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Prerequisite Basic Calculation Skills for Calculus Algebra: A Content Analysis of Student Responses

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Abstract:

Calculus and Algebra is a foundational mathematics course in Malaysian polytechnics that requires students to possess stable prerequisite basic calculation skills to engage effectively with higher-level mathematical concepts. Despite prior exposure to mathematics at the secondary school level and in earlier semesters, many students particularly those from diverse educational backgrounds, continue to experience difficulties in mastering the course. This study aims to explore students' prerequisite basic calculation skills for the Calculus and Algebra course using a qualitative approach. A diagnostic test consisting of ten short-answer questions was administered at the beginning of the semester to assess fundamental arithmetic and elementary algebra skills, including numerical operations, algebraic manipulation, equation solving, and symbolic interpretation. The data were analysed using deductive qualitative content analysis, guided by a coding framework adapted from the Calculus and Algebra course syllabus and commonly recognized prerequisite mathematical competencies. Students' written responses were examined across four content domains. The findings indicate that students' prerequisite basic calculation skills are largely unstable and inconsistently applied. While some students demonstrated surface-level familiarity with basic procedures, many exhibited partial understanding, conceptual misunderstandings, or an inability to initiate appropriate solution strategies. Blank responses further suggested limited conceptual readiness and confidence. Overall, students' prior knowledge was fragmented, with a strong reliance on memorized procedures rather than conceptual understanding. This research highlights substantial gaps in prerequisite basic calculation competencies as well as underscores importance of early diagnostic assessment and targeted foundational reinforcement to improve students' readiness for learning Calculus and Algebra in the polytechnic context.

Keywords — **Basic, Calculation, Calculus, Content, Diagnostic.**

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I. INTRODUCTION

Calculus and Algebra is a core mathematics course offered in Malaysian polytechnics, particularly within science, engineering, and technology-based diploma programmes[1]. The course is essential for providing learners by providing fundamental comprehension of mathematics required for subsequent technical and analytical courses. Successful engagement with Calculus and Algebra requires students to possess sound prerequisite basic calculation skills, including numerical operations, algebraic manipulation, factorisation, and the ability to solve linear equations.

In the polytechnic context in Malaysia, students enrolled in Calculus and Algebra come from

diverse educational backgrounds and demonstrate varying levels of mathematical preparedness. This diversity is especially evident among students who are required to repeat the course. Despite prior exposure to mathematics at the secondary school level and during earlier semesters, some students continue to experience difficulties in mastering fundamental concepts and procedures.

These challenges may hinder their ability to cope with the cognitive demands of the course and affect overall academic progression. Teaching and learning practices in polytechnics often operate under the assumption that students entering Calculus and Algebra have already acquired essential basic calculation skills[2], [3]. Consequently, limited instructional time is allocated to revisiting foundational concepts. When students' prior knowledge is weak or fragmented, this assumption can result in learning gaps that persist throughout the course. Without early identification of these gaps, lecturers may find it challenging to design appropriate instructional strategies that address students' actual learning needs.

Diagnostic assessment offers a practical approach to identifying students' readiness at the beginning of a course[4]. However, conventional assessments in mathematics education frequently rely on quantitative scores, which may not adequately capture the nature of students' understanding or the specific misconceptions underlying their errors. In the context of Malaysian polytechnics, there is limited qualitative evidence that examines how students interpret and apply basic calculation concepts when responding to mathematical tasks.

Therefore, this study seeks to explore students' prerequisite basic calculation skills for the Calculus and Algebra course in Malaysian polytechnics through a qualitative lens. By employing deductive qualitative content analysis of students' written responses to a diagnostic test, The study seeks to identify variation of understanding, misconceptions, and procedural difficulties. The results are anticipated to offer significant guidance for lecturers in planning targeted instructional support and strengthening students' foundational readiness for learning Calculus and Algebra.

II. PROBLEM STATEMENT

Calculus and Algebra is a foundational course in Malaysian polytechnic institutions, requiring students to possess stable prerequisite basic calculation skills such as numerical operations, algebraic manipulation, and equation solving. These foundational skills are essential for students to meaningfully engage with higher-level mathematical concepts and to progress successfully through the curriculum. However, a persistent challenge observed in the Calculus and Algebra course is the presence of students who continue to experience difficulties despite prior exposure to the subject.

Existing instructional practices often assume that students entering the course have already mastered essential basic calculation skills. As a result, lecturers may proceed directly to advanced topics without systematically identifying students' prior knowledge gaps. When such gaps remain undetected, students may struggle to follow instruction, apply concepts accurately, and develop confidence in mathematical problem solving, ultimately affecting their academic performance and retention[5], [6].

Although diagnostic assessments are commonly used to identify learning difficulties, many studies rely heavily on quantitative test scores, which provide limited insight into the nature of students' misunderstandings and procedural errors. There is a lack of in-depth qualitative evidence that examines how students' reason through basic calculation tasks and where breakdowns in understanding occur, particularly among second-semester students enrolled in Calculus and Algebra courses.

Therefore, there is a need for a qualitative investigation that explores students' prerequisite basic calculation skills through an analysis of their written responses. By employing deductive qualitative content analysis, this study seeks to uncover patterns of understanding, misconceptions, and procedural difficulties that are not readily captured through numerical scores alone. Such insights are crucial for informing targeted instructional strategies and remedial support aimed at strengthening students' foundational

mathematical readiness for Calculus and Algebra learning.

III. METHODOLOGY

This study adopted a qualitative research design using deductive qualitative content analysis to examine students' prior knowledge in prerequisite basic calculation skills for the Calculus and Algebra course[7], [8]. A qualitative approach was deemed appropriate as the study aimed to explore patterns of understanding, misconceptions, and procedural difficulties reflected in students' written responses, rather than to measure performance quantitatively. This study adopted a qualitative research design using deductive qualitative content analysis to examine students' prior knowledge in prerequisite basic calculation skills for the Calculus and Algebra course.

The instrument used in this study was a diagnostic test developed by the researcher to assess students' prerequisite basic calculation skills required for learning Calculus and Algebra. A diagnostic test is a short assessment administered at the beginning of a course to identify students' existing mathematical strengths and weaknesses. In this study, the use of a diagnostic test is justified as it allows the researcher to determine students' initial competency levels in fundamental calculations before formal instruction begins [4], [9]. This information is essential for understanding students' readiness for higher-level mathematical concepts and for ensuring that subsequent learning interventions and analyses are based on an accurate baseline of students' prior knowledge. The test consisted of ten short-answer questions covering fundamental arithmetic and elementary algebra concepts, including rounding numbers, working with fractions, algebraic manipulation, factorisation, evaluation of roots, and solving linear equations.

As the instrument was developed and adapted from the Calculus and Algebra course syllabus used in Malaysian polytechnic institutions and informed by foundational mathematics competencies commonly identified in the literature as prerequisites for calculus learning, thus to establish content validity, the test items were reviewed by subject-matter experts in mathematics education to evaluate their relevance, clarity, and alignment with the intended learning prerequisites [3], [10]–[12]. Feedback from the experts was used to refine the wording and structure of the items prior to administration. Given the diagnostic and qualitative nature of the study, the instrument was not intended for psychometric measurement but for eliciting students' reasoning and understanding.

The diagnostic test was administered at the beginning of the semester before formal instruction in Calculus and Algebra commenced. Students completed the test individually under supervised conditions. Written responses were collected for qualitative analysis to ensure that students' original work and reasoning were preserved.

IV. ANALYSIS

The data were analysed using deductive qualitative content analysis to examine students' prerequisite basic calculation skills required for learning Calculus and Algebra. This approach was selected to enable an in-depth interpretation of students' written responses and to identify patterns of understanding, misconceptions, and procedural difficulties that may not be evident through numerical scores alone[7]. The deductive coding framework was adapted from the prerequisite mathematical competencies outlined in the Calculus and Algebra course syllabus and supported by foundational mathematics topics commonly required for calculus learning, as documented in the literature[13]. The framework was further informed by the content domains assessed in the diagnostic test, including numerical operations, algebraic manipulation, factorisation, evaluation of roots, and solving linear equations.

Each student response was read repeatedly and coded according to the level of understanding demonstrated. Responses that showed correct reasoning and appropriate application of procedures were interpreted as reflecting clear conceptual understanding. Responses that indicated awareness of the underlying concept but contained incorrect or incomplete procedures were categorised as partial understanding. Responses that demonstrated

incorrect concepts or the use of inappropriate strategies were classified as misunderstandings.

Several student responses provided no evidence of understanding, as indicated by blank answer spaces for selected items. In particular, some students left questions related to algebraic manipulation and factorisation unanswered, suggesting an inability to initiate an appropriate solution strategy. The absence of any written attempt reflects not only procedural difficulty but also limited confidence or conceptual readiness to engage with the task[14], [15]. Responses that were blank, irrelevant, or did not meaningfully address the task were therefore categorised as showing no evidence of understanding. Following the initial coding, responses were compared across students and test items to identify recurring patterns and common difficulties. Similar misconceptions and procedural breakdowns were grouped into broader themes related to students' prerequisite mathematical readiness.

Particular attention was given to how students interpreted mathematical symbols, applied basic rules, and handled multi-step calculations. The analysis focused on explaining how weaknesses in basic calculation skills could contribute to difficulties in engaging with more advanced calculus concepts. These qualitative insights formed the basis for discussing instructional implications and the need for targeted remedial support

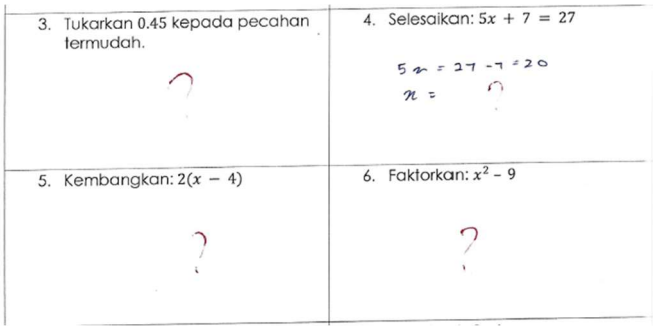

Fig. 1 Example of student responses showing blank answers for items related to algebraic manipulation and factorisation, indicating no evidence of understanding

V. DISCUSSION

This study examined students' prerequisite basic calculation skills for the Calculus and Algebra course through deductive qualitative content analysis of their written responses to a diagnostic test. The findings indicate that students' foundational mathematical knowledge is insufficient, unstable, and inconsistently applied, despite some surface-level familiarity with fundamental arithmetic and algebraic concepts[14], [16]. This suggests that exposure to prior mathematics content has not translated into the secure prerequisite understanding required for successful engagement with Calculus and Algebra.

Across the four content domains, numerical operations, algebraic manipulation, equation solving, and symbolic interpretation, students' responses consistently reflected partial understanding and conceptual weaknesses rather than mastery. Although many students were able to recognise the type of mathematical task presented, they frequently failed to apply appropriate procedures accurately and coherently[17]–[20]. These difficulties became more pronounced when tasks required multi-step reasoning or the transfer of basic rules to unfamiliar contexts, indicating fragile prerequisite knowledge rather than isolated errors. The use of conceptual domains as an analytical framework (refer Table I) enabled a systematic examination of these foundational weaknesses.

TABLE I
CONTENT DOMAINS

Content Domain	Related Test Items	Skill Focus
Numerical operations	Rounding, fractions, integers, order of operations	Accuracy in basic numerical calculations
Algebraic manipulation	Expansion and factorisation	Application of algebraic rules
Equation solving	Linear equations	Transposition and maintenance of equality
Symbolic interpretation	Roots and algebraic expressions	Interpretation of mathematical symbols

In the domain of numerical operations, students' responses revealed inconsistent application of basic rules related to place value, fraction equivalence, and order of operations. While some students recalled relevant procedures, their execution often lacked accuracy and conceptual justification. This reliance on surface-level recall, rather than

conceptual understanding, indicates that even the most fundamental numerical skills critical prerequisites for calculus remain weak at the pre-calculus stage[12], [21]. Similarly, in algebraic manipulation, students generally recognised tasks involving expansion and factorisation but frequently applied incorrect strategies. Misuse of distributive rules and persistent sign errors suggest that algebraic principles were memorised without being meaningfully understood. Such limited symbolic fluency reflects a lack of prerequisite algebraic competence, which is essential for engaging with calculus expressions, functions, and transformations.

Analysis of equation-solving items further revealed deficiencies in students' understanding of equality and systematic problem-solving processes[21], [22]. Many students struggled to maintain balance during transposition and simplification, and some appeared to confuse simplifying expressions with solving equations[23], [24]. These patterns point to a weak conceptual foundation in equation solving, a core prerequisite skill for calculus topics such as limits, derivatives, and integrals. Difficulties were also evident in symbolic interpretation, particularly in items involving roots and algebraic expressions. Students' responses frequently relied on memorised procedures without demonstrating an understanding of the meaning of mathematical symbols.

This inability to interpret symbols independently indicates weak foundational mathematical literacy, which undermines students' capacity to engage with the abstract symbolic language of calculus. Across all content domains, several cross-cutting themes emerged that further underscore the lack of prerequisite basic calculation skills. Students' prior knowledge was fragmented, consisting of isolated procedural fragments that were not coherently integrated[16], [25]. Many responses demonstrated procedural attempts without conceptual reasoning, reflecting a reliance on rote methods rather than understanding. Moreover, students frequently experienced breakdowns when required to apply basic rules beyond familiar or rehearsed contexts. Collectively, these patterns indicate that students are not adequately prepared to engage with higher-level Calculus and Algebra concepts.

Overall, the qualitative content analysis highlights significant gaps in students' prerequisite basic calculation skills, which pose a substantial barrier to successful learning in Calculus and Algebra. The findings emphasise the need for early diagnostic identification and targeted foundational reinforcement to address these weaknesses. Strengthening prerequisite numerical and algebraic competencies is essential to support students' readiness, progression, and long-term success in Calculus and Algebra within the polytechnic context.

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