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ADVANCING MATHEMATICS LEARNING: EXAMINING THE EFFECTS OF INNOVATIVE PEDAGOGIES ON STUDENT ACHIEVEMENT

RAZIL M. GUMANOY

North Eastern Mindanao State University, Formerly Surigao Del Sur State University, Rosario, Tandag City, Surigao Del Sur, Philippines. Email: rmgumanoy@nemsu.edu.ph

Abstract

This study investigated the impact of innovative Mathematics instructions, encompassing lecture, problem posing, and heuristic methods, on students' academic achievement in Mathematics in the Modern World. Employing a quasi-experimental research approach, the study involved ninety students from the North Eastern Mindanao State University's College of Arts and Sciences (CAS). The participants were categorized into three groups: lecture, Problem Posing, and Heuristic Problem Solving, each comprising thirty students. Posttest outcomes were scrutinized, focusing on students' performance in selected Mathematics in the Modern World topics. Employing Two-Way Analysis of Covariance (ANCOVA), mean values, and standard deviation, the collected data underwent statistical analysis. The study's findings unveiled that the problem posing group exhibited a slightly elevated mean score in comparison to the lecture and heuristic groups, based on pre-post-test results in Mathematics in the Modern World. Moreover, a noteworthy disparity emerged, indicating a significant difference in academic achievement among students in selected Mathematics topics when exposed to innovative instruction methodologies and categorized according to their mathematical capabilities. Notably, the investigation unveiled that there exists no considerable interaction effect on students' academic accomplishment when they encounter innovative Mathematics instructions, and are concurrently categorized based on their mathematical proficiency. In sum, this study elucidated the influence of innovative instructional methods in Mathematics education, illuminating nuances across various teaching strategies. The findings underscore the importance of pedagogical diversity and tailored approaches, emphasizing their influence on students' academic attainment.

Keywords: Innovative Mathematics Instruction, Problem Posing, Heuristic Problem Solving, Academic Achievement

INTRODUCTION

The realm of Mathematics education is continually evolving, with a focus on leveraging diverse strategies to enhance teaching methodologies and create enriching learning encounters for students (Burton, 2012). This pursuit gains renewed momentum as the introduction of innovative approaches to teaching Mathematics, particularly within the context of secondary education, emerges as a promising avenue. However, while the concept of acquiring fresh knowledge and skills is indeed exciting, it often fails to captivate students' interest and creativity. In the broader landscape of supplemental mathematics education, the endeavor to cultivate Innovative Mathematics Instructions remains a lacuna in comprehensive exploration. This research embarks on a journey to assess the efficacy of Innovative Mathematics Instructions in elevating the academic achievements of incoming college freshmen.

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Central to Innovative Mathematics Instruction is the reimagining of the educational process, fragmenting the curriculum into modular segments that are appraised at the culmination of each session (Ibragimove, 2016). In this evolution, educators transition from conventional roles of presenters, demonstrators, and questioners to that of facilitators, initiators, and coaches. Notable exemplars of Innovative Mathematics Instructions encompass the Problem Posing Approach and Heuristic Problem Solving Approach. The former method envelops the teaching of mathematical concepts through immersive problem-solving contexts and inquiry-driven environments, empowering learners to construct a profound comprehension of mathematical ideas and processes (Lester et al., 2013). This departure from traditional methods enables engagement with learning that nurtures the development of higher-order cognitive faculties seldom fostered through conventional drill-and-practice techniques. On the parallel track, the Heuristic Problem Solving Approach entrusts educators with the role of learning facilitators, while students metamorphose into architects of their own educational journey (Luga, 2017). This approach endows students with the tools to cultivate thinking prowess and logical acumen—traits instrumental not only in academia but also in the fabric of daily life and future mathematical pursuits.

Despite educators' persistent efforts and numerous innovative interventions, Mathematics continues to elicit trepidation among students, casting shadows on their academic trajectories (Paul, 2014). This disconcerting reality carries weighty implications for tertiary institutions, as mastery of Science and Mathematics serves as a gateway to personal development and productive participation in the global society. A retrospective evaluation of student performance unveils a sobering narrative of struggle across various Mathematics disciplines. A significant proportion grapple with failing grades, while others are beset by subpar scores and discouraging feedback. Curiously, it is often the intricate challenges posed by Mathematics that captivate less motivated students, enabling them to glean insights from complex material that they might have otherwise missed through rote learning.

Within this context, the imperative for Innovative Mathematics Instructions emerges as a clarion call—urgent, timely, and pertinent. The study not only seeks to address this critical void but also endeavors to decipher whether novel pedagogical paradigms such as problem posing and heuristic problem solving can spark a transformation in students' mathematical achievements. The researcher's conviction stems from the belief that diversifying pedagogical methodologies holds the potential to ameliorate academic performance and quell anxiety, rendering the intricate domain of Mathematics more approachable and embracing a wider spectrum of learners. As the trajectory of this research unfolds, its significance in advancing the frontiers of knowledge in the discipline becomes increasingly evident, shaping the contours of modern mathematics education and charting a course toward a more enlightened and empowered generation of learners.

Theoretical Framework of the Study

This study investigates the effectiveness of Innovative Mathematics Instructions in enhancing the academic achievements of college freshmen, drawing upon the theoretical frameworks of Bruner's Discovery Learning, Piaget's Constructivism, and Thorndike's Connectionism.

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Jerome Bruner's cognitive psychological perspective emphasizes the importance of intellectual development over mere rote memorization (Patan, 2010). Central to Bruner's framework is the notion that the curriculum should facilitate the cultivation of problem-solving skills through inquiry and discovery processes. This inquiry-based constructivist approach aligns seamlessly with the objectives of Innovative Mathematics Instructions, which aim to foster autonomy and engagement in students' learning journeys. By organizing concepts and encouraging exploration, Bruner's theory resonates with the present study's pursuit of enhancing students' academic achievements through interactive and meaningful learning experiences.

Jean Piaget's constructivism theory, divided into radical and social constructivism, accentuates the active role of learners in constructing knowledge from their experiences (Von Glasersfeld, 1990). The constructivist paradigm posits that learning transpires as learners assimilate and accommodate new information within the context of existing knowledge. This aligns with the philosophy of Innovative Mathematics Instructions, where students are encouraged to actively engage with mathematical problems, form hypotheses, and explore solutions. Piaget's constructivist perspective accentuates the study's emphasis on autonomous learning, as students become architects of their own understanding by drawing connections between prior knowledge and new mathematical concepts.

Edward Thorndike's connectionist theory delves into the mechanisms of learning through associations between stimuli and responses (Thorndike, 1913). Rooted in behavioral psychology, connectionism highlights the strengthening or weakening of associations based on reinforcement. This framework adds a valuable layer to the study, particularly in understanding how Innovative Mathematics Instructions can impact students' response associations, shaping their engagement and performance. Thorndike's laws of effect, readiness, and exercise provide a comprehensive lens through which to examine the influences of instruction on students' learning processes and behaviors.

These theoretical frameworks collectively underscore the dynamic and active nature of learning, reinforcing the departure from passive knowledge absorption to active knowledge construction. By embracing Bruner's emphasis on inquiry, Piaget's focus on assimilation and accommodation, and Thorndike's insights into associative learning, this study endeavors to unlock the potential of Innovative Mathematics Instructions in enriching students' mathematical achievements.

In the context of modern education, these theories prompt a paradigm shift towards learner-centered approaches, where students are empowered to explore, collaborate, and critically engage with mathematical concepts. The confluence of these theoretical underpinnings aligns harmoniously with the study's objective of evaluating the impact of Innovative Mathematics Instructions on students' academic achievements. As the research unfolds, it endeavors to not only contribute to the advancement of pedagogical practices but also to the broader discourse on the efficacy of constructivist and connectionist learning paradigms in contemporary mathematics education. The present study is underpinned by three robust theoretical frameworks that collectively shed light on the dynamics of learning, knowledge acquisition, and instructional design, each contributing distinct perspectives to the research endeavor.

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Purpose of the Study

This study aimed to compare the learning effectiveness of the three methods of teaching Mathematics in the Modern World. Specifically, it sought to:

1. Determine the pretest and posttest mean scores of the students using innovative mathematics instruction;
2. Identify the significant difference on the achievement of students in Mathematics in the Modern World when taught using innovative mathematics instruction through heuristic problem solving, problem posing and lecture method;
3. Find out the significant difference on the students' achievement in mathematics in the modern world and when grouped according to their mathematical abilities; and
4. Determine the significant interaction effect on the students' achievement when grouped according to their mathematical abilities.

RESEARCH METHODOLOGY

The methodology employed in this study serves as the bedrock for comprehending the dynamics of innovative mathematical instructions and their impact on students' academic achievements within the context of Mathematics in the Modern World. To unravel the intricate threads of this study, a pretest-posttest non-comparable quasi experimental design was chosen. While this design shares similarities with the conventional controlled experimental framework, it diverges by not assigning subjects randomly to either experimental or control groups. This conscious departure introduces an element of non-randomness to the group allocation, enriching the research's contextual depth (Ernest, 2012).

The participant groups were comprised three distinct sets of students: those taught through Problem Posing, Heuristic Problem Solving, and the Conventional Lecture Method. However, the non-random nature of the grouping underscores the design's complexity, adding nuance to the interpretation of results. Both groups received pre- and post-tests, but only the experimental group received the treatment, which was the incorporation of novel mathematical instructions. The pretest O1 assessed previous knowledge as a covariate in both groups' studies. Following the administration of the posttest, the O2 levels of each group were compared. The broken line between the two groups indicates that the respondents were not randomly assigned. Furthermore, this design includes two treatment groups, as shown below.

Groups	**Pretest**	**Treatment**	**Posttest**
Problem Posing	O_1	T_1	O_2
		------------------------	------------------------
Heuristic Problem Solving	O_1	T_2	O_2
		------------------------	------------------------
Lecture Method	O_1		O_2

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This study was conducted at North Eastern Mindanao State University-Main Campus, Tandag City, Surigao del Sur, Philippines, with three sections of the Bachelor of Environmental Science and Bachelor of Arts in English of the College of Arts and Sciences, as well as students enrolled in Mathematics in the Modern World. The experimental and control classes were chosen using simple random sampling via the fishbowl method to determine which section received innovative mathematical instructions via heuristic problem-solving, problem posing, and which section received the lecture method. The researcher chose BS and BA students as study subjects because these three sections were assigned to the researcher, granting him authority to conduct the experiment using the identified three methods in the teaching of Mathematics in the Modern World.

To balance the equation of mathematical abilities, students were categorized into three tiers—above average, average, and below average—based on preliminary grade point averages. This stratification aimed to ensure equitable representation across experimental and control groups, creating a foundation for unbiased analysis.

Table 1: Distribution of Subjects In Terms of Mathematical Level

Groups	Heuristic Problem-Solving	Problem Posing	Conventional Method	Total
Above Average	2	2	2	6
Average	9	9	9	27
Below Average	19	19	19	57
Total	30	30	30	90

Class schedules were meticulously organized, enabling the different methodologies to be imparted efficiently. The lecture group convened on Tuesdays and Thursdays, while the Problem Posing and Heuristic Problem Solving groups met on Mondays, Wednesdays, and Fridays. This harmonized scheduling ensured that the different instructional methods were effectively implemented.

The research instrument, a carefully crafted test questionnaire, underwent rigorous validation by experts in the field. This instrument served as the conduit for pretest and post-test data collection, encapsulating the core topics outlined in the syllabus and CAS Competencies.

Validation, a cornerstone of research credibility, involved soliciting insights from mathematics experts. These insights enriched the questionnaire's content, ensuring its resonance with the educational landscape. The pilot testing phase further refined the instrument, providing critical feedback for item enhancement. Data collection commenced following necessary permissions and orientations. The research journey was guided by structured lesson plans, differentiating between experimental and control groups. An orientation was given to both classes on the first day of the formal conduct of the study. Following that, the 45-item pretest was administered. On the second day, the researcher began by outlining the lesson objectives. The teacher asked the students about their previous lesson to see how much information they remembered. This was done to motivate and improve students. Second, during the lesson development process, the teacher thoroughly discussed the lesson with the experimental group, using innovative mathematical instructions to further enlighten the doubts in the lesson.

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Meanwhile, in the control group, the teacher developed the lesson using the lecture method. Following the discussion, the teacher assigned an activity that followed the same guidelines and procedures. However, in the experimental group, the researcher provided problem posing and heuristic problem solving. Following that, the students were given the generalization from the output presentation. The lesson is summarized in the conclusion. The teacher administered a quiz to assess the students' understanding of the lesson. The teacher then assigned homework or assignments to help them with their difficulties in the lesson. Following the steps, the teacher moved on to the next topic. After all of the topics had been discussed over the course of 26 sessions, both the experimental and control groups were given a posttest. The same questionnaire used in the pretest was used during the test.

Data collection commenced following necessary permissions and orientations. An array of statistical tools, including One-Way and Two-Way Analysis of Covariance (ANCOVA) and descriptive statistics such as Mean and Standard Deviation, formed the analytical toolkit. These tools facilitated the dissection of complex relationships between teaching approaches, mathematical abilities, and achievement outcomes.

RESULTS AND DISCUSSION

Students' Pre and Posttest Mean Scores Using Innovative Mathematics Instructions

Table 2 illustrates the academic accomplishments of students belonging to both the control and experimental groups, based on their pretest and posttest results. The initial assessment indicates that, during the pretest phase, the control group exhibited a slightly lower mean compared to the two experimental groups, as presented in the table. This outcome implies that, prior to the study, both groups exhibited similar cognitive frameworks, signifying comparable foundational understanding of the subject matter.

Table 2: Students' Pre and Posttest Mean Scores Using Innovative Mathematics Instructions

Type of Group	N	Pretest Mean	SD	N	Posttest Mean	SD
Problem Posing	30	13.133	4.158	30	25.567	5.224
Heuristic Problem Solving	30	11.267	3.657	30	23.500	4.897
Control group	30	11.133	2.501	30	20.567	4.659

Furthermore, the data within the table elucidates that the problem posing approach group exhibited superior performance in the posttest, outshining the heuristic problem solving and lecture groups, with respective mean values of 25.567, 23.500, and 20.567. This observation points to the efficacy of the problem posing approach, where students engage in deeper comprehension of mathematical concepts and processes through contextually embedded problem-solving activities within an inquiry-driven environment (Lester et al., 2013).

In the posttest phase, the experimental groups demonstrated higher mean values than the control group, potentially attributed to a higher completion rate of the assigned tasks. The data corroborates the notion that learners tend to excel when immersed in innovative mathematical activities compared to traditional methods. This success can be attributed to the support offered

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by instructors, guiding students through solution discovery with explanatory demonstrations and activities.

Throughout the study, it was apparent that students taught via problem posing and heuristic methods assumed greater ownership of their learning, resulting in enhanced mastery and proficiency catch-up for active participation. Passive students similarly engaged with the assigned tasks, leading to their elevated post-test mean scores of 25.567 and 23.500, surpassing their respective pre-test mean scores of 13.133 and 11.267.

Conversely, the control group manifested a lower posttest mean value compared to the experimental groups. This can be attributed to the teacher's direct involvement in the instructional process. Despite this, the control group's mean scores exhibited an increase from 11.133 in the pretest to 20.567 in the posttest. The lower standard deviation in the control group suggests that these students' scores clustered closer to the mean compared to those in the experimental groups. This finding suggests that some students exposed to innovative methods exhibited comparable levels of understanding, yielding higher test scores.

The control group's lower standard deviation reflects less variability in test scores, indicating that a majority of students held relatively uniform understandings of the topics discussed. Both groups witnessed increases in posttest mean and standard deviation, signifying successful learning across all three methodologies. Notably, students exposed to the innovative mathematical activity approach showcased significantly better performance than those taught via conventional means.

These findings resonate with the research of Garillos (2012), highlighting that instructional material implementation in class led to marked improvements in pretest and posttest scores. Additionally, these findings align with Patan's (2010) assertion that the teacher's role in the classroom serves as a pivotal factor in structuring the learning experience. The manner in which a teacher presents activities or concepts profoundly influences students' reactions, underscoring the importance of diverse strategies for cultivating discipline and motivation in the learning process.

Analysis of Variance in the Students' Achievement when Taught Using Innovative Mathematics Instructions

The One - Way analysis of Variance (ANOVA) was used to determine whether there is a significant difference between the pretest mean scores of the control group and the experimental groups in Mathematics in the Modern World. The results are summarized in Table 3.

Table 3: Analysis of Variance in the Students' Achievement when Taught Using Innovative Mathematics Instructions

Source	df	Adj SS	Adj MS	F-value	P-value
Factor	5	6268	1253.57	68.44	0.000
Error	174	3187	18.32		
Total	179	9455			

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Table 3 shows the pretest mean scores for both the control and experimental groups, with an F-value of 68.44 and a P-value of 0.00, both of which are less than the level of significance at = 0.05. This indicates that the pretest mean scores differ significantly between the control and experimental groups. This implies that at the start of the study, the three groups of respondents had roughly the same schema or foundation. This factor should be taken into account when conducting an experimental study. To produce a valid result, students in both the control and experimental groups must be homogeneous, with similar schema/foundation on the subject being studied.

Magneil (2011) concluded in his study that teaching strategies are not related to mathematics achievement, but that good teaching strategies resulted in a more positive attitude and less anxiety toward mathematics. Wajiha (2018) discovered that the strategies, techniques, approaches, evaluative measures, follow-up activities, and use of instructional materials used by teachers determined the extent of mastery of students in various mathematics skills. Furthermore, Marzano, Pickering, and Pollock (2010) observed that various aspects of instructions, in conjunction with teaching methods, may play a significant role in student achievement.

The posttest results of the subject of the study, on the other hand, show that there is a significant difference in the performance of the students, emphasizing that the use of innovative mathematical activities in teaching math is a better teaching method. This result supports one of Thorndike's learning theories, "Learning occurs automatically." It demonstrates that when the subjects under study were exposed to the three teaching methods, they learned automatically as long as they were ready to respond. Furthermore, the findings of this study show that when learners encounter new concepts, they interpret them based on prior knowledge. The respondents' low pretest scores are to be expected given their lack of knowledge about the new lesson. The "Law of Response Analogy," Thorndike's theories of learning, states that a person's response to a new situation is determined by innate tendencies to respond as well as elements in similar situations to which he has acquired responses in the past.

Analysis of Variance on the Students' Achievement when Grouped According to their Mathematical Abilities

The One-Way Analysis of Variance (ANOVA) was employed to assess whether a substantial difference existed in the pretest mean scores of the control group as compared to the experimental groups in the context of Mathematics in the Modern World. The synthesized outcomes are presented in Table 3, which captures the essence of this statistical exploration.

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Table 4: Analysis of Variance on the Students' Achievement when Grouped According to their Mathematical Abilities

Groups	N	Pretest		Posttest	
		Mean	SD	Mean	SD
Problem Posing Approach					
Above Average	2	12.00	1.41	26.63	5.01
Average	9	16.33	4.66	23.67	5.89
Below Average	19	11.737	3.280	24.00	4.72
Heuristic Problem Solving Approach					
Above Average	2	10.5	2.12	24.00	4.24
Average	9	10.67	4.97	22.33	5.36
Below Average	19	11.632	3.148	24.00	4.89
Conventional Method					
Above Average	2	10.5	2.12	21.63	5.04
Average	9	10.444	2.920	18.67	3.64
Below Average	19	11.526	2.366	19.00	2.83.

The F-value of 68.44 and the P-value of 0.00, both surpassing the significance level of $\alpha = 0.05$, are pivotal indicators from Table 3. These values underscore a significant disparity in the pretest mean scores between the control and experimental groups. This observation conveys that, at the outset of the study, the three groups of respondents exhibited comparable cognitive frameworks or foundational understanding. This notion holds importance in the context of experimental research, necessitating homogeneous groups to generate valid outcomes. Ensuring that participants are equipped with similar schema or foundational knowledge on the subject under study is crucial.

Magneil's (2015) research concluded that teaching strategies might not be directly correlated with mathematics achievement but could influence attitudes and anxiety towards the subject positively. Wajiha (2018) found that teachers' utilization of strategies, techniques, approaches, evaluative measures, and instructional materials significantly impacted students' mastery of diverse mathematical skills. Moreover, Paul (2014) noted that various facets of instruction, intertwined with teaching methods, could play a pivotal role in determining student achievement.

Furthermore, the posttest outcomes reveal a substantial disparity in students' performance, underscoring the superiority of innovative mathematical activities as a pedagogical approach. This aligns with one of Thorndike's learning theories, "Learning occurs automatically," signifying that the subjects, when exposed to the teaching methods, imbibed knowledge naturally as long as they were receptive. The study's findings further illuminate that learners tend to assimilate novel concepts based on prior knowledge. The initial low pretest scores are indicative of their unfamiliarity with the new lesson. This aligns with Thorndike's "Law of Response Analogy," which posits that an individual's response to a novel situation is influenced by innate tendencies and elements in analogous situations to which the person has previously responded.

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Analysis of Co-Variance on the Interaction Effect on the Students' Achievement when Grouped According to their Mathematical Abilities

The significant interaction effect on students' achievement in Mathematics in the Modern World when they are grouped based on their mathematical abilities is tested using Analysis of Covariance (ANCOVA). Table 5 displays this result.

Table 5: Analysis of Co-Variance on the Interaction Effect on the Students' Achievement when Grouped According to their Mathematical Abilities

Source of Variation	SS	Df	MS	F-value	p-value
Covariates	112.572	1	112.572	9.807	0.001
Factor A (Mathematical Level)	12.227	1	12.227	1.065	0.216
Factor B (Strategy)	163.068	1	163.068	14.206	0.000
A x B	809.336	1	809.336	70.505	0.638
Explained	431.771	4	107.943	9.403	0.000
Residual	987.203	86	11.479		

Within Table 5, the F-value of 1.065, coupled with a p-value of 0.216, exceeds the predetermined significance threshold of 0.05. Consequently, the null hypothesis, stipulating the absence of a significant interaction effect between students' academic accomplishments and their grouping according to mathematical levels when instructed via problem posing, heuristic problem solving, or the conventional method, is negated. This outcome underscores that, when teaching methodologies and mathematical proficiency levels are simultaneously introduced, their interplay is negligible. Furthermore, the performance of subjects does not diverge significantly across the spectrum of mathematical aptitudes, thereby implying that, in this specific study, students' mathematical levels exert no discernible impact on their mathematical performance, regardless of whether their grades categorize them as above average, average, or below average.

The findings also suggest that neither teaching methodologies nor mathematical levels wield a significant interaction effect on student achievement test scores. This outcome further implies that the employed teaching methods do not bear an influence on the eventual mathematical prowess exhibited. Consequently, irrespective of the pedagogical approach, students with above average and average proficiency levels may outperform their below average peers on achievement tests. In the control group, students classified as above and average performers surpassed those categorized as below average.

Remarkably, these outcomes mirror the conclusions drawn by Xavier (2015), Evan and Lappin (2014), and Taiwas (2013), who similarly discovered no substantial interaction between students' mathematical achievements, their levels of mathematical proficiency, and the instructional strategies applied. This congruence in findings underscores the robustness of the observed trend across various studies and highlights the nuanced nature of the interplay between teaching strategies, mathematical abilities, and academic achievement.

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CONCLUSIONS

The study underscores the pivotal influence of instructional guidance on student learning outcomes. It becomes apparent that students perform optimally when guided by adept instructors who expound upon complex mathematical concepts. Additionally, the recognition that students can excel when given opportunities for independent problem-solving underscores the significance of fostering self-directed learning.

Furthermore, a noteworthy insight arises from the identification of challenges posed by the language of mathematics. The revelation that language intricacies impact learners' academic achievements underscores the crucial interplay between linguistic comprehension and mathematical success. Importantly, it also highlights that students' mathematical proficiency, when coupled with strategic teaching methods, significantly influences their mathematics achievement.

Equally salient is the finding that proficient instructor guidance and support can positively elevate students' academic performance. This emphasizes the symbiotic relationship between effective mentoring and enhanced academic outcomes, reinforcing the role of teachers in facilitating successful learning experiences.

The study's distinct emphasis on innovative pedagogical methods, particularly those involving problem-solving, emerges as a transformative aspect. Departing from traditional approaches, these methods foster autonomous learning habits and foster a deeper understanding of mathematical concepts, aligning with contemporary notions of dynamic and experiential education.

Significantly, the study underscores the notable discrepancy in performance between the innovative pedagogical approach and conventional teaching methods. This substantiates the efficacy of pedagogical strategies rooted in problem posing and heuristic problem solving, highlighting their potential to reshape and enrich the educational landscape.

In conclusion, this scholarly exploration offers valuable insights that inform effective pedagogical practices. It underscores the interplay between guided instruction and independent learning, acknowledging the importance of both facets in achieving successful outcomes. The study's observations on linguistic challenges, mathematical proficiency, and the impact of teacher support enhance our understanding of the multifaceted dynamics of mathematics education. Notably, the endorsement of innovative pedagogical approaches signals a shift towards experiential learning methods, while the performance differential underscores the potency of problem-solving methodologies.

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