Conceptual Learning of Calculus in Teacher Education: A Time Series Approach to Visualization Over Math Solver in Diverse Learners

[1]Panneerselvam G, [2]Priyadharsini M

[1]Department of Education, National Institute of Technology Puducherry, India
[2]Sree Krishna College of Education, India

Corresponding Author Email: [1]reach@panneer@gmail.com

ABSTRACT

The objective of this paper is to assess the ambience of diverse learners practicing the contents in calculus with Microsoft Math Solver. Calculus problems involve abstract reasoning, particularly logical reasoning and abstract thinking, as well as equations as a platform. This study's primary goal is to evaluate conceptual learning in calculus in teacher education using an exploratory approach that prioritizes visuals over conventional math solvers. Aforementioned is primarily to assess how effectively student-teachers can develop a profound, long-lasting understanding of mathematical concepts through a preferred procedure. To help achieve the goals, an exploratory survey design is employed over a specified interval of time, known as a time-series approach. The convenience sampling technique is employed in this study. This approach seeks to explain phenomena, such as calculating derivatives in the advanced computational laboratory using Microsoft Math Solver, which forms the foundation for similar concepts carried out methodically in conventional classrooms. Additionally, the description refers to using a method that involved six math majors' student-teachers in various contexts. The Hawthorne effect is mitigated in this study, as the researcher can observe students in class while they receive instruction, allowing them to focus on problem-solving. As already stated, this is also possible in an advanced computing lab. The research yielded well-resourced, self-paced questions and answers, as well as an environment that facilitated the exposure of the concept of calculus in collaboration with Microsoft Math Solver. Learners save time, increase creativity and experience, and recapitulate solutions through visualization with updated, enhanced routines. This study captures the ambiance in the visualization of learning Calculus via MMS. The sample may include student teachers, who benefit significantly from applying the subject in this way, both in their teaching practice and in the early stages of their careers. Additionally, treating student-teachers as samples in this exploratory survey is a novel aspect of this study.

Keywords: Calculus, Derivatives, Microsoft Math Solver, Diverse Learners

Introduction

Teacher education is a multidisciplinary, holistic program that provides an appropriate platform for teachers to develop and enhance their individuality, cognitive skills, and multidimensional proficiencies. To create a platform for developing and enhancing conceptual learning, instructors go beyond conventional teaching, actively shaping the learning process to foster effective learning outcomes. In its application to the curriculum, the pre-service teachers should practice the Calculus through a unique discourse that evolves in conjunction with conceptual learning and a specific instructional strategy. Thus, instructional strategy may be practical and valuable in a classroom setting, also revealing the essentialities to consider how human cognitive processes function (Joshua et al., 2023). The

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methodology in research that effectively allows investigations into teachers' conceptual learning and cognitive processing: the information attended to, strategies employed, and inferences drawn from the information without interrupting the flow of working memory. Thus, to facilitate a working procedure, it is also essential to support calculus in evaluating the approach of conventional teaching methods.

Overall, the proposed method requires support, including visualization, problem-solving procedures, and relevance in conceptual learning, as the required variables are observed through grounded theory in a relevant setup. The investigation was conducted using a specific math tool, "Microsoft Math Solver", a free and open-source software that supports teaching and learning specific math content in a virtual environment, facilitating the visualization of abstract concepts in calculus. Thus, visualization can be a powerful tool for thinking and learning in mathematics, as it can help students understand abstract concepts and make connections between mathematical concepts (Schoenherr et al., 2024; Arcavi, 2003). Regardless of the teaching methods, solving or practicing a problem in calculus requires a basic formula, working rule, and norms to initiate. The problem will be solved with the individual ability of the learner.

An exploratory survey design in the time series is employed in this study to investigate conceptual learning in teacher education. First, similar to experimentation, calculus can be taught through conventional teaching methods over the course of a semester. This initial phase aims to make the masters in calculus as strong, and the proposed phase makes learners practice the same with math solvers. The second phase involves selecting appropriate tools for the problem, solving it, identifying steps, and focusing on visualizing the variable solution. Unlike an actual experiment, this second phase reveals that it investigates cause-and-effect relationships without random assignment, a method often used when randomization is impractical or unethical, focusing on distinct problem content and its impacts. Assisting calculus with a math solver develops skills such as mental abilities, including logical reasoning, critical thinking, problem-solving, memory, language skills, and abstract thinking, which can be significantly supported by learning content that utilizes visualization. This can be measured in a means-grounded theory approach, allowing learners to work in a self-regulated mode and observe students' interaction. When concentrated on the procedure, learning mathematics (calculus) is closely related to visualizing and representing mathematical objects and procedures (Oktaviyanthi & Supriani, 2015). In the course of study, content should be practiced through math solvers; by emphasizing a strategy, there may be more chances for the conceptual proficiency of the diverse learners in formal (inclusive) educational settings even though conceptual proficiency in teacher education is based on the concept that giving special needs to learners with diverse experiences will help them succeed more in social relationships, leading to further success in life (Wenxu & Yinhang, 2023). Teaching diverse learners requires that general teachers have essential competencies in individualized support. Teacher education currently faces the challenge of preparing general student teachers for teaching in inclusive classes and stimulating their integration of knowledge about inclusion, special education, general school pedagogy, subject didactics, and subject science (Steinert & Jurkowski, 2024). This study will address the potential difficulties encountered when practicing the content in conventional classroom settings and the rationale behind using the undefined software (AI) support tool. This

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research should begin by discussing the potential difficulties of practicing the content and the rationale for using the undefined software (AI) assistance tool, which is a math solver. This study is structured around two primary research questions. The first examines how the implementation of dynamic visualizations (MMS) influences student understanding of calculus over time. The second employs a grounded theory approach to measure and compare parameters of conceptual learning. Specifically, the research analyzes how visualization tools such as MMS affect critical cognitive traits including reasoning, problem-solving, and abstract thinking in pre-service teachers throughout the course of the investigation.

This exploratory time-series study examines how Microsoft Math Solver (MMS) affects the conceptual understanding of calculus among diverse pre-service teachers. Overall, rather than supporting the role of instruction, MMS works best as a helpful cognitive and visual scaffold. Fostering deep, inclusive, and transferable calculus comprehension among diverse learners requires hybrid pedagogy, which combines MMS with teacher-led questioning, discourse, and reflective scaffolding.

RESEARCH METHOD

This study aims to measure the conceptual learning proficiency of pre-service teachers when practicing calculus content to assist with math solvers. Here, the conceptual learning of learners will be compared based on their performance in working with content through the math solver. As a result, the research method needs to support comparison through qualitative aspects using an exploratory design, in the time series approach. This approach involves formulating or assessing generalizations that extend across multiple cases. Therefore, an exploratory survey design was adopted to examine emerging patterns in pre-service teachers' cognitive and qualitative engagement with Calculus across successive MMS-supported sessions.

Below the research design, the sampling framework will be elaborated, which leads to practice and individual reports. This study received appropriate ethical approval from the institution. Prior to participation, each participant provided written informed consent, which included guarantees of data confidentiality and the right to withdraw at any time.

Samples

A convenience sampling technique was employed to examine the six cases simultaneously. The samples include learners from mathematics majors from the Integrated Teacher Education Programme (ITEP) at the National Institute of Technology (NIT), Puducherry.

Glimpse of The Study (Grounded Theory Map)

An exploratory survey design simultaneously attends to the macro, meso, and micro dimensions of case-based research in time series. It is not a recipe or a set of rules. Instead, this approach is, first and foremost, a reminder of how much we might achieve through comparison (Bartlett & Vavrus, 2017). This inquiry may be conducted in two phases to investigate the historical and current processes that have resulted in a sense of shared place. The first comparison focuses on learning on a macro and meso level, while the second compares learning on a micro level. The macro level represents society (such as classrooms)

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as a whole, in which regulations and policies can induce both drivers (such as teaching) and barriers to innovation (Lindkvist & Govik, 2024). Calculus was taught for five credits in semesters I and II. Of these five credits, one was assigned for practical activities in the syllabus, and the remaining four can be done by a conventional method. The investigator/faculty considers that a single credit for practicing calculus through MMS should be reflected as a micro-credential.

Consequently, the micro dimension confirms micro-learning, and it is one of the reform-oriented approaches that can accelerate digital transformation in mathematics teaching, contribute to integrating technology in mathematics education, and engage students in mathematics (James et al., 2021) simultaneously. The learners have clarified calculus concepts within one and a half semesters. This allows folks to study calculus in an in-depth and evident manner. (In this period, the six learners' performances are monitored, and the quantitative data can be considered their academic performance; the investigator assessed the learners' qualitative traits only by exposing them to calculus in the traditional method. Then, for the case comparison phase (micro dimension), some selected problems (taught in the traditional method) on derivatives were given to the six cases, and they were instructed to practice calculus using a math solver in consecutive sessions up to the end of the semester. To document the data in the form of qualitative elements, investigators should compare, observe, and conduct interviews.

Parameters and Justification

The cases in this exploratory survey design often include practicing calculus derivatives using a math solver. Therefore, to launch and execute problems, a math solver needs a lot of prerequisites (skills/steps). Therefore, these prerequisites can be observed through specific parameters, which also help configure software tools, libraries, and frameworks to optimize performance . Investigators manipulate these parameters to operate a math solver with calculus content effectively, including;

P_1 — Selection of an appropriate tool (narrative analysis)
P_2 — Typing problems in the math solver tool (narrative analysis/ conceptual analysis)
P_3 — Narration and the resemblance of follow-up in detailed explanations (conceptual analysis
P_4 — Justifications and illustrations of the answer they discovered (conceptual analysis/ discourse analysis)
P_5 — Explanations and visualization of the solution they found (discourse analysis/ content analysis)
P_6 — Follow-up of the visualized images when reported in discourse analysis (discourse analysis/ narrative analysis)
P_7 — Mindfulness throughout the session (cognitive proficiency)
P_8 — Think logically and critically according to the undertaken problem (cognitive proficiency)
P_9 — Memory on matching the solution with visualization (cognitive proficiency)
P_{10} — Overall problem-solving ability (cognitive proficiency)

One of the foundational areas of mathematics is calculus. It encompasses concepts with applications in various other domains, including limits, derivatives, and integrals. A math solver is a program that provides step-by-step solutions, computational capabilities, and visualizations to aid in calculus study. Math solver's interactive features can make learning calculus more interesting and enjoyable.

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The learner's choice of an appropriate math solver depends on the problems that prompted them to use narrative analysis (Anton Sevilla-Liu, 2023). Recognizing diverse learner profiles can foster appreciation for individual differences in how cognitive processes, problem-solving techniques, and emotional reactions influence thinking and learning. Examining teachers' narratives about their classroom experiences can provide insight into their pedagogical beliefs, practices, and decision-making processes. Finally, it examines students' cognitive and emotional responses, as well as the role of narrative in mathematical communication. Narrative analysis, a common analytical technique in literary theory, examines the sequencing of the text's elements and how initial elements influence and shape subsequent events, focusing on the evolving relationship between characters. The key features of narrative analysis in mathematics (selection of appropriate tools in a math solver) are focused on meaning-making and emphasis on the context. However, content analysis can motivate learners to develop problem-solving strategies and gain a deeper understanding of the underlying concepts. The learner unquestionably improves their narrative analysis in calculus by addressing P_1 & P_2 typing problems in the math solver tool, narration, and the resemblance of follow-up in detailed explanations. At the same time, content analysis can facilitate students' comprehension of the underlying concepts and promote problem-solving. Content analysis (of P_3, P_4, and P_5) was utilized to examine the documents and identify themes relevant to the analysis of mathematics textbooks (Zeynivandnezhad et al., 2024). Over the past few decades, researchers have employed content analysis to enhance their understanding of research topics and trends in educational technology, including those related to students with disabilities (Shin et al., 2023). Learners can explore the content/concepts independently, try out various functions and parameters, and get quick feedback. Typing problems in the math solver tool and the resemblance of follow-up in detailed explanations, which the learner can adequately do in the math solver, can lead them to visualization, involving problem-solving skills, conceptual understanding, and enhancing procedural fluency while in calculus practice.

The learner unquestionably improves their conceptual analysis skills in calculus by (addressing P_2) selecting the appropriate tool and entering problems into the math solver tool in the MMS. Finally, discourse analysis examines how mathematical concepts, themes, and practices are corresponding and interpreted within the context of calculus education. It delves into the language, symbols, and social interactions that shape the understanding and learning of calculus. Discourse is how language is used socially, the people who use it, and the conditions that influence it. Discourse is a unique type of communication (clearly different from other communications), including the response to actions and reactions in it (Nisa et al., 2020;). Of course, discourse analysis enhances the use of mathematical language and symbolism, working with visual representations, while also fostering valid teacher-student interactions (Ayuwanti et al., 2021) and peer interactions. When observing learners' exposure to the math solver, P_5 and the researcher could analyze student responses to open-ended questions, observe classroom discussions, and examine student work to identify common misconceptions and alternative conceptions. Meaningful discourse in the mathematics classroom involves creating a learning community that empowers students to articulate their reasoning and make sense of their peers' contributions, while advancing the learning of mathematics for the entire class. Discourse also provides a robust source of

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assessment evidence to help teachers determine the depth of their students' mathematical understanding (Schmidt et al., 2024).

In relation to discourse analysis, participants demonstrated stronger abilities. During interviews, they were able to justify their reasoning (P_4) and explain solutions using visual representations (P_5) with clarity, often referring to MMS-generated graphs or symbolic outputs. These responses reflected coherent mathematical discourse and effective explanation strategies.

Regarding content analysis, participants consistently emphasized that MMS supported their ability to connect explanations with visual representations (P_5), thereby enhancing the clarity and completeness of their responses (Bengtsson, 2016). However, it suggests that the comprehension and representation were well supported through the digital environment.

Finally, reflections related to cognitive proficiency revealed contrasting patterns. While participants described strong logical and critical thinking (P_9) and confidence in overall problem-solving abilities (P_{10}), several acknowledged challenges in maintaining sustained attention and mindfulness (P_8) throughout extended tasks. Recognizing the impact of cognitive load and screen-based interaction can foster empathy and realistic expectations about learner experiences. Interview responses indicated that cognitive load and screen-based interaction occasionally affected focus, which may explain the relatively weaker mindfulness outcomes.

Overall, the interview phase corroborated the analytical framework by illustrating strong narrative, discourse, content, and higher-order cognitive skills, alongside identified limitations in mindfulness and selected aspects of conceptual proficiency.

Comparative Case Report

Overall, learners have shown improvement in perseverance while practicing calculus problems with the assistance of math solvers. The traditional classroom is characterized by recalling formulas, derivation, explanation, and rechecking. With these, some problem-solving skills and self-concepts concerning problem-solving abilities should be improved. These can be authenticated by observing, interacting with, and verifying the learners' notes against the relevant output. In contrast, assisting math solvers, selecting tools, inputting problems, solving, focusing, and saving the visualized image are the primary tasks for learners. Therefore, it allows learners to observe a problem from a multidimensional perspective, and with the visualized image, they can validate the solution. The section below clarifies learners' conceptual characteristics while exposed to math solvers.

Conceptual profile

Utilizing a math solver and learning calculus, researchers found that students who were taught using a math solver achieved higher results, which positively impacted students' confidence in mathematics (Rina & Suprina, 2015). This quote will support this study, and the observed traits are tabulated below in Table 1.

It outlines the characteristics of the learners, including their conceptual characteristics, their experiences practicing calculus using a math solver, and the pedagogical advantages they gain throughout their studies. The investigators' observations in the computational lab will clearly describe these characteristics.

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Table 1 Description of conceptual characteristics of pre-service teachers

Conceptual Characteristic		Description	Inclusive/Pedagogical Benefits
Accustom	Problem-Solving	Infer with; [different approaches] [solutions with numerical computation] [solutions with algebraic computation] [Representation of the solution in a graphical view]	Learners seem to. [be with maximum involvement] [be reduced with time to solve problems]
	Calculation	Determination of; [appropriate solution] [estimate derivatives and multiple expressions in calculus]	
Variation of parameters	As Visualization	To facilitate [visualization of a function] [changing parameters] [changes in the graphical characteristics]	Proposed with [direct feedback] [construction of variables] [provision of assistance]
	As a graph	Microsoft Math Solver equips [to graph a function] [to view the solution in two-dimensional aspects]	
Conceptual Understanding	As exploratory	[Investigate the concepts] [recognize the concepts] [exploration of data, and] [algebraic graphical representation]	Proposed with [more than one method]
	Authentication	[Validation of answers] [hierarchy of steps, and] [problem-solving skills]	

Some crucial factors related to cognitive aspects are highlighted below and are also to be considered during the study. *Over-reliance:* Although helpful, it is essential to refrain from depending too much on the software. Students should develop strong foundational knowledge of calculus concepts and problem-solving strategies. Conceptual Understanding: Getting the correct answer is not the primary goal; the emphasis should always be on comprehending the underlying mathematical concepts. *Teacher Guidance:* Teachers frequently need to guide students to ensure that they are using the software effectively and gaining a thorough understanding of the subject matter.

Case reports and content description

Diversity in education often highlights the diversity of learners and involves meeting each learner's unique learning needs in traditional classroom settings. Table 2 indicates that six samples' worth of data is utilized to determine which samples are diverse. Additionally, as shown below, the data showed the samples' demographic location, mother tongue, category, parental type, and academic achievement during the first semester. Except for semester grades, every other descriptor suggests that the instances will involve students who are diverse in all aspects.

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Table 2 Description of variables of samples

S. No	Samples	Major	Home Town	Mother Tongue	Category	Parental Type	Semester Grade
1	C_1	Mathematics	Puducherry	Tamil	OBC	Single	S
2	C_2	Mathematics	Telangana	Telugu	OC	Both	A
3	C_3	Mathematics	Telangana	Telugu	ST	Single	D
4	C_4	Mathematics	Kerala	Malayalam	OC	Both	E
5	C_5	Mathematics	Puducherry	Tamil	OBC	Both	E
6	C_6	Mathematics	Kerala	Malayalam	SC	Both	D

Note: For grade $> 90 - S$, $80 - 89 = A$, $70 - 79 = B$, $60 - 69 = C$, $50 - 59 = D$, $40 - 49 = E$, $< 39 - F$

Case C_1 received an S grade in traditional practice. C_1 will be identified with above average and average across all parameters in the computational lab, except parameter P_5 & P_8 (discourse analysis/content analysis). Comparing the results, C_1 shows no decline in the ability to study the contents, as is the case with $C2$, which received above-average and average grades. In the computational lab, case C_2 performed well on all parameters. According to the comparison C_2, there is no decline, making the concert on performing calculus unquestionably superior. There was no subpar performance on the factors pertinent to the calculus studies through the math solver, and the results in example C_3 showed a D in practicing calculus by traditional instruction. As demonstrated, case C_2 did well in calculus with the math solver compared to conventional instruction. Case C_4 will perform nicely and average across all parameters in the computational lab, except for parameter P_3 (content analysis), much like it did in conventional practice, obtaining an E. Comparing the C_4 results reveal that everything is fine, that the traditional technique has to concentrate more on content, and that there is no reduced ability to perform calculus using math solvers. The case C_5 will perform nicely and average across all parameters in the computational lab; in particular, no parameter will perform poorly, similar to how it received an E in standard practice. According to a comparison of C_5 findings, everything is satisfactory; the traditional method requires more focus, and the capacity to execute calculus using a math solver remains unaffected and is somewhat enhanced. In the computational lab, case C_6 will perform nicely and average across all parameters; specifically, no parameter will perform poorly, unlike what happened when it earned a D in the conventional practice of calculus. A comparison of the C_6 results shows that everything is fine; the traditional approach needs to concentrate more, and the ability to perform calculus using a math solver is unaffected and even improved.

The students required concept development in the fundamentals of dimension, degree, and other related concepts, despite initially having a general understanding of calculus. For instance, the math solver's customized graphical application enables it to view dimensions and degrees independently when solving any calculus problem. Two hours each week were set aside for a computational lab in the syllabus credit. Every lab exercise trains students to solve calculus derivative problems using math solvers. They thrived in the computer lab, helping with derivative issues using math solvers. The investigator serves as a resource, helping students with math solvers and guiding them through some mathematics without directly assisting them. Samples were immediately given calculus tasks to complete (Questionnaire). Since using MMS to practice the problems is a viable and dependable

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method, all problems will be taken from the recommended textbook, Higher Engineering Mathematics authored by Grewal (1965).

Every sample comes with its own set of problems; some sample problems related to MMS are provided below. P_1: $y = x^2y + xy^2$, solve for x. P_2: $y = -2 < 3x + 2 < 8$, solve for x. P_3: $3x + 5 > 4$; P_4: $4x^2 - 5x - 12$, $y = 0$, and $y = 0$, and the virtual image of the respective problem will be represented Figure 1, Figure 2, Figure 3, and Figure 4.
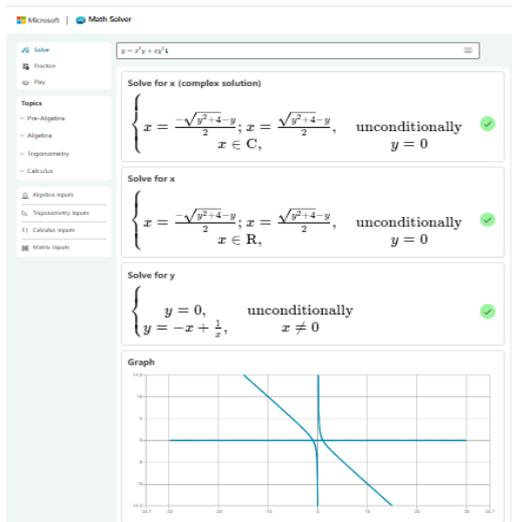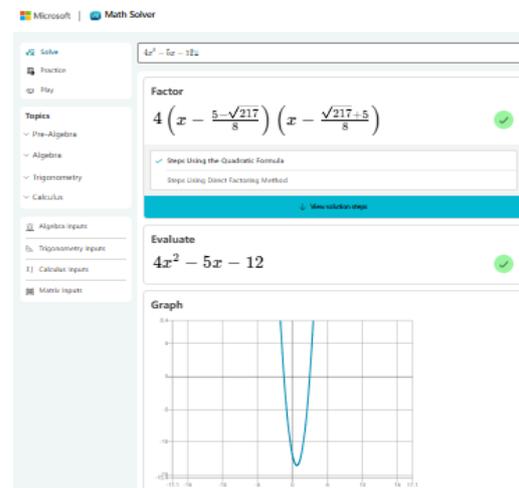

Figure 1 Graphical Representation of solution to P_1
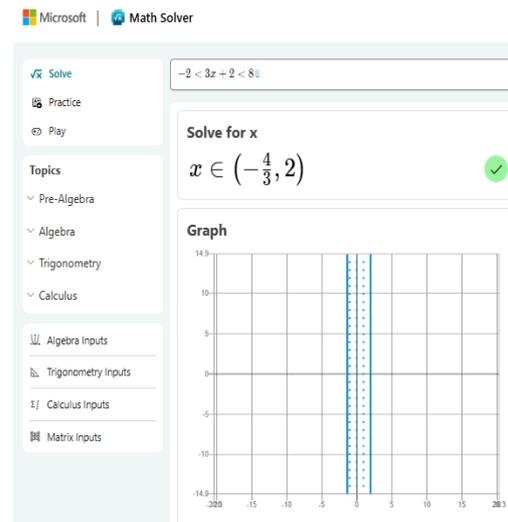
Figure 2 Graphical Representation of solution to P_2
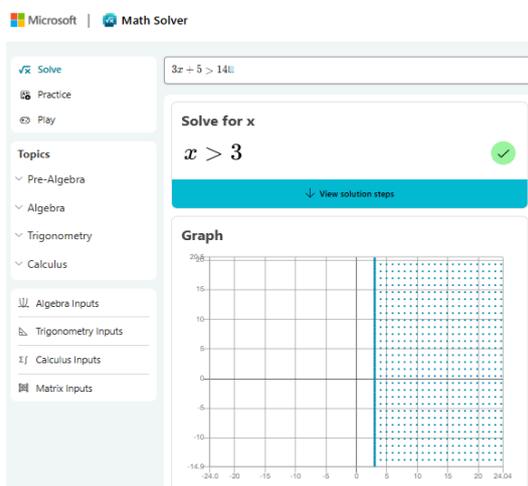
Figure 3 Graphical Representation of solution to P_3

Figure 4 Graphical Representation of solution to P_4

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RESULTS AND DISCUSSION

Overview of Participant Performance on Conceptual and Cognitive Parameters

Table 3 Integrated Qualitative–Cognitive Analytical Framework

Parameters	Case Performance						Qualitative Assessment
	C_1	C_2	C_3	C_4	C_5	C_6	
P_1	A	AA	AA	A	AA	A	Strong
P_2	AA	AA	A	AA	AA	AA	Strong
P_3	AA	AA	AA	BA	A	AA	Likely weak
P_4	A	AA	A	A	AA	AA	Strong
P_5	BA	A	A	A	AA	AA	Strong
P_6	AA	AA	AA	A	A	AA	Strong
P_7	AA	A	AA	AA	AA	AA	Strong
P_8	BA	AA	AA	AA	AA	BA	Weak
P_9	A	A	AA	A	AA	AA	Strong
P_{10}	A	AA	AA	A	AA	AA	Strong

Note: AA-Above average; A-Average; BA-Below average

Table 3 clearly demonstrated that the nature of the Integrated Qualitative–Cognitive analytical framework of learners from teacher education programs, such as narrative analysis, conceptual analysis, discourse analysis, cognitive proficiency, and content analysis on practicing Calculus in assisting with MMS.

In the view of narrative description, tool selection (P_1), typing skills (P_2) & visualization (P_6), resembles that the overall participant's demonstrated strength in narrative analysis. However parameters requiring Conceptual proficiency such as (P_2, P_3 & P_4), typing skills (P_2), analogue proficiency such as, Narration and resemblance (P_3), & Justifications and illustrative proficiency (P_4); in those P_2 & P_4 shows greater variance than (P_3).since it seems to be lightly weak. In case of discourse analysis, Justifications and illustrations(P_4), Explanations and visualization (P_5) indicates strong representation compared to the overall participants. Then the parameters reflecting content analysis such as explanations, visualization (P_5), representing the index as strong from the overall participants. Likewise in the framework, the parameters indicating; mindfulness(P_8), logical and critical thinking (P_9) and over all problem solving abilities (P_{10}) as cognitive proficiency parameters , the overall participants resembles that (P_8) will be weak and (P_9) &(P_{10}) reflects strong in assessment against overall participants.

When using MMS to practice calculus, teacher education students showed excellent performance in the narrative, discourse, and content analytical dimensions, according to the Integrated Qualitative–Cognitive Analytical Framework. Parameters about tool selection, typing proficiency, and visualization indicated robust narrative engagement. Strong qualitative representation was also evident in the discourse and content analysis parameters, especially in the areas of explanations, justifications, and visualization. Conversely, there was variation in the conceptual competency characteristics, with narration-resemblance and justification skills appearing to be relatively weaker. Logical and critical thinking, as well as general problem-solving skills, were strong in the cognitive competence category; however, the concept of mindfulness was identified as a relative limitation. Overall, the results indicate that while sustained attention and conceptual alignment call for additional instructional support, MMS successfully enhances higher-order cognitive and analytical skills.

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Profile and Development of Conceptual Characteristics

Descriptions of conceptual characteristics are performed through time series analysis. It shows how students progress over time while using MMS to practice calculus. Entirely in accordance with the curriculum, 20% of calculus will be taught in tutorial hours, meaning that about 20 sessions can be practiced via MMS.

Participant C_3 exhibited a clear developmental trajectory in visualization techniques, starting with a poor grade (D) and progressing to predicting graph shapes before system depiction. This progression can inspire the audience by illustrating the potential for growth with MMS practice.

Participant C_5, who also received an E, showed gradual but noticeable improvement. Early exchanges were primarily passive, but as visualization tools gained recognition, participation increased, and some conceptual linkages were established, particularly in situations involving recurring problems.

Initially, participant C_4, who received an E, had considerable difficulty deciphering mathematical representations. However, autonomous prediction abilities remained limited. C_4 demonstrated gradual improvements in engagement and responsiveness over the course of subsequent sessions, especially when assisted by guided visualization and repeated exposure.

Over time, participant C_6, who received a D, demonstrated a moderate level of progress. Later sessions demonstrated improved interpretive abilities and greater confidence in connecting graphical representations to underlying mathematical concepts, whereas a reliance on step-by-step coaching characterized early sessions.

The researcher noted significant differences in the participants' involvement and learning progress, which were related to their background characteristics and starting academic achievement. From the beginning, participant C_1 constantly showed confidence and intellectual clarity, earning a good semester grade (S). C_1 demonstrated excellent prior mathematical preparation by actively participating in learning challenges, using visualization techniques independently, and with minimal scaffolding.

With an initial grade of A, participant C_2 demonstrated consistent engagement and progressive improvement of problem-solving techniques. C_2 Gradually embraced analytical comparisons and demonstrated more autonomy in evaluating visual representations, indicating successful consolidation of conceptual understanding, although initially depending on structured instruction.

Utilizing a math solver and learning calculus, researchers found that students who are taught using a math solver achieved higher results, which positively impacted students' confidence in mathematics (Rina & Suprina, 2015). This quote will support this study, and the observed traits are tabulated below in Table 4.

It outlines the characteristics of the learners, including their conceptual characteristics, their experiences practicing calculus using a math solver, and the pedagogical advantages they gain throughout their studies. The investigators' observations in the computational lab will clearly describe these characteristics.

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Table 4 Description of conceptual characteristics of diverse learners

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	Authentication	[Validation of answers] [hierarchy of steps, and] [problem-solving skills]	

Some crucial factors related to cognitive aspects are highlighted below and are also to be considered during the study. *Over-reliance:* Although helpful, it is essential to refrain from depending too much on the software. Students should develop strong foundational knowledge of calculus concepts and problem-solving strategies. Conceptual Understanding: Getting the correct answer is not the primary goal; the emphasis should always be on comprehending the underlying mathematical concepts. *Teacher Guidance:* Teachers frequently need to guide students to ensure that they are using the software effectively and gaining a thorough understanding of the subject matter. This report aims to evaluate the effectiveness and limitations of Microsoft Math Solver in teaching calculus concepts, providing insights for pedagogical integration.

Impact of Dynamic Visualization on Understanding

Microsoft Math Solver enhances calculus understanding by converting abstract procedures into graphical representations, reducing cognitive load and fostering deeper conceptual engagement and progressive understanding among diverse learners. The emphasis on visualization demonstrates MMS's capacity to make complex ideas more accessible.

In addressing RQ_1, the pre-service teachers demonstrated excellence in calculus, utilizing Microsoft Math Solver to achieve strong results in tool use, visualization, explanation, and justification, aided by graphs and step-by-step outputs. A significant factor in improving performance was visualization. Calculus tasks become less procedurally

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demanding thanks to MMS's graphical and symbolic representations. Heither made it possible for students to concentrate less on manual computations and more on explaining their reasoning and understanding the results. Overall, the results show that MMS successfully improves narrative, discourse, and content-related performance; however, teacher support remains crucial for providing conceptual explanations and maintaining sustained focus.

In the phase of addressing (RQ_2), the weaker performance in P_3 (narration and conceptual resemblance) and P_8 (mindfulness) highlights the limits of technology-mediated learning without pedagogical support, rather than a flaw in Microsoft Math Solver (MMS). While MMS excels in procedural execution and visual interpretation, effective verbal articulation of concepts relies on guided discourse, which fosters the social construction of understanding.

Mindfulness challenges (P_8) relate to cognitive load theory. MMS reduces intrinsic cognitive load by automating steps; however, prolonged screen time and multitasking may increase extraneous load, potentially impacting attention. Learners demonstrated strong reasoning skills yet struggled to maintain focus during extended MMS use, indicating a need for structured environments that regulate pacing and attention. The findings indicate that MMS effectively promotes critical thinking, as evidenced by strong performance in justification, visualization, and problem-solving. However, verbal conceptual depth and sustained attentiveness require teacher intervention to enhance learners' understanding and discourse.

From an inclusive education perspective, this distinction is crucial. Diverse learners benefit from MMS for its multiple representations and self-paced engagement, but need individualized guidance for language-based reasoning and self-regulation. Effective learning arises from integrating digital tools with responsive teaching rather than mere technological substitution. MMS should serve as a cognitive scaffold, not a replacement for teachers, enhancing deep mathematical understanding through intentional mediation, discourse, and mindfulness.

In conclusion, the time-series analysis demonstrates that MMS-supported visualization fosters consistent conceptual growth, particularly by helping students make long-term connections between symbolic processes and pictorial meaning.

Critical reflections: Role, Strengths, and Limitations of the study

The investigator should reflect the computational lab environment (calculus & MMS). The perspectives of field specialists should be well-documented in this write-up, and indeed, some of the self-paced questions, along with their justifications, should be documented in this research.

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Table 5 Qualitative Insights into the Effectiveness and Limitations of MMS in Calculus

Q_1 —	Comment about MMS in giving steps for the problem in calculus
A_1 —	For practicing calculus problems, a math solver is a valuable tool with the following advantages: Step-by-Step Solutions: It breaks down complex issues into smaller, more manageable steps and offers thorough explanations. Hither can be invaluable for comprehending the fundamental concepts and methods. Numerous Problem Types: It addresses various calculus subjects, such as integrals, derivatives, and limits. Interactive Learning: The application frequently incorporates interactive features, such as graphs and visualizations, to help users comprehend the issue and its resolution.
Q_2 —	What is the ultimate aim of practicing a math solver for calculus?
A_2 —	It provides a precise answer and provides graphical support for the answer. Ultimately, it is a valuable tool for practicing calculus.
Q_3 —	What are the specifications of math solvers against calculus?
A_3 —	Math solver provides quick, secure, and detailed Training on various problem-solving techniques. Interactive definitions and explanations help learners understand and remember information more easily. Graphs facilitate a more thorough understanding of the concept. Overall, the math solver is a valuable resource for students and educators in calculus, providing a means to check answers, understand concepts, and gain confidence in problem-solving abilities.
Q_4 —	Is a math solver an accurate tool for practicing calculus?
A_4 —	A math solver utilizes artificial intelligence (AI) to recognize problems and deliver accurate solutions instantly. That is not all. It also provides a step-by-step explanation, along with additional learning materials such as worksheets and video tutorials. Finally, the server offers a wide range of practice problems at varying difficulty levels, allowing learners to test their understanding and skills.
Q_5 —	Spot out the characteristics of samples in a computational lab.
A_5 —	The students are eager to practice derivatives in the computational lab and gain speed in solving the problems. They will also be able to type more quickly in math and demonstrate interest in the problem's visual representation.
Q_6 —	Is there any limitation to assisting this math solver with calculus?
A_6 —	Yes, there is some delimitation, which is characterized by accuracy, limited conceptual understanding, and dependency on input. In terms of accuracy, the server may produce incorrect results if the problem is not correctly entered. The server is generally accurate, but occasionally, it may produce incomplete or incorrect solutions, particularly for complex problems or those involving non-standard techniques. Additionally, the server focuses primarily on the procedural aspects of calculus and may not provide sufficient explanations or insights into the underlying concepts. Recognizing these limitations enables educators and learners to collaborate in addressing potential gaps and enhancing understanding.

Table 5 highlights the limitations that explain the weaker performance in P_3 (narration and conceptual resemblance) and P_8 (mindfulness). Participants noted the risks of over-reliance on the tool, accuracy issues resulting from incorrect inputs, and the limited depth of MMS explanations for complex problems. Aforementioned suggests that while learners can follow procedures and interpret graphs, they often struggle to express deeper conceptual meanings, indicating that MMS prioritizes procedural fluency and visual confirmation over verbal elaboration or metacognitive reflection.

These limitations do not imply that MMS fails to promote critical thinking; rather, strong outcomes in reasoning and problem-solving indicate active engagement in higher-order thinking. The challenges in Table 5 highlight areas that require teacher intervention, as skills such as verbal reasoning and mindfulness necessitate interactive support beyond the capabilities of automated tools. The findings advocate for a hybrid pedagogy that integrates MMS with strategies promoting mathematical discourse and reasoning. Teachers facilitate

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learners in explaining solutions, comparing methods, reflecting on errors, and linking visual outputs to formal language. This approach aligns with sociocultural learning theory and inclusive education, emphasizing meaningful learning through interactions among tools, learners, and teachers.

Table 5 confirms that MMS is a valuable support tool, enhancing calculus learning for diverse learners, though it cannot replace teachers. Its benefits, alongside effective teaching, foster a prosperous and inclusive environment that balances procedural support with deep understanding.

This study investigates the effect of Microsoft Math Solver (MMS) on the conceptual understanding of calculus among diverse pre-service teachers, employing a time-series exploratory design. Findings indicate that MMS effectively enhances visualization, procedural fluency, justification, and overall problem-solving ability by providing immediate feedback and graphical representations. Learners, particularly those with lower initial achievement, demonstrated gradual conceptual growth over time. However, challenges were observed in verbal conceptual narration and sustained mindfulness, highlighting risks of over-reliance and limited conceptual depth. The results emphasize that MMS functions best as a supportive cognitive tool rather than a substitute for instruction. A hybrid pedagogy that integrates MMS with teacher-led discussion and conceptual scaffolding is essential for fostering deep and inclusive mathematical understanding.

To enhance the validity of the results, the limitations of this experiment are acknowledged below. The small sample of six pre-service teachers restricts the applicability of findings beyond this specific teacher education context. While the case-based time-series technique enables thorough qualitative analysis, larger samples from diverse institutions are necessary for confirming and expanding the results. Second, the intervention included only a few MMS-supported sessions, while extended studies may better demonstrate long-term conceptual retention in calculus, which often necessitates sustained exposure. Thirdly, the study focused exclusively on derivatives, one component of calculus. The results may not directly apply to other calculus areas, such as limits, integrals, or multivariable calculus, which may involve different cognitive demands and visualization issues, even though derivatives are fundamental to these areas.

The findings are exploratory and context-specific, highlighting patterns rather than causal conclusions. Future research should enhance robustness by using larger, more diverse samples, extending intervention duration, and exploring a wider range of calculus topics. While Microsoft Math Solver (MMS) offers significant pedagogical advantages, it also has notable limitations, including input dependency, occasional accuracy issues, and limited conceptual depth, particularly for complex or non-standard calculus problems. The tool primarily emphasizes procedural steps, which may not always foster deep conceptual understanding without instructional support.

Observations from the computational lab suggest that MMS fosters a positive, engaging, and innovative learning environment, particularly for diverse learners. Compared to traditional classrooms, where thinking can become monotonous, MMS encourages active exploration, visualization, and cognitive engagement ($P_7 - P_{10}$) particularly when supported by teacher questioning. Learners demonstrated enthusiasm, improved visualization skills, and greater confidence through graphical representations, aligning with evidence that image-

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based learning enhances mathematical understanding. However, effective use of MMS requires teacher mediation to address individual learning needs, prevent over-reliance, and ensure conceptual clarity. MMS should be integrated as a supplementary tool alongside traditional instruction rather than as a replacement. Strategic use of visualization, independent problem-solving practice, and verification of solutions are essential for maximizing learning outcomes.

Overall, MMS is a valuable technological resource for inclusive calculus education, particularly when used in conjunction with conventional teaching methods. Future research should explore additional AI-based tools and broader calculus topics to ensure that diverse learners can engage meaningfully and develop a deep, transferable understanding of mathematics.

CONFLICT OF INTEREST

There is no conflict of interest with anybody/any organization against this article.

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