MATH-CUPS: Addressing the Conceptual Understanding and Procedural Skills of Grade 10 STE Students and its Effect on their Academic Performance in Introduction to Calculus

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Abstract

This study aimed to investigate the impact of MATH-CUPS, an innovative teaching strategy focusing on conceptual understanding and procedural skills, on the academic performance of Grade 10 STE students in Introduction to Calculus. MATH-CUPS aims to foster a holistic approach to learning mathematics, ultimately achieving mathematical fluency among students. A mixed methods approach with a sequential explanatory design was utilized in this research.

The findings revealed a significant difference in the academic performance of the students in Introduction to Calculus before and after implementing MATH-CUPS, $Z=-7.435$, $p<.05$. Additionally, with a WAM of 3.51, the respondents strongly agreed that addressing conceptual understanding and procedural skills through this approach positively influenced their academic performance and mathematical fluency.

The responses led to the development of the MATH-CUPS framework, which demonstrated its potential to promote authentic learning, optimize critical thinking, enhance problem-solving abilities, personalize learning experiences, foster a positive attitude towards learning, and cultivate real-world relevance among students. This framework reflects the diverse benefits of the strategy, which extends beyond traditional teaching methods to address various aspects of students' learning and development.

Keywords: Conceptual Understanding; Procedural Skills; Intervention Program; Calculus

Context and Rationale

COVID-19 pandemic has significantly disrupted the education sector worldwide, leading to widespread learning gaps among students. The transition to remote learning and the limitations of online instruction have posed considerable challenges for both educators and learners (Schleicher, 2020). The disruptions in the regular classroom instruction have inevitably affected the acquisition and development of the conceptual and procedural skills of the students, particularly the students under Science, Technology, and Engineering (STE) program.

At present, there are 100 grade 10 students in Quezon National High School (QNHS) enrolled in STE program. One of their elective subjects is Introduction to Calculus which covers the topics from Analytic Geometry and Differential and Integral Calculus. Thus, students typically begin their journey into advanced mathematical concepts which forms the foundation for higher-level mathematics and scientific disciplines.

According to NCTM (2023), conceptual understanding involves grasping fundamental mathematical

principles, comprehending the underlying concepts, and applying them to solve complex problems. Procedural skills, on the other hand, refer to the ability to perform mathematical operations, execute calculations accurately, and follow systematic procedures in calculus. Both conceptual understanding and procedural skills are vital for students to learn the basic concepts in calculus effectively and succeed in subsequent academic pursuits.

The learning gap caused by the pandemic is likely to have diverse implications for students' academic performance. Students who have struggled to grasp the conceptual foundations of calculus or develop the necessary procedural skills may face difficulties in applying calculus principles to solve problems effectively. Consequently, their performance in assessments, examinations, and overall academic achievement may be adversely affected.

Addressing the impact of the learning gap in conceptual and procedural skills in Introduction to Calculus is crucial for developing targeted interventions and support mechanisms. This goal aligns with one of the four critical components of DepEd's MATATAG Agenda, which focuses on making the curriculum relevant to produce competent and job-ready, active, and responsible citizens (Babaran, 2023). This component plays a significant role in enhancing literacy and numeracy programs.

In a root-cause analysis conducted by the researcher, it was found out that misinterpretation of mathematical concepts, resorting to shortcuts, personal mindset, limited critical thinking abilities, and difficulty in comprehending problem-solving approaches were common challenges faced by Grade 10 STE students.

Thus, the researcher developed a teaching strategy named MATH-CUPS (Conceptual Understanding and Procedural Skills towards Mathematical Fluency) that is designed to holistically enhance students' conceptual understanding and procedural skills, ultimately fostering mathematical fluency and proficiency.

The implementation of MATH-CUPS is expected to create a positive and supportive learning environment that encourages active engagement, fosters a deeper appreciation for mathematics, and boosts students' confidence in tackling mathematical challenges. Through the MATH-CUPS approach, students are not only equipped with the necessary skills to excel in Introduction to Calculus but are also prepared for real-world applications of mathematics, making the learning experience meaningful and relevant to their lives. As the researcher applies and evaluates the effectiveness of MATH-CUPS, valuable insights and evidence-based practices can be garnered, contributing to the advancement of mathematics education and the improvement of students' academic performance in the subject.

Innovation, Intervention, or Strategy

The main purpose of this study is to address the conceptual understanding and procedural skills of grade 10 STE students in Quezon National High School through MATH-CUPS. The researcher also explored the effect of this approach on the academic performance of the students in Introduction to Calculus.

MATH-CUPS (Conceptual Understanding and Procedural Skills towards Mathematical Fluency) is an innovative teaching strategy designed to foster a holistic approach to learning mathematics. It focuses on two fundamental aspects of math education: conceptual understanding and procedural skills, with the ultimate goal of achieving mathematical fluency in students.

MATH-CUPS recognizes the importance of helping students grasp the underlying concepts and principles of mathematics. Instead of merely memorizing formulas and procedures, the emphasis is on comprehending the "why" behind mathematical concepts. This approach enables students to build a strong foundation and make connections between different mathematical ideas, leading to a deeper understanding of the subject.

While conceptual understanding is crucial, MATH-CUPS also acknowledges the significance of developing procedural skills. This involves teaching students' efficient methods and techniques to solve mathematical problems accurately and quickly. By combining conceptual understanding with procedural skills, students can apply their knowledge effectively and confidently when tackling various mathematical challenges.

MATH-CUPS aims to cultivate mathematical fluency, which goes beyond mere proficiency in performing calculations. Fluency entails having a flexible and intuitive grasp of mathematical concepts, being able to solve problems creatively, and adapting mathematical knowledge to real-world situations. Mathematical fluency empowers students to approach new and unfamiliar problems with confidence and competence.

One of the key strengths of MATH-CUPS is its focus on holistic development. It recognizes that each student learns differently and tailors teaching methods to cater to diverse learning styles. The strategy incorporates interactive and engaging activities, real-life applications of mathematics, and collaborative learning to create a supportive and enriching environment for students to flourish.

By nurturing both conceptual understanding and procedural skills, MATH-CUPS equips students with essential tools for lifelong learning and problem-solving. This approach is not just about passing exams but building a strong mathematical foundation that will serve students in their academic and professional lives.

Thus, by emphasizing both conceptual understanding and procedural skills, students develop a deeper appreciation for math and acquire the tools to become confident problem solvers with mathematical fluency.

This approach sets the stage for success in mathematics and beyond, empowering students to apply their knowledge effectively in various real-world scenarios.

This teaching approach encompasses three stages: pre-lesson activities, in-lesson strategies, and formative assessments. Each stage is carefully designed to engage students actively in the learning process and enhance their conceptual understanding and procedural skills in mathematics.

Pre-Lesson Activities: Before the actual lesson begins, the teacher employs various activities to prepare students for the upcoming topics. These activities include math drills, on-site visits, and explorations of applications like GeoGebra, which is a dynamic mathematics software. By engaging in these pre-lesson activities, students become mentally and emotionally invested in the lesson. These experiences create relevance and context for the upcoming material, helping to spark curiosity and interest in the subject matter.

In-Lesson Strategies: During the lesson, the teacher uses a range of interactive materials and games to facilitate the discussion. These resources are carefully selected to align with the specific mathematical concepts being taught. The interactive nature of these materials keeps the students actively involved, promoting a deeper understanding of the topic. By employing a variety of teaching methods, the teacher caters to different learning styles, ensuring that each student has the opportunity to grasp the concepts effectively.

Formative Assessments: Formative assessments are an integral part of this teaching approach. After the lesson, the teacher evaluates students' progress and understanding through formative assessment activities. One key aspect is requiring students to write their solutions to problems and, if applicable, the theorems they utilized to arrive at their answers. This practice encourages students to articulate their thought processes, promoting metacognition and reinforcing their learning. Even in assessments with multiple-choice questions, the teacher still emphasizes the importance of showing the solution. Additionally, the inclusion of challenge questions challenges students to apply their conceptual understanding and procedural skills to more complex problems, fostering critical thinking and problem-solving abilities.

By incorporating pre-lesson activities, in-lesson strategies, and formative assessments, this teaching approach ensures a comprehensive and engaging learning experience for students. It aims to go beyond rote memorization of formulas and procedures, focusing on the development of a deep understanding of mathematical concepts and the ability to apply them in practical situations. The interactive and exploratory nature of the approach fosters a positive and enjoyable learning environment, empowering students to become proactive learners in their mathematical journey.

Action Research Questions

This research investigated the impact of addressing the conceptual understanding and the procedural skills of Grade 10 STE students through MATH-CUPS on their academic performance in Introduction to Calculus.

Specifically, it sought answers to the following questions:

1. What is the academic performance of the students in Introduction to Calculus before and after the implementation of MATH-CUPS?
2. Is there a significant difference between the academic performance of the students in Introduction to Calculus before and after the implementation of MATH-CUPS?
3. What is the perceived impact of addressing the conceptual understanding and procedural skills in the academic performance and mathematical fluency of the students?
4. How do students perceive the effectiveness of MATH-CUPS in enhancing their conceptual understanding and procedural skills?

Hypothesis

There is no significant difference between the academic performance of the students in Introduction to Calculus before and after the implementation of MATH-CUPS.

Action Research Methods

The researcher utilized a sequential-explanatory design, employing both quantitative and qualitative research methods in a QUAN→qual approach. This design involves a two-phase process, where the collection and analysis of quantitative data are conducted first, followed by the collection and analysis of qualitative data to gain a comprehensive and deeper understanding of the research problem.

Participants and/or other Sources of Data and Information

The study involved 100 Grade 10 STE students from Quezon National High School, who were enrolled in the School Year 2022-2023. The researcher used purposive sampling to select the participants, specifically focusing on students taking the elective subject Introduction to Calculus. By specifically targeting this group, the researcher aimed to obtain a detailed understanding of how the MATH-CUPS approach impacted students' conceptual understanding and procedural skills in the context of this particular subject.

The decision to focus on Introduction to Calculus was based on several factors. Firstly, the researcher's current role as the teacher of this subject provided direct access to the students and the opportunity to implement the MATH-CUPS approach in the classroom. This allowed for a more controlled and consistent

application of the strategy.

Secondly, through observation, the researcher noted that the students initially struggled with the subject due to learning gaps caused by the COVID-19 pandemic. These gaps could have affected their conceptual understanding and procedural skills in mathematics. Hence, Introduction to Calculus was chosen as the subject of study to assess the effectiveness of the MATH-CUPS approach in addressing these challenges and improving students' performance.

For data collection, both quantitative and qualitative methods were employed. The quantitative data encompassed all 100 students and included their academic performance for two consecutive rating periods. This allowed for a comprehensive analysis of the overall impact of MATH-CUPS on the students' academic achievement. The MATH-CUPS was employed during the second quarter rating period.

On the other hand, the qualitative data focused on selected responses that directly addressed the research questions. By carefully choosing responses that provided valuable insights into the students' perspectives and experiences, the researcher ensured that the qualitative analysis complemented and enriched the quantitative findings.

Data Gathering Methods

Before conducting the study, the researcher obtained a permit from the school principal. The quantitative data for the research were collected from the students' grades in the first and second quarter rating periods, as well as from their responses to the Likert-typed research questionnaire. The questionnaire is composed of ten (10) statements about the perceived impact of addressing the conceptual understanding and procedural skills in the academic performance and mathematical fluency of the students. This questionnaire underwent validation by mathematics experts, and a pilot test was conducted to assess its internal consistency and validity using Cronbach's Alpha. The result, with a value of .761, was deemed acceptable.

Upon analyzing the quantitative data, the researcher proceeded to collect qualitative data through an open-ended survey questionnaire. To minimize disruption to classes, the survey was conducted using Google Form. Additionally, the researcher took measures to ensure the anonymity of the students, assuring them that their responses would not have any impact on their academic performance.

Data Analysis

The following statistical treatment were used to analyze and interpret the data gathered from the respondents.

The researcher utilized the mean to assess the students' academic performance during the first and

second quarter rating period. After collecting the academic performance data, the normality of the data was examined using the Shapiro-Wilk test. The test result (W = 0.952, *p* value = 0.001) indicated that the data was not normally distributed. Consequently, the researcher employed the non-parametric Wilcoxon Signed Rank Test, an equivalent of the t-test, at a significance level of .05, to determine if there was a significant difference between the students' academic performance. The data analysis was conducted using the Data Analysis Tool in Microsoft Excel.

On the other hand, the perceived impact of addressing the conceptual understanding and procedural skills in the academic performance and mathematical fluency of the students was determined using the Weighted Arithmetic Mean. The table of the following summated Likert scale were used to interpret the result.

Point Scale	Mean Range	Qualitative Index
4	3.26 – 4.00	Strongly Agree
3	2.51 – 3.25	Agree
2	1.76 – 2.50	Disagree
1	1.00 – 1.75	Strongly Disagree

Furthermore, the qualitative responses were categorized into relevant themes using the in vivo coding technique. Subsequently, the responses from each theme were analyzed to identify patterns or commonalities across the study participants.

Discussion of Results and Reflection

The present study investigated the effect of addressing the conceptual understanding and procedural skills through MATH-CUPS in the academic performance of grade 10 STE students in Introduction to calculus.

Academic Performance of the Students in Introduction to Calculus Before and After the Implementation if MATH-CUPS

Table 1

Academic Performance of Grade 10 STE Students in Introduction to Calculus Before and After the Implementation of MATH-CUPS

	Mean	SD	p	Z-crit	Z-cal	Decision
Before	91.15	2.72	.000*	-1.96	-7.435	Reject Ho
After	92.90	2.71				

* significant at .05 level (2-tailed)

Table 1 presents the academic performance of Grade 10 STE students in the subject Introduction to Calculus, both before and after the implementation of MATH-CUPS teaching approach. Prior to implementing MATH-CUPS, the average academic performance was 91.15. However, after the adoption of MATH-CUPS, the average performance significantly improved, with the mean score rising to 92.90. The result concurred with the findings from the study of Laswadi et al. in 2016 in which it was observed that the development of both conceptual understanding and procedural fluency among Junior High School students has a substantial impact on their academic achievement. The study's findings also resonate with the NCTM's (2014) guidance on integrating concepts and procedures, aligning with the principles of the MATH-CUPS. By creating opportunities for students to demonstrate their solutions and the concepts they applied, MATH-CUPS fosters a deeper understanding of mathematics and supports the development of students' problem-solving abilities. These insights contribute to the ongoing efforts to enhance math education and promote effective learning strategies in the field of mathematics.

Furthermore, a Wilcoxon test was conducted to evaluate the difference between the academic performance of the students in Introduction to Calculus before and after the implementation of MATH-CUPS. The result indicated a significant difference, $Z=-7.435$, $p<.05$. This suggests that the implementation of MATH-CUPS has resulted in a significant difference in the academic performance of Grade 10 STE students in Introduction to Calculus, comparing their performance before and after the approach was introduced.

The current research aligns with the results of a study conducted by Hussein and Csikos in 2023, which similarly discovered a significant statistical difference in the mathematics achievement of students when taught using a combination of conceptual teaching and procedural knowledge. Accordingly, the findings emphasize the importance of providing students with practical mathematics classes, encouraging active thinking and analysis, rather than mere memorization and application of rules (as stated by Curtain-Phillips in Hussein and Csikos, 2023).

By incorporating conceptual teaching, students are encouraged to grasp the underlying principles and logic behind mathematical concepts. This deeper understanding allows them to apply their knowledge more effectively and adapt it to various problem-solving situations. On the other hand, procedural knowledge equips students with the practical tools and techniques necessary to carry out mathematical calculations accurately and efficiently.

The notion that students need practical mathematics classes aligns with modern pedagogical approaches that prioritize active learning and critical thinking. Rote memorization and rule-based learning can hinder students' ability to comprehend the significance and relevance of mathematics in real-life situations. Encouraging students to think critically and analyze problems fosters a more profound appreciation for the

subject and enhances their problem-solving capabilities.

Curtain-Phillips' statement, as cited in Hussein and Csikos' study, reinforces the importance of engaging students in thinking and analyzing mathematical concepts. This approach not only supports their academic performance but also nurtures a deeper interest in mathematics as a dynamic and applicable discipline.

Perceived Impact of MATH-CUPS in the Academic Performance and Mathematical Fluency of the Students

Table 2

Perceived Impact of Addressing the Conceptual Understanding and Procedural Skills through MATH-CUPS in the Academic Performance and Mathematical Fluency of the Grade 10 STE Students

No	Statements Addressing the conceptual understanding and procedural skills in mathematics through MATH-CUPS…	WAM	Verbal Interpretation
9	enhance your ability to analyze and interpret mathematical data.	3.69	Strongly Agree
3	positively impact your overall academic achievement in mathematics.	3.63	Strongly Agree
5	help you perform better in mathematics.	3.56	Strongly Agree
2	help you demonstrate a deeper understanding of mathematical concepts.	3.55	Strongly Agree
1	enhance your ability to solve complex mathematical problems.	3.50	Strongly Agree
6	contribute to your success in more advanced mathematical concepts.	3.50	Strongly Agree
10	contribute to your ability to explain and justify mathematical reasoning.	3.50	Strongly Agree
7	influence your long-term mathematical fluency and success.	3.42	Strongly Agree
4	influence your confidence and self-efficacy in approaching mathematical challenges.	3.38	Strongly Agree
8	facilitate your ability to transfer mathematical knowledge to real-world contexts.	3.32	Strongly Agree
	Average Weighted Arithmetic Mean	3.51	Strongly Agree

Note. WAM refers to the computed weighted arithmetic mean which is described based on the following ranges: 1.00 – 1.75 (Strongly Disagree), 1.76 – 2.50 (Disagree), 2.51 – 3. 25 (Agree), and 3.26 – 4.00 (Strongly Disagree). The results are presented in descending order of WAM values.

Table 2 illustrates the perceived impact of implementing the MATH-CUPS approach to address conceptual understanding and procedural skills on the academic performance and mathematical fluency of Grade 10 STE students. The overall weighted arithmetic mean (WAM) of 3.51 indicates that the students

"Strongly Agree" that MATH-CUPS has helped them improve their performance in Mathematics, particularly in Introduction to Calculus. It indicates that the approach is positively influencing their learning journey and contributing to their academic success. The focus on addressing both conceptual understanding and procedural skills in the MATH-CUPS approach aligns with the belief that a well-rounded education in mathematics is essential for students' comprehensive development. By incorporating interactive activities, real-life applications, and opportunities for analysis and interpretation of mathematical data, MATH-CUPS fosters a deeper understanding of the subject and encourages students to be proactive learners.

Among the statements, Statement number 9, "Addressing the conceptual understanding and procedural skills in mathematics through MATH-CUPS enhances your ability to analyze and interpret mathematical data," received the highest WAM of 3.69, also interpreted as "Strongly Agree." This integration allows them to not only perform calculations but also to interpret and analyze mathematical data with confidence.

The positive perception of students towards the MATH-CUPS approach is a promising indicator of its effectiveness in enhancing their learning experience. Students' belief that MATH-CUPS contributed to their improved academic performance and mathematical fluency suggests that the approach is successful in achieving its intended goals of fostering a holistic understanding of mathematics.

Implication of MATH-CUPS in Conceptual Understanding and Procedural Skills of the Students

Figure 1

MATH-CUPS Framework: Students Perception on the Implication of MATH-CUPS on their Conceptual Understanding and Procedural Skills

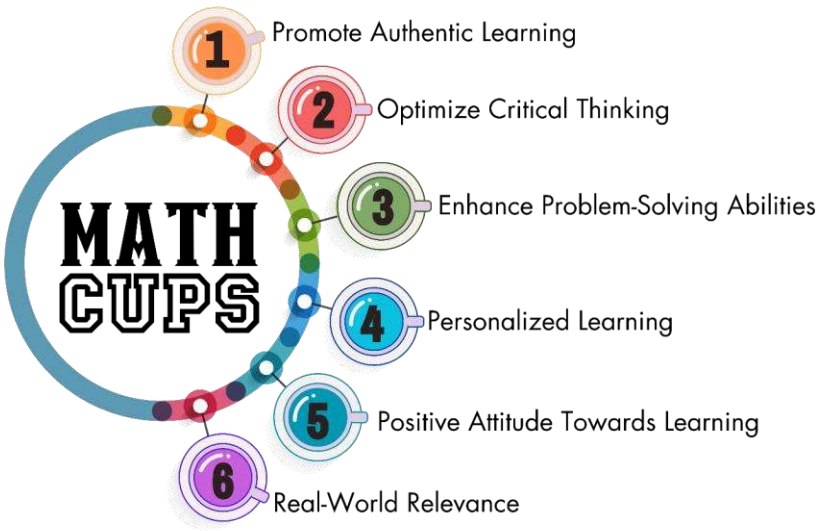

Figure 1 illustrates the MATH-CUPS framework which was derived on the insights gathered from the participants' responses that sheds light on the perceived impact on their conceptual understanding and procedural skills in mathematics. After analyzing the responses, they were organized and grouped into distinct themes.

Promote Authentic Learning

MATH-CUPS promote authentic learning, as indicated by the participants' responses. S1 pointed out that this strategy "*serves as somewhat of a great verification system on how legitimate one has actually answered a specific item.*" S2, S5, S12, S29, and S33 expressed that MATH-CUPS helps them genuinely understand the lesson, while S7 and S12 highlighted the usefulness of this approach in validating their answers. While some students may perceive it as time-consuming, they acknowledge the value of genuine learning over rote memorization or guessing. S1 mentioned that "*this strategy requires us to show solutions. I don't mind it though because it's a staple procedure if one's truly trying to learn it and trying to get used to it*." Thus, students recognize its importance as a fundamental practice for genuine learning and acclimatization to the subject.

Optimize Critical Thinking

MATH-CUPS help in optimizing the critical thinking skills of the students. S32 stated: "*Requiring solutions in calculus problems is crucial as it trains individuals to think critically and analytically. By engaging in the process of finding solutions, we develop problem-solving skills that transcend mathematics and become applicable to real-life situations. This practice teaches us to break down complex problems into manageable steps, fostering a systematic approach to challenges we encounter in various aspects of life."* This statement implies that requiring solutions in calculus problems is an essential practice that goes beyond the realm of mathematics. It nurtures critical thinking, analytical skills, problem-solving proficiency, and fosters a positive mindset that embraces challenges as opportunities for growth.

S3 stated that MATH-CUPS is "*a practical approach to assess the students' understanding, problem-solving skills, and identify areas for improvement. It promotes active engagement with the material and encourages us to think critically, which are essential aspects of learning calculus."* This statement highlights the practicality and pedagogical strengths of the MATH-CUPS approach in assessing and enhancing students' understanding and problem-solving skills in calculus. By promoting active engagement, critical thinking, and a holistic understanding of the subject, MATH-CUPS empowers students to become more proficient learners and problem solvers. S33 stated that "*by reviewing our work and the solutions provided, we can identify where we made mistakes and gain a deeper understanding of the concepts we need*

to work on. This can help us focus our study efforts and improve our overall mastery of the subject."

Enhance Problem-Solving Abilities

This strategy also helps the students to enhance their problem-solving abilities. S17 stated that MATH-CUPS enables them to discern the various pathways to a solution. Before solving equations or problems, careful examination is necessary to determine the most effective method. Moreover, in certain cases, multiple approaches may lead to the correct answer. By comprehending these diverse methods, they gain a thorough understanding of how they arrived at the final solution. Consequently, their procedural skills improves as they engage in practice.

S24 mentioned that "*As a learner who wants to know how we arrived to that answer or conclusion, I have to know the process of arriving to it. In that way, I can understand the problem better and how can I arrive to the solution in a way that I can understand how it arrived to this, how it arrived to that. Therefore, by seeing how it actually works, I can learn better and know better. Moreover, it makes learning easier."* The student's perspective expressed in this statement emphasizes the importance of understanding the process behind arriving at an answer or conclusion. The desire to comprehend the problem-solving process stems from a genuine curiosity and a recognition that understanding the "how" is just as crucial as knowing the "what." By seeking to understand the "how" of arriving at a solution, the learner cultivates a more versatile problem-solving skillset and develops a deeper appreciation for the subject. This approach to learning exemplifies the essence of being a proactive and motivated learner, making the journey of education more fulfilling and enjoyable.

Further, S13, S15 and S24 underscore the effectiveness of the MATH-CUPS approach in promoting better problem understanding and efficient problem-solving. Additionally, S30 said that "*it would be complicated sometimes to have a multiple-choice question that requires a solution, it helps students analyze the given problem more efficiently."* Thus, this approach helped them in effectively navigating the problem-solving process to reach the correct answer.

Personalized Learning

MATH-CUPS promote personalized learning experience among the students. S6 mentioned: "*I draw the conclusion that this activity can actually help us to increase our knowledge about mathematics since challenging ourselves has a significant impact on our future and that it helps to shape our minds in helpful ways."* S35 also pointed out that *"Solving calculus problems requires a deep understanding of the underlying principles, as well as the ability to apply various techniques and formulas. Requiring solutions in a quiz provides an opportunity for us to practice these skills and reinforce are understanding of calculus concepts."*

The activity's impact on increasing mathematical knowledge and shaping individuals' minds in helpful ways resonates well with the principles of personalized learning. By empowering learners to take ownership of their learning, tailor their experiences, embrace challenges, and cultivate a growth mindset, personalized learning creates an environment where learners can thrive and become lifelong learners. As educators, recognizing the value of challenging activities and personalized learning can guide us in creating learning experiences that cater to students' unique strengths and aspirations, fostering a love for learning and self-driven growth.

Moreover, S11 said: "*Although giving the correct answer without showing the solution may be seen as a sign of skill, it would still be better to showcase how you arrived at the answer. Writing down the solution before giving the answer is very beneficial for both students and teachers. It is because the students, have they gotten the answer wrong, could check the solution they used and try and fix it and arrive to the right answer. Students could also use it as study material and practice to further enhance their knowledge of a particular formula. And for the teachers, it makes their task easier since they could easily point out if the student is struggling or not."* With this, MATH-CUPS strategy does not only empower students to take ownership of their learning and foster reflective practice but it also enables personalized support and instruction.

Positive Attitude Towards Learning

MATH-CUPS cultivates a positive attitude towards learning among Grade 10 STE students. Although Introduction to Calculus may seem daunting, this approach enables students to embrace the subject, appreciating the underlying beauty of the key concepts they need to grasp. S14 stated that this strategy solidifies their understanding of the subject and improve their willingness to try problems while also improving their perseverance in problem solving. This statement was supported by S32 who stated that this strategy "*cultivates persistence and resilience, as we learn to overcome obstacles and persevere until we find the solution."* The strategy described in the statements is closely related to fostering a positive attitude towards learning. By promoting success, embracing challenges, encouraging active engagement, and building resilience, the strategy creates a learning experience that is enjoyable, empowering, and meaningful for students. This positive attitude towards learning extends beyond the specific subject and lays the foundation for a lifelong passion for knowledge and personal growth.

Furthermore, S41 expressed that MATH-CUPS promotes a more serious approach to problem-solving, discouraging mere guessing of answers. Instead, students are prompted to engage thoughtfully with the problem, analyze the given information, and apply relevant concepts to arrive at a solution. This encourages a more diligent and careful problem-solving process. Additionally, S31 highlighted that the

strategy assists them in identifying specific areas that require further learning and study. When students showcase their solutions and identify areas for improvement, they gain a sense of control over their learning process. This self-regulated approach fosters confidence and self-efficacy—the belief in their ability to succeed through effort and learning. With increased confidence, students are more likely to approach challenges with a positive outlook, which enhances their attitude towards learning.

Real-World Relevance

MATH-CUPS highlights the real-world relevance of the lessons. According to S27, it aids in understanding the various applications of the lesson, while S44 emphasized *"that "demonstrating the practical applications of the concepts helps me recognize the relevance of calculus in everyday life, making it more meaningful and relatable."* When students see how mathematical concepts are applied in real-life scenarios, it enhances their understanding of the subject. By experiencing the practical implications of what they are learning, students grasp the relevance and usefulness of the lessons beyond abstract theory.

Thus, MATH-CUPS effectively bridges the gap between theoretical knowledge and practical application. When students observe how mathematical concepts are used in real-world contexts, it strengthens their ability to apply the theory to solve real-life problems.

Conclusion

In view of the findings, prior to implementing MATH-CUPS, the average academic performance was 91.15. However, after the adoption of MATH-CUPS, the average performance improved, with the mean score rising to 92.90. It signifies tangible progress in the students' mathematical abilities.

A Wilcoxon test was conducted to evaluate the difference between the academic performance of the students in Introduction to Calculus before and after the implementation of MATH-CUPS. The result indicated a significant difference, $Z=-7.435$, $p<.05$. This suggests that the implementation of MATH-CUPS has resulted in a significant difference in the academic performance of Grade 10 STE students in Introduction to Calculus, comparing their performance before and after the approach was introduced.

With an overall weighted arithmetic mean (WAM) of 3.51, the students' perception of the impact of addressing conceptual understanding and procedural skills in their academic performance and mathematical fluency indicates a strong agreement that MATH-CUPS has notably enhanced their performance in Mathematics, particularly in Introduction to Calculus. The approach positively influences their learning journey and contributes to their academic success. MATH-CUPS' focus on both conceptual understanding and

procedural skills aligns with the belief that a well-rounded mathematics education is crucial for comprehensive student development.

The MATH-CUPS framework, derived from students' perceptions, shows positive impacts on Grade 10 STE students' conceptual understanding and procedural skills in mathematics. It promotes authentic learning, critical thinking, problem-solving abilities, personalized learning, a positive attitude towards learning, and real-world relevance.

MATH-CUPS fosters a true understanding of the subject and validates students' answers, leading them to strongly agree that authentic learning is vital, and rote memorization should be avoided. It optimizes critical thinking by teaching problem-solving skills applicable beyond mathematics, promoting active engagement and a deeper grasp of calculus concepts. The approach enhances problem-solving abilities by encouraging diverse approaches to solutions and understanding the process behind arriving at answers.

MATH-CUPS provides a personalized learning experience, empowering students to take ownership of their learning and use solutions for improvement. The approach cultivates a positive attitude towards learning, as students embrace challenges, improve perseverance, and become more resilient problem solvers. Moreover, MATH-CUPS highlights the real-world relevance of calculus, making it more meaningful and relatable to everyday life.

Recommendations

Based on the significant improvement in the academic performance of students in Introduction to Calculus after the implementation of MATH-CUPS, it is recommended to the **teachers** to continue utilizing this teaching approach in their future instruction.

To ensure the successful and sustained implementation of MATH-CUPS, school **administrators** could offer professional development opportunities for teachers, enabling them to further enhance their skills in using the approach effectively. Additionally, conducting long-term monitoring of student performance would be valuable in assessing the durability of the improvements achieved through MATH-CUPS. Expanding the use of MATH-CUPS to other mathematics subjects and grade levels should also be considered by school administrators. By applying the approach across various mathematical topics and student age groups, a more comprehensive assessment of its effectiveness can be achieved.

For future research, it is recommended to conduct cross-cultural studies to evaluate the generalizability of the findings. Such studies would assess the efficacy of MATH-CUPS in diverse educational settings and cultural contexts, helping to identify any necessary adaptations or modifications required to accommodate different cultural backgrounds.

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