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Upholding Mathematics Learning: Investigating the Result of an Authentic Innovative Approach on Student Academic Achievement

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Abstract

This study addresses the growing need for engagement in the teaching of Mathematics and for student success. It assessed the success of an innovative, student-centered approach to teaching compared with a more traditional one. In particular, it assessed the teaching of Mathematics as a whole using creative and Comprehensive Instructional Resources. The research was conducted in the North Eastern Mindanao State University for the Academic Year 2025–2026, using a quasi-experimental approach. Of the 60 students, 30 were assigned to the experimental group and taught using the innovative teaching method, while the other 30 were assigned to the control group and taught using the Concrete–Pictorial–Abstract (CPA) approach. The students' achievement in Mathematics was evaluated using both pre-test and post-test metrics. The data suggested that both groups had approximately the same level of performance and achievement before the intervention. However, the control group significantly outperformed the experimental group in the post-test. The innovative, student-centered approach was more effective than traditional methodologies in enhancing students' control over the concepts in Mathematics. Instructional materials of this sort may be used in a hybrid manner alongside other teaching methodologies to meet the varying needs of learners.

Keywords: Authentic Instruction, Innovative Teaching Strategies, Mathematics Achievement, Quasi-Experimental Design

Introduction

The persistent global and local issues in higher education mathematics education, particularly in disciplines where students are not mathematics majors but are still expected to acquire strong quantitative reasoning skills, are notable. Educators in most countries still report insufficient student participation, enduring misconceptions, and mathematics-related anxiety, especially in abstract, conceptually dense courses (OECD, 2022; Schoenfeld, 2019). In the Philippines, the enactment of competency-based curricula, together with the Commission on Higher Education (CHED) lesson-level curriculum standards, has increased demand for instructional methods that go beyond traditional approaches and promote deeper learning. This study responds to this demand by exploring whether authentic, innovative teaching strategies, particularly modeling and simulation, are more effective than the widely adopted Concrete–Pictorial–Abstract (CPA) approach in enhancing students' academic achievement in Comprehensive Mathematics. The study employs a quasi-experimental design to answer

the research question: Is there a notable disparity in students' achievement in Comprehensive Mathematics when they are instructed using modeling and simulation compared to the CPA method? The study, by analyzing both global reform movements and local instructional practices, attempts to address the call for urgent evidence-based pedagogical innovation in mathematics education at the higher education level.

Recent studies have recognized the effectiveness of student-centered, authentic pedagogy and the criticism of traditional pedagogy in fostering deep understanding of mathematics. Mathematical modeling and simulations have been shown to understand and solve problems by relating mathematics to the real world (Borromeo Ferri, 2022; Stillman et al., 2023). The progression from concrete to abstract in the CPA approach has been praised for facilitating conceptual understanding (Barmby et al., 2019; Li & Fuson, 2020). However, the debate over these approaches remains, particularly at the tertiary level. While CPA has empirical support at the primary and secondary levels, it has been suggested that higher education students benefit from more flexible approaches, such as modeling and simulations, that incorporate technology (Moyer-Packenham & Westenskow, 2021; Sriraman & Kaiser, 2022). The literature shows that these empirical gaps exist, particularly in the less developed world, where innovative approaches are often resource-constrained.

Researchers on innovative pedagogy have yet to provide comparative empirical studies on the Philippines' modeling and simulation versus CPA in higher education mathematics. Most studies conducted locally focus on CPA or problem-solving strategies in the basic education sphere, leaving a gap in evidence for these approaches in college-level Comprehensive Mathematics courses. Moreover, research investigating the direct comparison of two learner-centered methodologies and determining which, under the same instructional atmosphere, yields higher learning outcomes is remarkably scarce. This is both an empirically and theoretically important gap in research, given that the higher education sector usually imposes more complex cognitive demands on learners, which, in turn, may require the use of different teaching strategies. There is an overwhelming sense of teaching mathematics in a service course, particularly in state universities, where instructors witness low achievement and high anxiety among students, warranting the implementation of more refined, context-specific strategies. This gap is what the present study seeks to address, as such, providing valuable evidence on the application of innovative pedagogy in a higher education setting.

The study's contributions to scholarship and practice are twofold. First, it confirms the role of modeling and simulation in fostering understanding in higher education mathematics. This empirically situates the study within the constructivism and discovery learning frameworks. Second, the study provides a methodologically sound, ‘quasi-experimental’ structured comparison where lessons learned may enhance the design of future research in comparable contexts. The study's findings may address instructional, curricular, and policy issues at the micro (university) and macro (national) levels, especially regarding the Commission on Higher Education (CHED) policies that emphasize flexible, outcomes-based teaching. The study's findings support the assertion that teaching, at least in mathematics, can and should be evidence-based, enhance student engagement, and reduce student anxiety. The study investigates innovative, student-centered pedagogical practices that are authentic and empirically support criticisms of mathematics teaching regarding the integration of innovations.

Theoretical Framework

This research draws on Constructivist Learning Theory and Discovery Learning Theory. Constructivist

Learning Theory explains how learners actively engage in a process of creating knowledge, understanding, and formulating meaning, beyond the simplistic framework of memorization. This gives the best perspective for analyzing the effectiveness of the CPA and other innovative student-centered instructional strategies, particularly modeling and simulation.

The Constructivist Learning Theory, as developed by Jean Piaget and further developed from a social constructionist perspective by Vygotsky, explains the role of the learner as a knowledge constructor, grounded in where the learner is situated, their prior knowledge, and the social environment (Ernest, 2020; Jones, 2020). Learning is a process in which students develop and adjust their mental models and structures through exercises, problem-solving, and reflective thinking. Constructivism in the mathematics classroom emphasizes teaching strategies that encourage students to be engaged, active, and hands-on in working with mathematical concepts and to make connections between their ideas and real-life scenarios. Both modeling and simulation, as well as CPA strategies, align with constructivism because they require students to actively construct mathematical concepts.

Jerome Bruner's Discovery Learning Theory further informs this study, emphasizing that learners construct relationships best through inquiry-based exploration (Ambrosio, 2021). While Bruner suggested that a teacher's goal should be to lead students from tangible to more abstract ideas, this goal would align with a CPA approach. Discovery learning, modeling, and simulation, integrated with a constructivist approach, help students understand and explore mathematical constructs, the relationships within complex systems, and the margins of error in what-if scenarios. These features help support higher-order cognitive processes, conceptual understanding, and knowledge transfer, all of which are essential in the discipline of mathematics at the tertiary level.

The use of modeling and simulation, along with constructivist and discovery-based frameworks, enhances learning, specifically collaborative constructivism. There is a focus on contextualized, collaborative, authentic problem-solving (Verschaffel et al., 2021). Through interaction with peers, instructional resources, and mathematical simulations, learners can deepen their understanding and reduce misconceptions.

Guided by these theories, the current study posits that achievement with teaching practices based on active engagement, inquiry, and contextualized learning will surpass achievement with traditional, teacher-centered instruction. The study analyzes the comparative impact of modeling and simulation vis-à-vis the CPA (Concrete-Representational-Abstract) approach and how varying interpretations of constructivism affect students' learning outcomes in Comprehensive Mathematics. Hence, this theoretical perspective offers a comprehensive framework that enables the study to account for and interpret variations in student performance.

Methodology

Research Design

The effectiveness of authentic and innovative teaching strategies on students' academic achievement in Comprehensive Mathematics was measured using a pretest-posttest non-equivalent quasi-experimental design. The two instructional strategies compared were modeling and simulation (the experimental treatment) and the Concrete–Pictorial–Abstract (CPA) approach (the control condition). Random assignment of participants was not applicable; hence, intact classes were utilized. To achieve baseline equivalence between the two groups, pretest scores were administered before the intervention.

Research Locale and Participants

The study took place at North Eastern Mindanao State University (NEMSU)–Cantilan Campus during the first semester of Academic Year 2025-2026. The participants were 60 first-year Bachelor of Science in Industrial Technology students taking Comprehensive Mathematics. There were thirty (30) students in the experimental group and thirty (30) students in the control group. The two groups were paired by mathematical ability level to ensure comparability. One instructor taught both groups to achieve consistency in instruction.

Instructional Intervention

The experimental group used genuine, original teaching methods, especially active learning, visualization, and contextual problem-solving strategies, with a focus on creating models and simulations. The control group used the Concrete–Pictorial–Abstract (CPA) strategy, a more structured method that focuses on three phases: concrete (real-life situations), pictorial (drawings), and abstract mathematical symbols. The intervention spanned 26 instructional sessions focused on the following topics: Conic Sections, Systems of Non-Linear Equations, Sequences and Series, and Mathematical Induction.

Research Instrument

The researcher created a 45-item multiple-choice achievement test that served as both the pretest and posttest. The test was structured in accordance with the course syllabus and the learning competencies. Content validity was evaluated and confirmed by a panel of experts. Mathematics educators served as the panel of experts. Prior to the formal implementation, a pilot test and item analysis were performed. A pre-test reliability analysis yielded a Cronbach's alpha coefficient of 0.921, indicating very high internal consistency. Since the data met the assumptions of parametric statistical analysis, a normality test was performed.

Data Collection Procedure

The Graduate School administration granted permission to conduct the study. A pretest was given to both groups prior to the intervention. The experimental and control groups were taught using their respective teaching methodologies. A posttest identical to the pretest was administered after all lessons were taught to assess learning gains. The test administration adhered to standardized procedures.

Statistical Analysis

Mean scores and standard deviations were calculated to provide an overview of students' academic performance. To analyze the data, an independent-samples t-test was used to compare the pretest and posttest mean scores of the experimental and control groups. A 0.05 level of significance guided all statistical analyses.

Results

This study results from data collected from the pretest and posttest administered to both the control and experimental groups. The primary focus is on students' academic achievement in Comprehensive Mathematics, with the Concrete–Pictorial–Abstract (CPA) method and the modeling and simulation method used. The results will be presented in line with the earlier-established research questions.

Table 1 presents the mean scores and standard deviations of student performance on the pretest and posttest for the two instructional methods. According to the table, the control group had a mean pretest score of 11.10 (SD = 1.97), while the experimental group had a mean pretest score of 11.67 (SD = 1.90). The similarity of these mean scores indicates that both groups had similar levels of prior knowledge before the instructional interventions were implemented. Hence, these groups are baseline-equivalent, which strengthens the validity of future comparisons.

Following the instructional intervention, both groups saw an increase in their posttest scores. The experimental group, however, had a higher mean posttest score of 34.93 (SD = 3.72) compared to the control group's mean score of 22.13 (SD = 3.99). The experimental group's higher scores indicate that the modeling and simulation approach, as compared to the CPA approach, more effectively improved students' academic achievement. The smaller standard deviation in the experimental group further suggests that the students' performances were more consistently aligned.

Table 1. Pretest and Posttest Mean Scores

Group	Pretest Mean	SD	Posttest Mean	SD
Control (CPA)	11.10	1.97	22.13	3.99
Experimental	11.67	1.90	34.93	3.72

Independent-samples t-tests were used to assess the statistical significance of differences between the control and experimental groups. The result is presented in Table 2. For the pretest, the t-statistic was 1.21 with a p-value of 0.234, which is greater than 0.05. Therefore, there is no statistical significance between the two groups prior to the intervention.

On the other hand, in the posttest, the t-statistic was 34.64 with a p-value of 0.000, which is less than 0.05. Thus, there is a statistically significant difference between the mean posttest scores of the control and experimental groups. Therefore, the null hypothesis is rejected, and the results suggest that the instructional method used for the experimental group had an impact on students' academic performance in Comprehensive Mathematics.

Table 2. Difference Between Group Means

Test	Test Statistic	p-value	Decision
Pretest	1.21	0.234	Not Significant
Posttest	34.64	0.000	Highly Significant

Overall, the results show that although both teaching methods helped students learn, the modeling and simulation method led to much greater success than the CPA method. The lack of notable differences in pretest scores and the presence of a highly significant difference in posttest scores support the claim that the improvement in the experimental group is due to the teaching method used.

Discussion

One of the study's findings showed that the modeling and simulation approach led to better student academic achievement in Comprehensive Mathematics than the Concrete–Pictorial–Abstract (CPA) approach. While both groups had prior knowledge that was statistically similar, the experimental group showed greater learning gains after the teaching intervention. This suggests that although CPA is an

effective tool for building understanding, modeling and simulation have greater teaching value for higher education students, who must grapple with more advanced and complex mathematical abstractions.

The constructivism and discovery learning theories may explain the notable learning gain in the experimental group. Learners can construct their own mathematical knowledge through modeling and simulation by building an understanding of relationships, examining and testing their own theories, and manipulating different representations of concepts. These activities stimulate different levels of thinking and facilitate the integration of concepts, a process critical to the development of advanced mathematical thinking. These findings align with other studies indicating that genuine, technology-based instruction fosters a better understanding of concepts and stronger problem-solving skills than traditional or representational instruction (Borromeo Ferri, 2022; Stillman et al., 2023).

While the CPA approach offers benefits for fundamental understanding, it may be more useful for advancing conceptual development when used exclusively in higher education contexts. CPA's stepwise progression from concrete to abstract representations is recognized as useful for primary and secondary levels; however, advanced education students may benefit from a pedagogy that is more focused on real-world contexts and active engagement with mathematical systems. The relatively poorer performance on the posttest by the control group suggests that in the absence of other teaching approaches, the CPA approach may fall short of meeting the cognitive demands of the more advanced courses in mathematics at the tertiary level, given that they are probably the students enrolled in non-mathematics courses (Li & Fuson, 2020; Barmby et al., 2019).\New line.\Smoother posttest score distribution of the students in the experimental group also suggests that modeling and simulation may foster more uniform positive learning outcomes across different levels of ability. This indicates that the use of new teaching methodologies not only elevates the average level of achievement but also helps close the achievement gap by creating multiple pathways to understanding. This aligns with the literature, which emphasizes the use of a framework that is organized and patterned, and that incorporates movement activities, supporting inclusively balanced learning for diverse and varied needs and learning styles (Moyer-Packenham & Westenskow, 2021).

When viewed as a whole, the findings reveal a need for more genuine, constructive, student-centered practices in the teaching of mathematics in higher learning. Although CPA still holds some teaching value, the findings indicate that its value is more pronounced when used alongside other modeling and simulation techniques, as this gives the instructor the opportunity to address both the conceptual underpinnings and the applied higher-order facets of mathematics. The research adds to the empirically based scholarship seeking to answer the question of which teaching practices work best in tertiary mathematics teaching and supports the need for more flexible, evidence-based teaching to accompany the more contemporary practices implemented in the curriculum.

Conclusion

This study assessed the impact on student academic achievement of the Comprehensive Mathematics course and of simulation and modeling versus the Concrete–Pictorial–Abstract (CPA) approach. The study found that both strategies were effective. However, modeling and simulation yielded better post-test results. This reinforces the notion that new and creative teaching strategies assist student conceptual understanding and higher-order thinking.

Positive results support both discovery and constructivism theories. These theories state that discovery

and constructivism are learner-centered and emphasize active/engaged learning and contextualized learning. In modeling and simulation, students learn and understand mathematics at a conceptual level, and when paired with diverse real-world contexts, they achieve better learning outcomes. This study confirms that modern teaching methodologies are essential, especially in post-secondary education.

The study highlights the need to incorporate new teaching methods in mathematics to mitigate ongoing problems of low achievement and high anxiety towards the subject. There is some evidence that incorporating CPA with modeling and simulation can provide an instructional approach that balances primary and secondary levels of understanding. Research examining integrated approaches and their potential across diverse areas and institutions is warranted.

Recommendations

From the study's conclusions, several recommendations are provided to improve the practice of teaching math, the development of math-related policy, and the direction of future research. To start, a key recommendation for college-level math teachers is to incorporate quantitative and qualitative modeling and simulation strategies into Comprehensive Mathematics courses, especially when covering more abstract and conceptually challenging subject matter. These strategies, along with the CPA (Concrete-Pictorial-Abstract) instructional strategy, may emphasize and strengthen students' understanding of concepts, foster their participation, and improve their academic performance.

Innovative math teaching practices that emphasize student-centered learning also require supportive administrative, curricular, and organizational structures, particularly instructional resources and professional development processes, to be more readily available. Faculty Manual on Models and Simulation and Constructive (or Authentic) Learning strategies may assist in developing more engaged and inclusive learning environments. To an even greater extent, dual alignment to competency-based and outcomes-based instructional strategies will improve instructional delivery.

Students are also encouraged to learn by incorporating hands-on activities into their instruction, such as exploring new content, creating visual representations, and solving problems. Implementing a variety of instructional strategies will positively contribute to the development of students' mathematical reasoning, reduce their anxiety about mathematics, and improve their confidence in applying mathematics to real-life situations.

Finally, it is hoped that future researchers will replicate and build on this study by looking at the enduring impacts of modeling and simulation on students' retention and transfer of mathematical knowledge. Further studies may also analyze the effectiveness of these methods across various disciplines, year levels, and institutions, and examine the impact of blended or hybrid teaching models on learning outcomes in mathematics.

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