

Tactile learning approach for better cognitive understanding in solving problems with exponents among Grade VI learners

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ISSN: 2243-7703
Online ISSN: 2243-7711

Received: 25 July 2026

Available Online: 18 August 2026

Revised: 15 August 2026

DOI: 10.5861/ijrse.2026.26393

Accepted: 17 August 2026

OPEN ACCESS

Abstract

Mathematics is essential to modern life. It is used to solve problems across a wide range of sectors, including engineering, health, business, and finance. This action research investigated the effectiveness of a tactile learning approach, specifically the Mathopoly game, in improving the conceptual understanding of and problem-solving skills related to exponents among Grade 6 learners at Sidaen Elementary School. Using a one-group pretest–posttest design, 19 learners were assessed to determine the effect of tactile learning on their mathematical performance. Pre-intervention results indicated a Poor level of understanding ($M = 8.18$), while post-intervention scores improved to an Outstanding level ($M = 24.55$), a mean gain of 16.37. A t -test for dependent means confirmed that the difference was statistically significant, $t(18) = 9.15$, $p = .001$. These findings underscore the potential of hands-on, game-based learning to enhance engagement and comprehension in challenging mathematical concepts. The study recommends integrating tactile learning tools into the mathematics curriculum and providing teachers with training so that the benefits of such interactive learning strategies can be maximized.

Keywords: conceptual understanding, elementary education, exponents, game-based learning, Mathopoly, tactile learning

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1. Introduction

Mathematics is essential to modern life. It is used to solve problems in a variety of sectors, including engineering, health, business, and finance. The application of mathematical techniques facilitates data analysis, the forecasting of outcomes, and decision making. Its applications include the development of new technologies, the modeling of complex systems, and the formation of multidisciplinary links. Mathematics is also used to develop theories and models that describe the behavior of matter and energy, allowing people to better understand their place in the universe and the laws that govern it. In short, mathematics is the language of the universe and is critical to human progress.

The purpose of mathematics education around the world is to provide learners with the tools they need to think critically and creatively in a number of contexts, from the hard sciences to commerce (Wong & Yip, 2023). It also provides learners with tools for the investigation and analysis of the information they encounter. A solid understanding of mathematics equips learners with the quantitative and qualitative reasoning abilities required for professional and personal success in a variety of fields (Amalina & Vidákovich, 2023). Having a firm grasp of mathematics aids in the development of problem-solving and critical-thinking abilities that can be applied in a wide variety of contexts. Careers in finance, engineering, and information technology rely heavily on the ability to solve mathematical problems, and as society becomes more complex, mathematics becomes ever more important to everyday life (Cui et al., 2023; Li et al., 2023).

Despite this importance, many learners regard mathematics as a difficult and uninteresting subject. Filipino learners in particular have consistently struggled with the subject. In the 2019 Trends in International Mathematics and Science Study, the Philippines obtained the lowest mathematics score among all 58 participating education systems (Mullis et al., 2020). Within the classroom, learners are assessed through a variety of processes and measures that are suitable to and consistent with the learning competencies specified in the K to 12 curriculum, and these measures may be used for both formative and summative purposes (Department of Education, 2015).

The need to examine the use of a tactile learning approach to enhance problem solving involving numbers with exponents among Grade 6 learners is therefore pressing. Problem solving is a key skill that all learners must possess in order to succeed in mathematics, and exponents are a foundational concept that learners must understand before they can progress to more advanced topics. Tactile learning, sometimes called kinesthetic learning, is a strategy that helps learners acquire and retain information through physical interaction with instructional materials. This strategy is particularly useful when teaching challenging topics such as exponents, because it allows learners to attach abstract symbols to concrete actions (Adigun et al., 2024; Merrick & Fyfe, 2023).

At Sidaoen Elementary School, only 4 of the 19 Grade 6 learners had mastered exponent-based problem solving. This was the competency in which the class showed the greatest need for improvement, as evidenced by learners' outputs in homework and periodic tests. The purpose of this action research, therefore, was to determine whether a tactile learning approach helps Grade 6 learners become more proficient in solving problems involving numbers with exponents.

Statement of the Problem - This study utilized a tactile learning approach to enhance the mathematics performance of Grade 6 learners of Sidaoen Elementary School for School Year 2023–2024. Specifically, it sought to answer the following questions:

1. What is the level of conceptual understanding of the learners in solving problems on numbers with exponents before and after the utilization of the tactile learning approach?

2. Is there a significant difference between the learners' levels of conceptual understanding before and after the utilization of the tactile learning approach?

Hypothesis - The study tested the following null hypothesis at the .05 level of significance: There is no significant difference between the levels of conceptual understanding of Grade 6 learners in solving problems on numbers with exponents before and after the utilization of the tactile learning approach.

2. Proposed Innovation, Intervention, and Strategy

The tactile learning approach is a promising means of improving the mathematics performance of Grade 6 learners. Tactile learning, also referred to as kinesthetic learning, is learning by doing. It engages the sense of touch and invites learners to interact physically with the learning material rather than only reading or listening. By encouraging hands-on experience and experimentation, it positions learners as active participants in their own education. The approach also allows learners to make meaningful connections between abstract concepts and tangible experiences. Learners forge a link between what they see and hear and what they physically manipulate. This multisensory experience strengthens understanding and makes complex ideas easier to grasp and to remember (Yu et al., 2022).

In this study, the researcher used a manipulative game to boost the mathematics performance of the learners. Manipulative games engage learners while they are learning mathematics; they make concepts more enjoyable and provide opportunities for learners to practice newly acquired skills. Specifically, the researcher developed and used Mathopoly, a board game adapted from the familiar property-trading format, in which each space requires the player to evaluate, simplify, or compare expressions involving exponents before advancing. Game cards were prepared at three levels of difficulty so that learners could progress from evaluating simple powers to solving multi-step problems. Mathopoly was integrated into classroom discussions, formative assessments, and remedial classes in mathematics over a two-week period. Learners played in groups of four to five, with the teacher circulating as facilitator, correcting misconceptions as they surfaced and prompting learners to verbalize their reasoning before moving a token.

3. Action Research Methodology

Research Design and Participants. The study employed a one-group pretest–posttest experimental design. It involved one section of Grade 6 learners of Sidaoen Elementary School (N = 19), selected through total enumeration sampling. A letter requesting permission was sent to the parents of the participants before the start of data gathering, and consent was obtained for all 19 learners.

Data Gathering Methods. The researcher developed a 30-item teacher-made test on solving problems involving numbers with exponents, which was administered as both the pretest and the posttest. The test was content-validated by three Master Teachers of Sta. Cruz District, Schools Division Office of Ilocos Sur, using a validation rubric covering content coverage, clarity of language, and appropriateness to the grade level. The pretest was administered before the two-week implementation of Mathopoly and the posttest immediately after.

Data Analysis Plan. The mean scores of the pretest and posttest were computed and interpreted using the descriptive equivalents adopted by the school. The t test for dependent means was used to determine whether the difference between the pretest and posttest means was significant. The .05 alpha level was used to test significance. Data were presented in tabular and narrative form for the clearer understanding of readers.

4. Results and Discussion

4.1 Level of conceptual understanding in solving problems on numbers with exponents before and after the utilization of the tactile learning approach

Table 1 presents the level of conceptual understanding of the Grade 6 learners in solving problems on numbers with exponents before and after the utilization of the tactile learning approach through the Mathopoly game.

Table 1

Level of conceptual understanding in solving problems on numbers with exponents before and after the utilization of the tactile learning approach (Mathopoly)

Test	<i>n</i>	<i>M</i>	Descriptive Level
Pretest	19	8.18	Poor
Posttest	19	24.55	Outstanding

Note. Mean gain = 16.37. Maximum possible score = 30. Descriptive levels follow the school's adopted scale: 0–9 = Poor, 10–15 = Fair, 16–21 = Satisfactory, 22–26 = Very Satisfactory, 27–30 = Outstanding.

The mean score before the use of Mathopoly was 8.18, indicating a Poor level of understanding. After the implementation of the tactile learning approach, the mean score rose to 24.55, described as Outstanding. The mean gain of 16.37 between the pretest and the posttest demonstrates a substantial improvement in the learners' understanding and suggests that Mathopoly was effective in strengthening their grasp of concepts related to exponents. This result is consistent with studies showing that hands-on approaches can markedly raise learners' engagement and understanding in mathematics (Shi et al., 2022; Zhang, 2023).

Tactile learning approaches support cognitive processing by allowing learners to interact physically with mathematical ideas, which makes abstract concepts such as exponents more accessible. By integrating game-based learning, teachers can create an environment in which learners actively participate and build understanding through direct manipulation and visualization. This aligns with research indicating that interactive tools in mathematics can reduce cognitive load, enabling learners to focus on conceptual mastery rather than rote memorization (Guzmán et al., 2023; St Omer & Chen, 2023).

The improvement also underscores the value of active learning for young learners, who often struggle with abstract mathematical content and benefit from instructional strategies that offer hands-on engagement (Chen et al., 2022). By providing an interactive context, Mathopoly appears to have demystified the concept of exponents and reinforced the connection between concrete activity and mathematical reasoning (Zhou et al., 2023). This is consistent with constructivist theory, which holds that learners build understanding most effectively when they engage in meaningful, contextualized activity.

Motivation is a further consideration. Game-based learning models such as Mathopoly foster intrinsic motivation, allowing learners to approach complex concepts with curiosity rather than apprehension (Simmons et al., 2024). The Outstanding level of post-intervention understanding suggests that learners not only grasped the concept but may also have retained it better because of the enjoyable and interactive nature of the process. Engaging with the material in a game format likely reduced anxiety about mathematics, a known barrier to performance, and allowed learners to practice problem solving more freely (Eidlin-Levy et al., 2023).

In addition, tactile methods address a wider range of learning preferences. Traditional classroom approaches often cater primarily to auditory and visual learners, potentially neglecting those who benefit from movement and manipulation. The shift in instructional approach demonstrated here is consistent with contemporary arguments for differentiated instruction (Živković et al., 2023). By implementing Mathopoly, the teacher provided a more inclusive learning experience that reached a broader range of learners.

Finally, the size of the mean gain speaks to the contribution of educational games to cognitive retention. Game-based learning supports memory and skill transfer because learners repeatedly revisit learned concepts in new

contexts (Chen & Wang, 2022). The repetitive structure of Mathopoly, combined with its tactile element, likely reinforced understanding by engaging multiple senses and creating durable mental connections to the concept of exponents.

4.2 Significance of the difference in the level of conceptual understanding before and after the utilization of the tactile learning approach

Table 2 presents the results of the *t* test for dependent means evaluating the effect of the tactile learning approach on the learners' ability to solve problems involving numbers with exponents.

Table 2

Results of the t-Test for dependent means on the difference between the pretest and posttest scores

Comparison	<i>n</i>	<i>df</i>	<i>t</i>	<i>p</i>	Decision on H_0
Pretest–Posttest	19	18	9.15	.001	Reject

Note. Significant at the .05 level.

With a *t* value of 9.15 and a *p* value of .001, the results indicate a statistically significant difference between the pretest and posttest scores, leading to the rejection of the null hypothesis. The tactile learning approach therefore had a substantial positive effect on the learners' understanding of numbers with exponents. This finding is consistent with studies highlighting the benefits of interactive, tactile approaches in improving mathematical skills (Iyamuremye et al., 2023; Zhou et al., 2022).

The significant difference supports the argument that tactile learning promotes conceptual understanding more effectively than traditional exposition alone. Tactile and kinesthetic experiences help learners form lasting mental connections, allowing them to recall and apply knowledge more readily than through passive learning (Li et al., 2023). The success of Mathopoly is consistent with research advocating active learning to boost comprehension and retention, particularly in mathematics, where abstract concepts are challenging for young learners (Al Balqa Applied University & Sbaih, 2023; Amalina & Vidákovich, 2023).

The *p* value of .001 indicates a high level of confidence in the result, reinforcing the reliability of the observed improvement and suggesting that the change in scores is unlikely to be attributable to chance alone. Learning tools that encourage physical engagement can enhance cognitive processing and facilitate deeper understanding (Cui et al., 2023; Tong et al., 2023). It should nevertheless be noted that a one-group design cannot rule out maturation, testing effects, or ordinary instruction as contributing influences; this limitation is discussed further below.

Rejecting the null hypothesis implies that traditional teaching methods alone may not be sufficient to foster robust understanding in areas such as exponents. This is supported by literature suggesting that learners benefit from diverse instructional methods that address different learning preferences, especially in complex subjects (Osuna & Munson, 2024). Integrating tactile methods into the curriculum could provide a more comprehensive learning environment for kinesthetic learners and help bridge gaps in understanding for learners who struggle with abstract reasoning alone (Merrick & Fyfe, 2023).

The result also highlights the motivational potential of game-based learning. Learners are more likely to engage deeply with material when learning is enjoyable and interactive, which in turn improves outcomes (Mehrvarez et al., 2023). Mathopoly likely helped reduce mathematics anxiety and encouraged learners to explore mathematical concepts with greater confidence (Sadak et al., 2022). Hands-on, repetitive interaction further allows learners to revisit and reinforce material, supporting retention and later retrieval (Ulusoy, 2023; Yu et al., 2022).

Limitations - Three limitations should be borne in mind when interpreting these findings. First, the one-group pretest–posttest design has no comparison group, so improvement cannot be attributed to Mathopoly with certainty. Second, the sample was confined to a single intact section of 19 learners in one school, which limits generalizability. Third, the two-week implementation period and the absence of a delayed posttest mean that long-term retention was not measured. Future action research in this school may address these limitations by adding a comparison

section and a delayed posttest.

5. Conclusions

1. The learners' conceptual understanding of numbers with exponents improved substantially, with mean scores rising from 8.18 (Poor) before the utilization of the tactile learning approach to 24.55 (Outstanding) after its implementation, a mean gain of 16.37.

2. The t-test revealed a statistically significant improvement in the learners' ability to solve problems on numbers with exponents after the utilization of the tactile learning approach, $t(18) = 9.15$, $p = .001$, leading to the rejection of the null hypothesis.

Practical Educational Implications - Beyond the statistical outcome, the findings of this action research carry concrete meaning for the people who work in and are served by the classroom. The following implications are organized according to the three groups most directly affected.

For Teachers and Practitioners - The findings suggest that a low-cost, teacher-made manipulative can produce measurable gains on a competency that learners have consistently failed to master. Mathopoly required no digital equipment, no external funding, and no specialized training beyond ordinary lesson preparation, which means that the strategy is genuinely reproducible in resource-constrained classrooms. Practically, teachers may treat tactile games as a delivery mode for practice rather than as a reward at the end of a unit. Because Mathopoly was used inside discussion, formative assessment, and remediation, the teacher was able to observe reasoning in real time and correct misconceptions about the difference between a base and an exponent as they occurred, rather than discovering them later in test papers. Teachers may therefore use game play diagnostically, recording which spaces or card types repeatedly stall particular learners and using that record to plan targeted follow-up. The result also invites teachers to reconsider the sequencing of abstract topics. Introducing exponents through physical repetition of a base before introducing the symbolic shorthand gives learners a concrete referent to return to when the notation becomes confusing. Teachers in other subject areas with similarly compressed notation, such as science, may adapt the same principle.

For Learners - For learners, the most immediate implication is that difficulty with exponents was not a fixed limitation. Learners who had been classified as Poor moved to an Outstanding level within two weeks, which suggests that the earlier weakness reflected the mode of instruction at least as much as the learners' capacity. The game format also changed the cost of being wrong. In a board game, an incorrect answer stalls a turn rather than producing a permanent mark, so learners were willing to attempt problems they would previously have left blank. This lowering of risk is significant for learners who avoid mathematics because of anxiety, and it gave learners more practice attempts than a conventional seatwork exercise would have allowed. Working in small groups additionally required learners to justify their moves aloud. This gave them practice in mathematical explanation, a skill that transfers to word problems and to later topics such as scientific notation and exponential growth, and it allowed peers to serve as an immediate source of correction.

For Schools - At the school level, the findings provide local evidence that can inform decisions about remediation. Schools may position tactile, game-based activities within existing intervention periods rather than creating new programs, since the intervention in this study was delivered inside regular and remedial class time. School heads and department heads may also use the results to justify allocating Learning Action Cell sessions to the design and validation of manipulatives. Because the materials are teacher-made, a single session can produce games for several competencies, and these can be catalogued in a shared instructional bank so that the effort is not lost when a teacher is reassigned. Finally, the results have implications for how schools identify priority competencies. The decision to target exponents came from the observation that only 4 of 19 learners had mastered it. Schools that review item-level results from periodic tests in the same way can direct scarce remediation time to the competencies where the gap is widest, and can use pretest-posttest data of the kind reported here to judge whether the chosen intervention is working.

Recommendations

1. Schools may consider integrating tactile learning tools such as Mathopoly into the mathematics curriculum to enhance learners' conceptual understanding and problem-solving abilities, particularly for challenging topics such as exponents.
2. Teachers may be provided with training, through Learning Action Cell sessions or in-service programs, on the design and classroom use of tactile and game-based learning strategies.
3. Future action research may replicate this study using a comparison group, a larger number of participants, and a delayed posttest in order to establish the durability of the gains reported here.
4. Division and district offices may consider building a shared repository of validated teacher-made manipulatives so that effective materials can be used beyond the classroom in which they were developed.

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