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Universiti Teknologi MARA Cawangan Pulau Pinang

ANALYSIS OF MAPLE-BASED SOLUTIONS AMONG FIRST YEAR CIVIL ENGINEERING STUDENTS IN CALCULUS 1 ASSESSMENT

*Norshuhada Samsudin¹, Wan Nur Shaziayani², Mawardi Omar³ and Sharifah Sarimah⁴
*norsh111@uitm.edu.my¹, shaziayani@uitm.edu.my², mawardio@uitm.edu.my³,
sh.sarimah@uitm.edu.my⁴

^{1,2,3,4}Jabatan Sains Komputer & Matematik (JSKM),
Universiti Teknologi MARA Cawangan Pulau Pinang, Malaysia

**Corresponding author*

ABSTRACT

This study investigates the use of Maple, a Computer Algebra System (CAS), by first year Civil Engineering students in Calculus I course at UiTM Cawangan Pulau Pinang, focusing on conceptual understanding and mathematical communication. Using qualitative document analysis, fifteen student Maple assessment scripts were examined to identify patterns of tool usage, procedural accuracy, and conceptual alignment. Findings indicate that while students were generally proficient in executing commands such as diff () and solve (), there was a significant disconnect between symbolic outputs and underlying calculus concepts. Key issues included over reliance on Maple outputs, confusion between the first order and second order derivatives, and incomplete mathematical communication. These results suggest that CAS tools alone do not guarantee conceptual development while guided interpretation and justification are essential for meaningful learning. The study highlights the need for instructional designs that integrate Maple with problem based or inquiry-oriented approaches to foster deeper understanding and higher order thinking skills in introductory engineering mathematics courses.

Keywords: *Maple, Calculus I, Civil Engineering students, computer algebra system (CAS)*

Introduction

Calculus 1 is a foundational subject in engineering education, particularly for engineering students, as it provides essential mathematical tools for modelling and problem solving. However, first year university students often struggle with abstract calculus concepts such as derivatives and concavity. Research has shown that these difficulties are frequently rooted in weak conceptual understanding rather than procedural errors alone (Ghazali and Zakaria, 2011).

To address these challenges, Computer Algebra Systems (CAS) such as Maple software have been increasingly integrated into calculus instruction. Maple offers symbolic computation and dynamic visualization capabilities that allow students to explore calculus concepts through multiple representations. Maple software is used to solve mathematical problems in the form of numeric or symbolic (Parma & Saparwadi, 2015). According to Kossivi (2025), using dynamic visualization could improve the way calculus is taught in college so that students can become more confident and gain a deeper understanding of arithmetic.

Despite these benefits, previous research has cautioned that students may use CAS tools in a procedural manner, focusing on executing commands without adequately interpreting results. This concern is particularly relevant in introductory calculus courses, where students are still developing foundational reasoning and mathematical communication skills. However, most existing studies have examined learning outcomes or instructional interventions, with limited attention given to students' actual CAS-based solution scripts.

Therefore, this study analyses Maple based solutions submitted by first year Civil Engineering students enrolled in a Calculus 1 course. Using qualitative document analysis, the study focuses on conceptual alignment and the quality of mathematical communication demonstrated in students' Maple assessment scripts.

Methodology

Participants and Context

The participants in this study were 30 first year Civil Engineering students enrolled in a Calculus 1 course. As part of a course assignment, students were required to use Maple to solve calculus problems involving differentiation and analysis of functions including sketching a graph of function.

Research Design

A qualitative document analysis approach was adopted. Student scripts were treated as documents that reflect students' mathematical reasoning and use of CAS tools. From 30 submissions, fifteen Maple scripts were selected for analysis. These scripts were chosen as representative samples that exhibited common solution strategies and errors observed across the class.

Data Analysis Procedure

Each selected Maple script was analyzed based on the several criteria such as types of Maple commands used (e.g. diff, solve), correctness of mathematical procedures, conceptual understanding of calculus principles, and completeness and clarity of solution presentation. Errors identified in the scripts were coded into categories to facilitate systematic analysis.

Result

Analysis of the Maple scripts revealed that most students were able to use basic symbolic commands correctly, particularly for differentiation and inequality solving. Commands such as diff () and solve () were frequently used to determine intervals of increase, decrease, and concavity.

However, many students applied these commands procedurally, without explicitly linking the outputs to calculus concepts or verifying the mathematical context of the problem.

Table 1 below shows four main types of errors that was identified in the analysed scripts. The most frequent issue was over reliance on Maple outputs (Error 3), followed by conceptual errors related to derivative tests (Error 1).

Table 1: Main Types of Errors Identified in the Analysed Scripts

Code	Error Type	Description	Frequency
Error 1	Conceptual Error	Incorrect application of calculus concepts (e.g. using first derivative for concavity)	9
Error 2	Procedural Error	Correct command applied to an incorrect or unverified function	4
Error 3	CAS Over-reliance	Direct use of Maple outputs without interpretation or justification	11
Error 4	Incomplete solution	Missing conclusions or explanatory statements	5

Besides that, analysis of the selected Maple scripts revealed several instances of conceptual misalignment between calculus theory and the use of computer algebra system commands. Although most students were able to generate correct symbolic outputs using Maple, misunderstandings of fundamental calculus concepts were evident.

One prominent issue involved confusion between the use of first and second derivatives. In several scripts, students applied first derivative tests when analyzing concavity, indicating incomplete understanding of higher-order derivatives. While Maple correctly computed derivatives and solved inequalities, students frequently misapplied these results to draw incorrect or unsupported conclusions.

Another form of conceptual misalignment was observed in the interpretation of inequality solutions. Some students obtained correct solution intervals from Maple but failed to relate these intervals to the original calculus problem, such as identifying regions of increase, decrease, or concavity. This suggests that Maple outputs were often treated as final answers rather than as intermediate results requiring mathematical interpretation.

Discussion

This study examined how first year Civil Engineering students used Maple to solve Calculus 1 problems, focusing on conceptual alignment and mathematical communication. The findings show that although students were generally able to execute Maple commands correctly, accurate computational outputs did not consistently reflect strong conceptual understanding. This supports previous research

demonstrating that students' difficulties in calculus are often rooted in weak conceptual understanding rather than procedural errors alone (Sofroniou et al., 2015).

A key issue identified was students over reliance on Maple outputs, with limited interpretation or justification provided in their solutions. While Maple successfully generated derivatives and solution intervals, several students struggled to apply these results meaningfully, particularly when analyzing function behavior. Similar findings have been reported in recent studies, which suggest that technologies such as dynamic mathematics software, intelligent tutoring systems, and online assessment platforms have been widely adopted to improve both cognitive and affective outcomes in mathematics classrooms. (Omer et al., 2025).

Despite these challenges, Maple remains a valuable tool for supporting calculus learning through symbolic computation and visualization. Recent literature emphasizes that using maple software in learning mathematics affects students' ability to solve a problem (Ni'mah et al, 2024) Therefore, the findings of this study highlight the importance of designing Maple based tasks and assessments that explicitly require students to explain and justify their reasoning in order to support deeper conceptual understanding in introductory engineering mathematics courses.

Teaching Implications

The results of this study have several implications for teaching Calculus 1 to first-year engineering students. First, Maple based assignments should explicitly require students to interpret and explain Maple outputs. Instructors should emphasize the conceptual meaning of derivatives before introducing CAS tools. Beside that, Scaffolded tasks that separate computation from reasoning may help students develop deeper understanding. Finally, the assessment rubrics should include marks for interpretation and mathematical explanation, not just focused on the correct outputs.

Conclusion

This study investigated the conceptual alignment and mathematical communication of first year Civil Engineering students within a Maple based Calculus 1 course. The qualitative document analysis of student scripts revealed that while students possess a high level of proficiency in executing procedural commands such as `diff()` and `solve()`, there remains a significant disconnect between these symbolic outputs and the underlying calculus theory.

The results identified three primary areas of concern such as CAS over reliance, conceptual misalignment and incomplete mathematical communication. For CAS over reliance, students frequently treated Maple as a "black box," accepting symbolic results as final answers without interpretive justification. For conceptual misalignment, a critical confusion between first and second-order derivatives was observed, leading to incorrect conclusions about function behavior like concavity.

Other than that, the incomplete mathematical communication indicates that many students failed to relate their computational findings back to the original problem context.

These findings align with recent literature, such as Ni'mah et al. (2024), which suggests that the effectiveness of software like Maple is highly dependent on the pedagogical framework in which it is placed. While their research demonstrated that a Problem-Based Learning (PBL) model can achieve 100% group effectiveness by making mathematics more contextual and enjoyable, our data suggests that without such a structured inquiry-based model, students may default to a passive relationship with technology.

Technology offers powerful tools that can enhance both teaching and learning in mathematics. When used appropriately, it can help students visualize abstract concepts, receive immediate feedback, and personalize their learning experience (Radha, 2015). The significant interaction between dynamic visualization and conceptual gain noted by Kossivi (2025) suggests that for students to overcome the abstract nature of derivatives and integrals, instructors must go beyond teaching software syntax and focus on synchronized animated representations.

In summary, the integration of Maple into engineering education provides a powerful platform for computation, but it is not a substitute for conceptual development. In order to provide future Civil Engineers with the requisite Higher Order Thinking Skills (HOTS), instructional designs must change from a product orientation to a process orientation. This study recommends the adoption of hybrid models, such as PBL-Maple integration, to ensure that students use technology not just to solve problems faster, but to understand them more deeply

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