-existing classroom differences, teacher expectations, and history effects—cannot be fully ruled out and are considered in interpreting the findings. To enrich and explain the quantitative results, qualitative data were gathered through learner journals and semi-structured interviews with selected students from the experimental group.

### 2.2 Participants and Sampling

The participants were Grade 9 students enrolled at PRAIHS during School Year 2023–2024. Two intact sections were purposively selected in consultation with the school head and mathematics coordinator. Selection criteria were: (a) both sections were taught by the same Grade 9 mathematics teacher, (b) both followed the same curriculum and assessment schedule, and (c) both had a substantial number of learners with quarterly mathematics grades between 75 and 79 in the first grading period.

The focus on learners with grades in the 75–79 range was intentional. In the PRAIHS grading system, this range represents students who are barely meeting the minimum passing standard and are officially identified by the school as struggling learners in need of remediation. Targeting this group aligns with the school's goal of raising the performance of learners at risk of failure and with the Department of Education's emphasis on addressing learning gaps among low-performing students.

One section (n = 10) was designated as the experimental group, which received the SRMT intervention, and the other section (n = 9) served as the control group, which received the usual teacher-led remedial instruction. Assignment of sections to conditions was based on practical considerations (e.g., class schedule and availability of the classroom) rather than randomization. The experimental and control groups had similar mean quarterly mathematics grades of 78.50 and 79.79, indicating broadly comparable mathematical abilities at the outset. This is supported by the pretest scores of students with grades between 75 and 79 on the radicals achievement test, which averaged 7.70 for the control group and 7.78 for the experimental group. Although no formal statistical test of baseline equivalence was conducted, these descriptive indicators suggest that the two groups were reasonably similar in initial performance in mathematics and in radicals.

### 2.3 Research Instruments

In the process of gathering data needed for the study, the following research instruments were used:

#### 2.3.1. Radicals Achievement Test

A 30 item multiple-choice test on radicals was developed by the researcher based on the Grade 9 mathematics curriculum guide of the Department of Education. The test covered simplifying radicals, operations with radicals, and



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applications of radicals in problem situations. Items were classified according to cognitive demand (remembering, understanding, applying).

*Content validation.* The initial test blueprint and item pool were reviewed by three experts: two Grade 9 mathematics teachers with at least fifteen years of teaching experience and one mathematics supervisor. The experts rated each item for relevance, clarity, and alignment with the curriculum. Item-level content validity indices (I-CVI) ranged from 0.80 to 1.00, and the scale-level CVI (S-CVI/Ave) was 0.93, indicating acceptable content validity. Items with low ratings were revised or replaced based on the validators' comments.

*Pilot testing and reliability.* The revised test was pilot-tested with 45 Grade 9 students from another public high school within the same division who were not part of the main study. Item analysis was conducted to examine item difficulty and discrimination indices, and poorly performing items were modified or discarded. The internal consistency reliability of the final 30 item test yielded a reliability index of 0.84 using Cronbach's Coefficient Alpha.

### 2.3.2. Interview Guide

Interview Guide (IG). After the intervention, semi-structured interviews were conducted with 10 purposively selected learners from the experimental group, representing a range of achievement levels and participation patterns. The interview guide focused on learners' perceptions of SRMT, perceived benefits and challenges, and suggestions for improvement. The guide was reviewed by two colleagues for clarity and appropriateness and revised accordingly.

### 2.3.3. Learners' Journal (LJ)

Learners' Journals (LJ). Students in the experimental group were asked to keep brief reflective journals after each SRMT session. Prompts guided them to describe what they found easy or difficult, how they worked with their teammates, and how the activity affected their understanding and confidence in dealing with radicals.

## 2.4 SRMT Intervention

The Square Root Maze with a Twist (SRMT) is a game-based, collaborative remedial activity designed to provide intensive practice on radicals while promoting peer interaction and strategic problem solving. The SRMT builds on a traditional "square root maze" worksheet, where learners must evaluate or simplify radical expressions to navigate from a starting point to an exit. In this study, the maze was redesigned with added game mechanics, including team-based play, limited "powers," and a scoring system.

### 2.4.1. Game mechanics and learning targets

Each SRMT maze consisted of a grid of cells containing radical expressions or "blocked" cells. To move from the starting point to the exit, a team had to correctly simplify or evaluate the radical in the adjacent cell following the allowed moves. The SRMT targeted:

- Conceptual understanding, by requiring learners to recognize equivalent forms of radicals and to relate radicals to exponents and factorization;
- Procedural fluency, through repeated practice in simplifying radicals, rationalizing denominators, and performing operations with radicals;
- Error analysis, as incorrect moves led to "dead ends" or penalties, prompting teams to revisit and correct their procedures; and
- Problem-solving strategies, since teams had to plan routes, decide which expressions to attempt, and allocate their limited "powers" strategically.

Each team was given a fixed number of "powers" per maze: (a) Hint – a short clue from the teacher about a rule or step; (b) Answer Check – one opportunity to verify a solution before committing to a move; and (c) Pass – the option to skip one particularly difficult cell. Powers were limited to encourage discussion and careful reasoning before using them.

### 2.4.2. Implementation sequence

The SRMT intervention was implemented over two weeks, with 6 sessions of 60 minutes each. Six maze designs were prepared by the researcher, arranged in increasing complexity from basic square roots of perfect squares



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to more complex expressions involving variables and operations. All six mazes were used, with approximately one maze per session.

At the beginning of the first session, the teacher explained the rules of the game, formed heterogeneous teams of 3–4 learners, and modeled sample moves on a simple practice maze. In each subsequent session, the procedure was as follows:

1. The teacher distributed the maze and reviewed the target skills (e.g., simplifying radicals, rationalizing denominators).
2. Teams worked collaboratively to solve the radicals and decide their path, recording solutions and justifications in their answer sheets.
3. The teacher circulated to monitor participation, clarify instructions, and provide facilitative feedback without directly supplying answers.
4. At the end of each session, teams' paths and solutions were checked, scores were tallied, and brief whole-class reflection was conducted on common errors and strategies.

This structure was intended to maximize engagement, provide multiple opportunities for practice, and integrate immediate feedback into a collaborative, game-like environment. In contrast, the control group received the usual remedial instruction consisting of teacher-led review, board work, and individual worksheets covering the same set of radicals competencies but without game or team-based elements.

### 2.5 Data Gathering Procedure

Data collection proceeded in three main phases:

*Pre-intervention phase.* After securing necessary permissions, the radicals achievement test was administered to both experimental and control groups as a pretest under standard classroom conditions. The researcher explained the purpose of the test and assured learners that results would be used for research and instructional improvement, not for grading.

*Intervention phase.* Over a period of two weeks, the experimental group participated in SRMT sessions during their scheduled remedial periods, while the control group received traditional remedial instruction on the same content. During this phase, learners in the experimental group also completed short reflective journal entries after each session.

*Post-intervention phase*. After the completion of the intervention, the same radicals achievement test was administered as a posttest to both groups. Within one week after the posttest, semi-structured interviews were conducted with selected learners from the experimental group. Interviews were audio-recorded with consent and later transcribed verbatim for analysis.

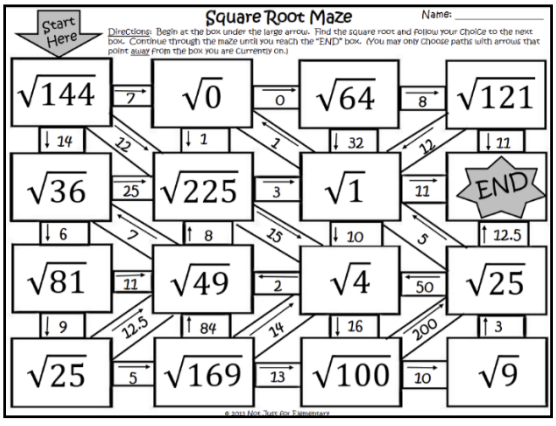


**Figure 1. A sample of adopted Square Root Maze from Vicki Massey, 2013**



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## 3. RESULTS AND DISCUSSIONS

### 3.1. Achievement Levels in Radicals

The study employed a quasi-experimental nonequivalent control-group design with pretest and posttest measures to assess changes in learners' achievement levels in radicals. Both the experimental and control groups completed the researcher-developed achievement test.

As indicated in Table 1, during the pretest, the majority of students in both groups performed at the "Fairly Satisfactory" level (67% for both control and experimental groups), with a significant portion falling into the "Did Not Meet Expectations" category (33% for control, 44% for experimental). No students scored in the "Satisfactory" or higher categories at this stage.

Following the intervention, both groups showed slight improvements. In the control group, 22% of students reached the "Satisfactory" level in the posttest, while 11% of the experimental group achieved this. However, the majority of students in both groups remained in the "Fairly Satisfactory" category (67% for control, 78% for experimental). Notably, no students in either group attained "Very Satisfactory" or "Outstanding" levels even after the intervention. The total mean scores also reflect this trend: the control group's mean increased from 7.78 to 9.56, and the experimental group's mean from 7.70 to 8.40. The control group demonstrated a slightly larger increase in average performance.

**Table 1. Comparison of Raw Scores in the Achievement Test**

| RAW SCORES | PRETEST | | POSTTEST | |
|---|---|---|---|---|
| | Control[a] | Experimental[b] | Control[a] | Experimental[b] |
| 25-30 (Outstanding) | 0 (0%) | 0 (0%) | 0 (0%) | 0 (0%) |
| 19-24 (Very Satisfactory) | 0 (0%) | 0 (0%) | 0 (0%) | 0 (0%) |
| 13-18 (Satisfactory) | 0 (0%) | (0%) | 2 (22%) | 1 (11%) |
| 7-12 (Fairly Satisfactory) | 6 (67%) | 6 (67%) | 6 (67%) | 7 (78%) |
| 0-6 (Did Not Meet Expectations) | 3 (33%) | 4 (44%) | 1 (11%) | 2 (22%) |
| **Total Mean** | **7.78** | **7.70** | **9.56** | **8.40** |

*Note:* [a]n=9, [b]n=10

The comparison of test scores within groups (experimental and control groups), as shown in Table 2, reveals that there is no significant difference in the students' achievement test scores before and after exposure to the "Square Root Maze with a Twist" (SRMT). To assess changes in achievement, the Wilcoxon signed-rank test was used to compare pretest and posttest scores within each group for a subset of participants, and the Mann-Whitney U test was used to compare posttest scores between groups using these subsets.

**Table 2. Difference of Scores in the Achievement Test**

| Group | | n | Test Used | Z-value | p | Decision |
|---|---|---|---|---|---|---|
| Within Groups | Pretest vs Posttest (control group) | 10 | Wilcoxon Sign Rank Test | -1.706 | 0.088 | Not significant |
| | Pretest vs Posttest (experimental) | 9 | | -1.725 | 0.084 | Not significant |
| Between Groups | Posttest(control) vs Posttest(experimental) | 10 vs 9 | Mann-Whitney Test | -0.909 | 0.400 | Not significant |

** Significant at 0.05 level of significance*



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### 3.2. Learner Experiences with SRMT

Qualitative data from learner journals and semi-structured interviews were analyzed using thematic analysis to understand students' perceptions and experiences with the SRMT intervention. The analysis revealed four prominent themes:

*Theme 1: Enhanced Engagement and Motivation through Game-Based Learning.* A strong theme was the positive reception of the SRMT's game-like features. Learners consistently reported that the activity was more enjoyable and less intimidating than traditional methods. They appreciated the "maze" format, the element of competition within teams, and the strategic use of "powers," which increased their interest and willingness to engage with the mathematical content. This aligns with literature suggesting that game-based learning can boost motivation and time-on-task by embedding practice in enjoyable contexts (Mayer, 2005; Dalidig, 2019).

Representative Quote: *"This game is more enjoyable than ordinary worksheets. Even if the math is difficult sometimes, I feel like I prefer doing it because it's a game, and we even have powers."*

*Theme 2: Value of Collaboration and Peer Learning.* Learners highly valued the collaborative aspect of SRMT. Working in teams allowed them to explain concepts to each other, seek clarification without fear of judgment, and collectively strategize. This collaborative problem-solving environment is known to support mathematical understanding by enabling peer explanation and shared construction of knowledge (Anthony & Walshaw, 2007; Ornstein, 2005).

Representative Quote: *"When I don't know something, I ask my team. It's easier because you have someone to talk to; they explain it to you in different ways until you understand."*

*Theme 3: Perceived Improvement in Understanding and Confidence.* Many learners reported feeling a sense of increased understanding of radicals and a boost in their confidence as they navigated the mazes. This perception of improvement, even if not fully reflected in statistically significant gains on the test due to statistical power limitations, suggests a positive impact on their self-efficacy and their willingness to engage with the topic.

Representative Quote: *" Before, I had difficulty with radicals, but because of this maze, I feel like I'm getting more used to it. Even numbers with square roots, I'm no longer afraid to answer them."*

*Theme 4: Challenges and Areas for Improvement.* Despite the overall positive feedback, learners also identified challenges. These included occasional difficulty with complex radical expressions, frustration from running out of "powers" prematurely, and a desire for more immediate answer verification before committing to a move. These insights align with the potential reasons for the non-significant quantitative results and suggest that the intervention might benefit from adjustments such as more targeted scaffolding, additional "powers," or an integrated immediate feedback mechanism for every step.

Representative Quote*: "Sometimes the expressions are really hard, and we run out of powers. I hope we can check our answers immediately before moving to the next cell."*

## 4. CONCLUSIONS AND RECOMMENDATIONS

Based on the findings, the following conclusions are drawn:

The SRMT did not produce statistically significant improvements in radicals achievement compared to traditional remedial instruction. Both groups showed modest numerical gains, but neither reached higher performance levels, and the experimental group's improvement was smaller than the control group's. The limited sample sizes for statistical testing reduced the power to detect true effects, which may partially explain the non-significant outcomes.

However, the SRMT demonstrated clear value in the affective and motivational domains. Learners consistently described the activity as enjoyable, less intimidating, and more engaging than conventional worksheets. The collaborative structure of the intervention encouraged peer support, reduced anxiety, and fostered a sense of shared problem-solving—outcomes that are recognized as important precursors to sustained mathematical learning.

The qualitative evidence also highlighted areas for refinement. Learners expressed a desire for more immediate feedback, additional strategic "powers," and better scaffolding for complex expressions. These insights suggest that the SRMT, in its current form, may benefit from design adjustments to maximize both engagement and learning gains.



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### 4.1. Implications for Practice

The findings offer practical guidance for mathematics teachers and school administrators working with struggling learners:

- Game-based and collaborative activities should be integrated into remedial instruction. Even when achievement gains are modest, such activities can reduce mathematics anxiety, increase willingness to participate, and build learner confidence—outcomes that support long-term academic engagement.
- Intervention duration should be extended for conceptually demanding topics. A two-week, six-session intervention may be insufficient to produce measurable gains in a topic as complex as radicals, particularly for learners with fragile foundational knowledge.
- The SRMT should be used as a supplementary tool rather than a standalone solution. Its benefits are most likely to be realized when combined with explicit instruction, targeted scaffolding, and formative assessment.
- Peer learning structures should be deliberately fostered. Learners benefit from opportunities to explain concepts to one another and to hear explanations in accessible, peer-friendly language.

### 4.2. Recommendations for Future Research

To strengthen and extend the findings of this study, future research should consider the following directions:

1. Larger sample sizes should be employed to improve statistical power and increase the likelihood of detecting true effects.
2. Longer intervention periods should be tested. Extending the SRMT implementation to four or more weeks, with additional maze levels and cumulative review, may allow for deeper conceptual development.
3. The SRMT mechanics should be refined based on learner feedback. Adjustments such as additional "powers," immediate answer verification, adaptive difficulty levels, or integrated mini-lessons could enhance both engagement and learning outcomes.
4. Long-term retention and transfer should be assessed. Investigating whether any gains persist over time and whether learners can apply their understanding to related algebraic topics would provide stronger evidence of the intervention's educational value.
5. Different learner profiles should be examined. Future studies could explore whether SRMT is differentially effective for learners with varying prior knowledge, learning styles, or motivational orientations.

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