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Challenges faced by first-year university students in learning calculus

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ABSTRACT

This study examines the calculus learning experiences of first-year university students in a multilingual classroom in the Kurdistan Region of Iraq (KRI), with a particular focus on students from diverse regional and educational backgrounds. A purposive sampling method was used to select 23 students enrolled in a foundational calculus course, including two students from central Iraq and 21 from the KRI. The study aimed to explore performance and behavioral differences in classroom engagement, particularly in response to abstract mathematical concepts such as limits. Data were collected using a structured classroom observation checklist and field notes maintained over twelve instructional sessions. The observation rubric included behavioral indicators such as participation, engagement, peer interaction, and visible confusion. A quantitative content analysis approach was employed, utilizing Likert-scale ratings to convert qualitative observations into numerical data for comparison. Descriptive and nonparametric statistical methods, including time series plots, were employed to visualize and analyze patterns in student behavior over time. The findings revealed stark differences in engagement and confusion levels between the two student groups, attributable to disparities in prior learning experiences, language proficiency, and cultural learning norms. These insights contribute to our understanding of how regional educational inequalities and linguistic diversity impact mathematics learning. The study recommends aligning the curriculum across regions and implementing bridging courses, as well as culturally responsive pedagogies, in multilingual settings. Limitations and directions for future research are also discussed.

Keywords: calculus, challenges, first-year, students, university

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INTRODUCTION

The education system in Iraq is divided into two categories: the first for the northern region, specifically the Kurdistan Region of Iraq (KRI), and the second for the central and southern parts, including Baghdad. These two divisions vary in governance, administration, educational curricula, content, language of instruction, examinations, assessments, higher education, international engagement, policies, reforms, school infrastructure, and teacher training, among other key variables (Mohammed et al., 2021; World Bank, 2021). The KRI has its autonomous education system, which is overseen by the Ministry of Education and the Ministry of Higher Education and Scientific Research of the Kurdistan Regional Government (KRG). In contrast, the southern region of Iraq operates under a centralized education system, managed by the Federal Ministry of Education and the Ministry of Higher Education and Scientific Research in Baghdad (ACAPS, 2020).

The KRI has its own regional curriculum that emphasizes Kurdish history, culture, and identity, focusing on secular content and regional heritage (Rohde, 2014). In contrast, the southern region of Iraq follows a standardized national curriculum that prioritizes a pan-Iraqi identity, the Arabic language, and Islamic studies (Al-Husseini, 2015). In the KRI, the primary language of instruction is Kurdish. Arabic is taught as a second language, while English is used in private or international schools (KRG Ministry of Education, 2019). In the southern region of Iraq, Arabic is the primary language of instruction, with Kurdish used only in areas where Kurds form the majority (Shanks, 2018).

The KRI administers its own regional examinations, including the KRG-specific baccalaureate exam. The southern region, on the other hand, utilizes federal baccalaureate and national assessment systems (World Bank, 2021). The KRI is more open to international education initiatives and reform projects and has greater interaction with global educational organizations, whereas the southern region of Iraq has limited internationalization due to instability and bureaucratic constraints (UNICEF, 2018). In terms of educational reforms, the KRI has focused on modernization and decentralization, including pilot projects in digital education (Vernez et al., 2016). In contrast, reform efforts in the southern region of Iraq have been sporadic, moving at a slower pace, with limited digital integration (World Bank, 2021).

In terms of school resources, the Kurdistan region has better-maintained schools with newer facilities, improved access to electricity, the internet, and sanitation, along with a growing number of private and international schools. Class sizes are generally smaller, with a focus on maintaining manageable student-to-teacher ratios (Vernez et al., 2016). In contrast, many schools in southern Iraq face overcrowded classrooms, poor infrastructure, limited technology, and a lack of basic amenities, especially in rural and conflict-affected areas (UNICEF, 2018; World Bank, 2021). Pre-service teacher training in the Kurdistan region included modern pedagogy and an emphasis on critical thinking. Non-governmental organizations and international partners support in-service teacher professional development training (World Learning, 2019). In contrast, pre-service teacher training in southern Iraq follows a traditional content-heavy approach. In-service training for teachers is often sporadic and relies on outdated methods, with limited opportunities for professional development due to security concerns and funding issues (Al-Husseini, 2015).

In the Kurdistan region, higher education institutions are overseen by the KRG, and there has been notable growth in private universities, as well as collaborations with international institutions (KRG Ministry of Higher Education, 2020). In contrast, universities in the southern region of Iraq are managed by the Federal Ministry, which grants them less institutional autonomy and fewer opportunities for international partnerships (Zipoli et al., 2021).

Educational curricula, multilingual and cultural differences, can significantly impact how students comprehend and articulate mathematical concepts, particularly those that are abstract, such as those encountered in calculus. For instance, using Kurdish as the language of instruction can influence how students process and retain mathematical terminology compared to those learning in Arabic, particularly when there is a lack of alignment between the language and instructional materials (Kirkpatrick, 2017). Additionally, research indicates that multilingual students may encounter specific challenges in mastering subjects like calculus due to code-switching and inconsistencies in terminology (Adler, 2001).

Calculus is a critical foundation for higher mathematics, often regarded as a gateway to advanced studies in science, technology, engineering, and mathematics (STEM). It is essential for understanding continuous change and modelling real-world situations. However, it presents significant challenges for first-year university students. Research has pinpointed various barriers that contribute to students' struggles with calculus. One major hurdle is the lack of conceptual understanding; many students arrive at university prioritizing procedural skills but lacking a deep understanding of mathematical reasoning (Alam, 2020; Collins et al., 2020). Concepts like limits, derivatives, and integrals can be particularly challenging for students, who may find these abstract ideas quite different from the arithmetic and algebraic methods emphasized in high school (Orton, 1983). The transition from concrete operations to abstract thinking can be overwhelming for those unfamiliar with higher-level mathematics.

Language and notation also emerge as significant obstacles. Many students are not accustomed to the symbolic representations and precise terminology used in calculus, which can lead to confusion before they attempt to solve problems (Mainali, 2021). This issue can become even more pronounced in situations where calculus is taught in a second language, such as when non-native English speakers are instructed in English (Ling & Mahmud, 2023).

Moreover, emotional factors like mathematics anxiety, low self-efficacy, and past negative experiences with mathematics can significantly impede student performance (Ramirez et al., 2013; Zakaria & Nordin, 2008). Traditional teaching methods that emphasize rote memorization and passive learning, rather than inquiry-based learning and real-world application, often exacerbate these emotional challenges (Stanberry, 2018; Hammoudi, 2020).

Another concern is the misalignment between secondary and tertiary education curricula. Students transitioning from high school frequently find university-level calculus to be unfamiliar and challenging, particularly because it requires a higher level of abstraction and self-direction (Rešić et al., 2012). This issue can be particularly pronounced in areas where the quality and focus of secondary mathematics education vary significantly. Students from less-resourced schools may not have been exposed to essential foundational concepts, putting them at a disadvantage compared to their classmates (Koch & Herrin, 2006).

Instructional methods and curriculum design play a crucial role in promoting student engagement. Traditional lecture-based teaching, limited opportunities for formative assessment, and inadequate use of visual aids or technology can disengage students and hinder meaningful participation (Mesa, 2010). On the other hand, research indicates that active learning strategies, such as collaborative problem-solving, conceptual discussions, and real-world applications, can enhance students' understanding and retention of calculus concepts (Freeman et al., 2014; Stanberry, 2018). Sadly, the lecture method, where instructors speak and students take notes, remains the most prevalent form of instruction in many universities and colleges worldwide (Jaani, 2022).

Private universities in the KRI enroll students from diverse educational, geographic, and cultural backgrounds, primarily from the Kurdish region, as well as individuals from other parts of Iraq and neighboring countries. English is the main language of instruction, and proficiency is emphasized. However, the challenges faced by first-year students in learning calculus at these universities have not been thoroughly researched. This issue is particularly significant in the context of ongoing educational reforms and the uneven distribution of resources in Iraq. By identifying key obstacles and linking them to systemic and instructional factors, the study aims to inform effective teaching strategies and curriculum designs that enhance student success in calculus. The research questions will focus on these challenges:

1. What specific challenges do Iraqi first-year civil engineering students face in learning the calculus course?
2. How might university instructors address students' challenges in learning calculus?

LITERATURE REVIEW

The Importance of the Teaching Process in Calculus Education

The teaching process is crucial in shaping student outcomes in calculus. Effective instruction in this foundational subject has a significant impact on students' conceptual understanding, procedural fluency, and problem-solving skills. Calculus is not just a technical subject; it represents the mathematical language of change and serves as a gateway to advanced studies in STEM fields. Research indicates that students' performance in calculus often predicts their persistence in science and engineering programs (Bressoud et al., 2015; Ellis et al., 2014).

Teaching strategies such as active learning, formative assessment, and conceptual scaffolding are associated with higher retention and achievement rates. When calculus instruction emphasizes conceptual understanding and mathematical reasoning rather than rote procedures, student learning deepens and becomes more transferable (Laursen & Rasmussen, 2019). In contrast, teacher-centered methods often result in superficial learning, increasing the risk of failure and withdrawal (Rasmussen & Ellis, 2013).

Link Between the Teaching Process and Calculus Outcomes

The relationship between teaching practices and success in calculus is well-established. For example, the calculus concept inventory has demonstrated that students' conceptual understanding improves in direct relation to the level of instructional interaction and clarity (Epstein, 2013). Additionally, the Mathematical Association of America (MAA) highlights that success in calculus depends more on teaching methods than on content alone. They note that instructor engagement and inclusive teaching practices significantly enhance learning outcomes (MAA, 2015). Instructors who adapt to students' backgrounds, experiences, and skill levels, especially in introductory calculus, report higher classroom engagement and lower dropout rates. Instructional interventions such as just-in-time reviews, differentiated pacing, and the use of real-world applications are effective strategies for supporting diverse learners (Kim et al., 2021).

Operational Definition of Challenges in Learning Calculus

In this study, "challenges in learning calculus" are defined as obstacles that impede students' understanding of concepts, their ability to perform calculations, and their emotional engagement with the material. These challenges can be categorized into three groups:

(1) cognitive,

(2) linguistic, and

(3) affective and cultural.

Cognitive challenges refer to difficulties in understanding abstract concepts, such as limits, derivatives, and integrals, often stemming from weak mathematical foundations. Linguistic challenges arise from insufficient proficiency in academic language, which affects students' comprehension of terminology and problem statements. Affective and cultural challenges include feelings of anxiety, a lack of confidence, and a disconnect between classroom norms and students' cultural backgrounds.

The framework for this analysis is based on constructivist learning theory, which emphasizes how learners actively construct knowledge through interactions with instructors, peers, and their contextual environment (Vygotsky & Cole, 2018).

Cultural Backgrounds and Calculus Learning Challenges

Students' cultural backgrounds significantly influence their experiences in learning calculus. Norms surrounding authority, communication, and learning styles shape how students engage with the material and their instructors. For example, students from high power-distance cultures may be less likely to ask questions or seek help, which can limit their participation in active learning environments (Hofstede, 2001). In the KRI, as in many multilingual and multicultural academic settings, students often struggle to connect their previous educational experiences with the expectations of calculus courses taught in English.

Many Iraqi students encounter linguistic difficulties while studying in KRI. Language barriers remain a significant issue, particularly for Arab students entering Kurdish universities (KRG Ministry of Education, 2019). Since English is the primary language of instruction in most private institutions, students with limited English proficiency may face significant challenges due to the technical terminology associated with calculus. For example, students may struggle to communicate and understand calculus concepts taught in English. These difficulties also manifest in various assessments, such as quizzes, chapter tests, midterm tests, and final examinations, leading to undesirable outcomes.

Research indicates that culturally responsive pedagogy can help overcome these obstacles by integrating students' cultural knowledge, adapting communication styles, and validating various problem-solving methods (Gay, 2018; Hammond, 2015). Furthermore, studies show that students from underrepresented or minority groups frequently lack access to rigorous mathematical preparation, which exacerbates challenges in advanced topics such as calculus (Leyva, 2017). When instructors do not acknowledge these cultural and educational disparities, achievement gaps tend to widen.

Research Gaps

Over the past two decades, the KRI has witnessed a substantial increase in student enrolment in higher education institutions (Atrushi & Woodfield, 2018). This rise has sparked a growing interest in identifying effective strategies to support students in achieving academic success during their university studies. Understanding the factors that predict student performance in calculus is crucial for improving educational practices and theoretical frameworks.

Johns (2020) found that self-regulatory skills predicted students' final calculus grades at Midwestern University in the United States. Hurdle et al. (2022) found that the timing of the calculus course may affect students' achievement at a southeastern university in the United States. In India, Alam (2020) found that teaching methods disconnected from real-life contexts, combined with the state of calculus education in secondary schools, contributed to low academic achievement in calculus courses at universities and colleges. Similarly, Duran et al. (2022) found that active learning approaches lead to higher effect sizes on undergraduate students' calculus grades compared to traditional lecture-based methods in the United States.

Despite the wealth of research available on calculus learning in higher education across various global contexts, a substantial gap remains in understanding the unique challenges faced by students enrolled in calculus courses at Iraqi universities. Most existing research tends to generalize across different contexts without considering the regional nuances. This study aims to fill that gap by exploring the interconnected roles of instructional methods, cultural dynamics, and language proficiency in shaping calculus outcomes for students in the KRI. The goal is to provide evidence-based recommendations for improving calculus pedagogy and student achievement through more inclusive, adaptive, and culturally sensitive teaching strategies.

Table 1. Specific behavior scoring rubric

Specific behaviors	Performance ratings				
	1	2	3	4	5
Participation	Participated or raised hand once during the lesson	Participated or raised hand twice during the lesson	Participated or raised hand three times during the lesson	Participated or raised hand four times during the lesson	Participated or raised hand more than four times during the lesson
Engagement	Not focused most of the time; rarely seen taking notes	Occasionally focused; seen taking notes once or twice	Mostly focused with some notetaking	Focused most of the time; engaged and frequently took notes	Entirely focused throughout the lesson; consistently took notes
Confusion	Frequently appeared bewildered; needed constant help	Often appeared confused; asked for help more than once	Sometimes confused; sought clarification once or twice	Rarely confused; generally worked independently	No signs of confusion; showed full confidence throughout
Peer interactions	Did not interact with peers	Minimal interaction with peers	Occasionally participated in group work or asked for peer help	Actively engaged in group activities; some peer assistance	Regularly collaborated and both sought and provided peer help
Instructor-student interactions	Never asked questions or responded to the instructor	Asked or responded once to the instructor during the lesson	Interacted (asked/responded) two to three times during the lesson	Frequently interacted with the instructor; showed good engagement	Very active in communication; made insightful contributions

METHODS

Research Design

This investigation is a cohort mixed-methods observational study in which the researchers observed a defined group of participants over time, collecting both quantitative and qualitative data. Data were collected only from ongoing events at the research site, without assigning any treatments or interventions to the participants. Observation is an empirical research approach that generates descriptions of firsthand, real-world naturalistic occurrences to acquire insight into their defining traits and contextual and time-sensitive properties (Berg, 2004). Naturalistic observation requires researchers to immerse themselves in the field, taking meticulous notes and documenting events, behaviors, and interactions in social settings (Rossman & Rallis, 2017).

Participants Sampling

A purposive sample of 23 students participated in this study. Among them, two students were from central Iraq (Baghdad), while the remaining participants were local students from the KRI. All participants were first-year civil engineering students enrolled in a calculus course at a private international university in Iraq.

Participation was voluntary and based on informed consent. The students were provided with information about the study's objectives, its duration, and the activities involved. They were assured of their anonymity and the confidentiality of the information they provided. Additionally, participants were informed that they could withdraw from the study at any time without needing to provide a reason. They were also reassured that their involvement would not negatively affect their academic performance in any way. This approach aligns with the protocols for obtaining informed consent that is freely and voluntarily given.

Instruments and Validation

Quantitative data were collected using an observation record sheet accompanied by a behavior scoring rubric developed by the researchers. The scoring rubric had performance ratings ranging from 1 to 5 for each specific behavior of interest, with one (1) representing "very low" and five (5) representing "very high". The specific behaviors of interest included participation (raising hands, responding to questions), engagement (focused attention, note-taking), confusion (appearing bewildered, asking for help), peer interactions (group work, requesting peer assistance), and instructor-student interactions (asking questions and receiving comments. The scoring rubric used to record student behavior is outlined in **Table 1**.

Table 2. Cohen's kappa reliability coefficients

Behavior of interest	Measure of agreement
Participation	.776
Engagement	.836
Confusion	.833
Peer interactions	.872
Instructor-student interactions	.780

The observation record sheet included elements such as the week number, student pseudonym, date, specific behaviors of interest, and a section for additional notes, including the calculus concepts covered during the observed session. The observation sheet, along with the scoring rubric, was initially reviewed by two experienced faculty members in mathematics education. Their goal was to assess how well the components of the observation sheet and scoring rubric aligned with the study's objectives and to evaluate the usefulness of the provided categories. Based on their feedback, minor adjustments were made to the scoring rubric to clarify the rating criteria for each behavior of interest.

A pilot observation session was conducted to evaluate the clarity, applicability, and comprehensiveness of the instrument in a real classroom setting involving students outside the targeted group. Two experienced faculty members in mathematics and science education were asked to rate the same students during a mathematics lesson. The evaluations were used to calculate the inter-rater reliability of the scoring rubric for each specific behavior using Cohen's kappa. The Cohen's kappa coefficient was computed in the statistical package for social sciences (SPSS). The Cohen's kappa coefficients for each variable of interest are displayed in **Table 2**. The results show good reliability (0.61–0.80) for participation and instructor-student interactions, and very good/near-perfect reliability (0.81–1) for engagement, confusion, and peer interactions (Dettori & Norvell, 2020).

Qualitative data were collected through field notes and descriptions of student behavior and interactions, specifically focusing on patterns related to challenges and engagement among the Bagdadi and Kurdish freshmen. The instructor who led the observed calculus sessions reviewed the notes at the end of each session to ensure accuracy and consistency.

Data Collection Procedure

We conducted general briefings within the mathematics and science department and obtained written consent from the departmental head. Other faculty members involved in teaching the calculus course were also informed, and we secured their approvals as well. The calculus instructor for the targeted group was asked to suggest his preferred days and times for the observations. Observations took place twice a week, on Mondays and Wednesdays, for a total of six weeks, comprising 12 class sessions. Students were invited to participate, with a clear communication that their involvement was voluntary and that their identities would remain confidential in any research publications. They signed informed consent forms. The students were assigned codes to ensure their anonymity. The two students from central Iraq were designated as C1 and C2, while those from the Kurdish region were labelled K1, K2, K3, and so on up to K21.

Before the observations, we held a briefing as researchers to agree on what to observe, how to use the scoring rubric, and what to include in the field notes. Observations were conducted during regular calculus class sessions without any interference from the observer. The observer did not participate in the class activities. One of the researchers carried out the observations to ensure consistency in recording and data collection. Although the participants were aware of the observer's presence, they remained undisturbed, as the observer refrained from engaging with the students or the instructor. This approach helped maintain the regular flow of the class. Besides documenting participants' ratings using the observation record sheet, the observer also wrote additional notes about the participants' behaviour patterns to support the ratings. Although there was no specific format for writing the field notes, we agreed that the notes should include descriptions of the calculus concepts presented in the classes.

Data Analysis

Quantitative data were analyzed using time series plots, Friedman's test, and Wilcoxon signed-rank tests, all conducted in SPSS. Time series analysis was appropriate because we collected data over an extended period, allowing us to identify trends and patterns as we transitioned between different aspects of calculus. This method is particularly suitable for data that fluctuates over time. The Friedman test is a non-parametric statistical method comparable to one-way analysis of variance for repeated measures. It examines differences between groups when the dependent variable is ordinal.

In this study, we measured students' behavioral patterns regarding participation, engagement, confusion, peer interactions, and instructor-student interactions on an ordinal scale ranging from 1 to 5. The Wilcoxon signed-rank test was used to perform post-hoc pairwise comparisons, identifying where significant differences occurred following the Friedman test.

Qualitative data, collected through field notes, were analyzed thematically using predetermined themes. These field notes served to complement our observations, provide contextual details to the quantitative ratings, and capture nuances that were not reflected in the numerical data.

Ethical Considerations

The research adhered to ethical standards, with students providing informed consent. It ensured that the information collected from participants would remain anonymous and be treated with the utmost confidentiality. Additionally, the study received ethical approval from the Research Ethics Committee of Tishk International University on November 11, 2023, under Protocol Number 198.

FINDINGS AND DISCUSSION

Observation Ratings

Table 3 displays the evaluation ratings assigned to participants in each category based on the observation criteria, which include five variables: participation, engagement, confusion, peer interactions, and instructor-student interactions. The ratings for participants K1–K21 were combined into a single average rating per category, as similar patterns were observed among this group of students. However, this could not be done for the other group of students (C1 and C2) because their behavioral patterns were different. **Table 3** shows that weeks 1–2 were dedicated to functions, weeks 3–4 to limits, and weeks 5–6 to derivatives. Each of these three calculus concepts thus required two weeks for completion.

While **Table 3** captures the data for the entire observation period, the behavioral patterns of the students are not easily discernible. Further processing of the data is required. Time series plots will display the trends and patterns of each behavioral aspect over the six-week period.

Participation

The time series plot in **Figure 1** shows that KRI students maintained a fluctuating but generally above-average participation rate throughout the observation period. In contrast, two students from central Iraq struggled, falling behind from the second week until the fifth, particularly during the introduction of limits and derivatives. The drop in participation during the third week highlights their difficulties with limits and its terminology. The participation gap between these students and their peers was more pronounced during the limits sessions than during the functions and derivatives sessions, suggesting differences in their prior educational experiences.

However, student C1 demonstrated a steady adaptation and a willingness to contribute, as evidenced by gradual increases in participation rates. This suggests that C1 was gaining confidence and adjusting to the course's language and academic expectations. Thus, student-level characteristics such as self-esteem, ability to adapt, and self-regulation also contributed to the students' participation rates.

The results in **Table 4** for the Friedman test show that the differences in students' participation rates were statistically significant ($2 [2] = 14.6837$, $p < .001$). Higher education instructors should be concerned when some students are less engaged in class activities, as this behavior can indicate underlying challenges that the students may be experiencing. Some students often lack the confidence to discuss their issues with the instructor for various reasons, including a fear of being ridiculed by their peers.

Table 3. Observation recordings

Time	Student	Session date	Participation	Engagement	Confusion	Peer interactions	Instructor-student interactions	Notes
1st week	C1	04/12/2023	4	4	1	5	4	**Functions:** This section includes observations made after providing some basic information (related to pre-calculus) while teaching the first introduction to calculus, the functions lesson.
	C2		4	3	2	4	3	
	K1–K21		5	5	2	4	3	
	C1	06/12/2023	4	3	2	3	4	
	C2		3	3	2	3	4	
	K1–K21		3	4	1	4	3	
2nd week	C1	11/12/2023	4	3	3	4	3	
	C2		4	3	3	4	2	
	K1–K21		5	4	2	4	3	
	C1	13/12/2023	3	4	2	2	3	
	C2		3	4	2	3	4	
	K1–K21		4	4	1	4	2	
3rd week	C1	08/01/2024	1	2	5	3	4	**Limits:** This section includes observations made while teaching the limits lesson, which follows the functions section.
	C2		1	2	5	2	4	
	K1–K21		4	5	1	4	2	
	C1	10/01/2024	2	3	4	3	5	
	C2		2	2	5	3	4	
	K1–K21		5	4	2	3	1	
4th week	C1	15/01/2024	2	2	4	3	4	
	C2		1	2	4	3	3	
	K1–K21		4	4	2	4	4	
	C1	17/01/2024	3	3	3	3	4	
	C2		3	2	4	2	2	
	K1–K21		5	4	1	4	4	
5th week	C1	05/02/2024	3	4	3	4	4	**Derivatives:** This section includes observations made during lessons, during which students, having learned functions and limits, delved into the topic of derivatives and their applications.
	C2		2	3	3	2	3	
	K1–K21		5	4	1	4	4	
	C1	07/02/2024	3	4	2	4	3	
	C2		4	4	2	4	2	
	K1–K21		5	4	1	4	3	
6th week	C1	12/02/2024	5	5	2	4	4	
	C2		3	4	3	3	4	
	K1–K21		4	5	2	5	4	
	C1	14/02/2024	4	4	1	3	3	
	C2		3	2	2	2	4	
	K1–K21		5	4	1	4	5	

Note: 1: Very low, 2: Low, 3: Moderate, 4: High, 5: Very high.

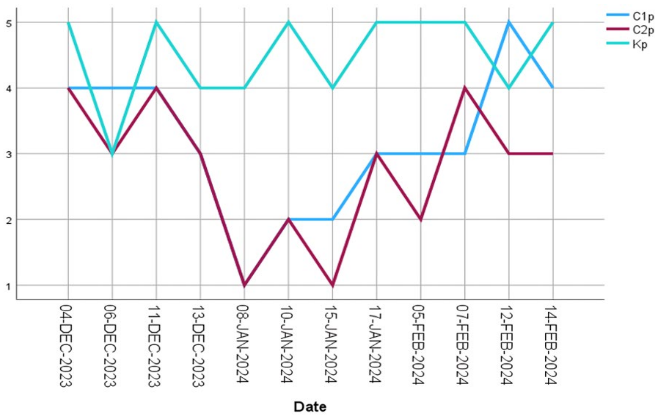

Figure 1. Time series plot of student participation over the six weeks (Source: Authors' own illustration)

The Friedman test indicates that there are differences in participation rates, but it does not specify where those differences lie. To further investigate, post-hoc pair-wise comparisons were conducted using Wilcoxon signed-rank tests, with a Bonferroni correction applied to the significance level (**Table 5**).

Table 4. Friedman test on participation ratings

Ranks	
	Mean rank
C1p	1.83
C2p	1.38
Kp	2.79
Test statistics[a]	
N	12
Chi-square	14.683
Df	2
Asymptotic significance	< .001

[a] Friedman test

The results showed a statistically significant difference in participation ratings between K and C1 ($Z = -2.556, \mathrm{p} = .011$), as well as between K and C2 ($Z = -2.980, \mathrm{p} = .003$). However, there was no statistically significant difference between C2 and C1 ($Z = -1.667, \mathrm{p} = .096$).

Although student C1 demonstrated better adaptation to the learning environment than student C2, analysis of their participation ranks reveals that they had identical participation ratings in six out of the twelve observations. The students K1–K21 outperformed student

Table 5. Wilcoxon signed-rank tests on participation ratings

Ranks		N	Mean rank	Sum of ranks
C2p-C1p	Negative ranks	5[a]	3.60	18.00
	Positive ranks	1[b]	3.00	3.00
	Ties	6[c]		
	Total	12		
Kp-C1p	Negative ranks	2[d]	3.50	7.00
	Positive ranks	10[e]	7.10	71.00
	Ties	0[f]		
	Total	12		
Kp-C2p	Negative ranks	0[g]	.00	.00
	Positive ranks	11[h]	6.00	66.00
	Ties	1[i]		
	Total	12		

[a] C2p < C1p, [b] C2p > C1p, [c] C2p = C1p, [d] Kp < C1p, [e] Kp > C1p, [f] Kp = C1p, [g] Kp < C2p, [h] Kp > C2p, [i] Kp = C2p.

Test statistics[a]	C2p-C1p	Kp-C1p	Kp-C2p
Z	−1.667[b]	−2.556[c]	−2.980[c]
Asymptotic significance (2-tailed)	.096	.011*	.003*

[a] Wilcoxon signed ranks test, [b] Based on positive ranks, [c] Based on negative ranks.
Note: Bonferroni adjusted significance level = .05/3 = .017

Table 7. Wilcoxon signed-rank tests on engagement ratings

Ranks		N	Mean rank	Sum of ranks
C2e-C1e	Negative ranks	6[a]	3.50	21.00
	Positive ranks	0[b]	.00	.00
	Ties	6[c]		
	Total	12		
Ke-C1e	Negative ranks	0[d]	.00	.00
	Positive ranks	7[e]	4.00	28.00
	Ties	5[f]		
	Total	12		
Ke-C2e	Negative ranks	0[g]	.00	.00
	Positive ranks	10[h]	5.50	55.00
	Ties	2[i]		
	Total	12		

[a] C2e < C1e, [b] C2e > C1e, [c] C2e = C1e, [d] Ke < C1e, [e] Ke > C1e, [f] Ke = C1e, [g] Ke < C2e, [h] Ke > C2e, [i] Ke = C2e.

Test statistics[a]	C2e-C1e	Ke-C1e	Ke-C2e
Z	−2.333[b]	−2.456[c]	−2.859[c]
Asymptotic significance (2-tailed)	.020	.014*	.004*

[a] Wilcoxon signed ranks test, [b] Based on positive ranks, [c] Based on negative ranks.
Note: Bonferroni adjusted significance level = .05/3 = .017

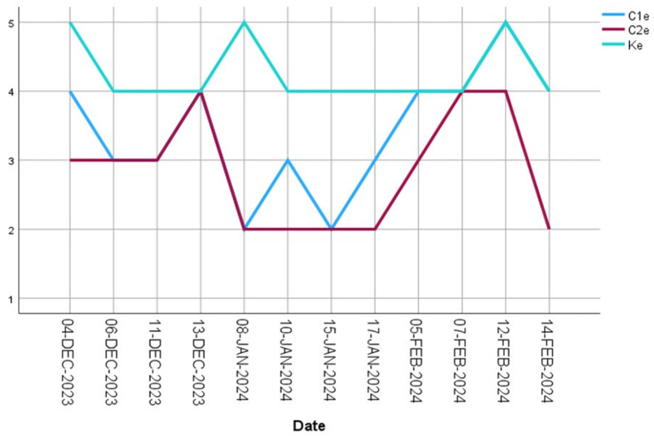

Figure 2. Time series plot of student engagement levels over the six weeks (Source: Authors' own illustration)

Table 6. Friedman test on engagement ratings

Ranks	Mean rank
C1e	1.96
C2e	1.33
Ke	2.71
Test statistics[a]	
N	12
Chi-square	16.545
df	2
Asymptotic significance	< .001

[a] Friedman test

C1 in ten of the twelve participation observations and student C2 in eleven of those observations. The following section examines the observation ratings related to the behavioral aspect of "engagement."

Engagement

Figure 2 shows that all students were highly engaged during the functions and derivatives sessions; however, engagement ratings were below expectations for C1 and C2 during the limits sessions. C1 shows consistent engagement levels during the derivatives sessions, highlighting the student's resilience and growing interest in learning complex calculus content. In contrast, C2's engagement declined mid-course but recovered slightly toward the end, possibly reflecting an initial struggle with limits followed by a better understanding of derivatives.

Students K1 to K21 exhibited high levels of engagement during the functions and limits sessions, always maintaining an engagement rating of at least four. They consistently paid attention and took notes, in contrast to their peers, whose engagement levels varied. This trend may indicate initial difficulties with adapting to English instruction for students C1 and C2.

The Friedman test showed a statistically significant difference in students' engagement levels ($\chi^2(2) = 16.545$, $p < .001$) (**Table 6**). Although taking notes in higher education is not mandatory for students, university instructors should pay attention to those who seldom write notes during lectures. This behaviour may indicate that these students are having difficulty understanding the material or the language of instruction. Many private universities provide instruction in English to accommodate students from various geographical regions worldwide. Some students may struggle to adapt to the private university learning environment if support measures are not implemented, depending on how well they were prepared for university studies during secondary education.

Post-hoc pair-wise comparisons using Wilcoxon signed-rank tests with a Bonferroni correction applied to the significance level showed a statistically significant difference in engagement ratings between K and C1 ($Z = -2.456, p = .014$), as well as between K and C2 ($Z = -2.859, p = .004$) (**Table 7**). However, there was no statistically significant difference between the engagement ratings for C2 and C1 ($Z = -2.333, p = .020$).

Analysis of the engagement ranks shows that C1 and C2 had identical engagement ratings in six out of the twelve observations. K1–K21 outperformed C1 in seven of the twelve engagement observations and student C2 in ten of those observations. C1 was less engaged

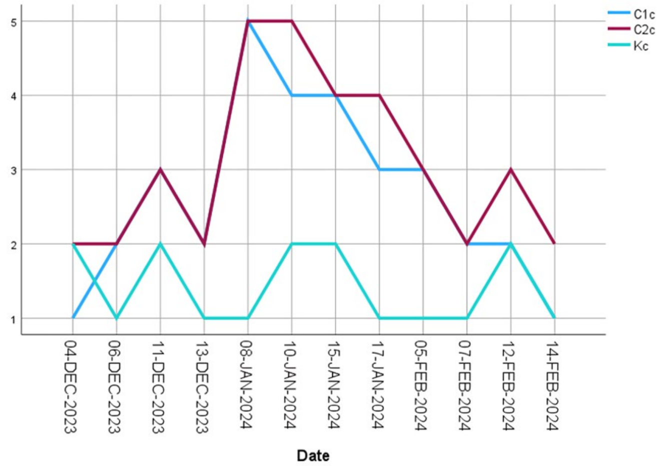

Figure 3. Time series plot of student confusion levels over the six weeks (Source: Authors' own illustration)

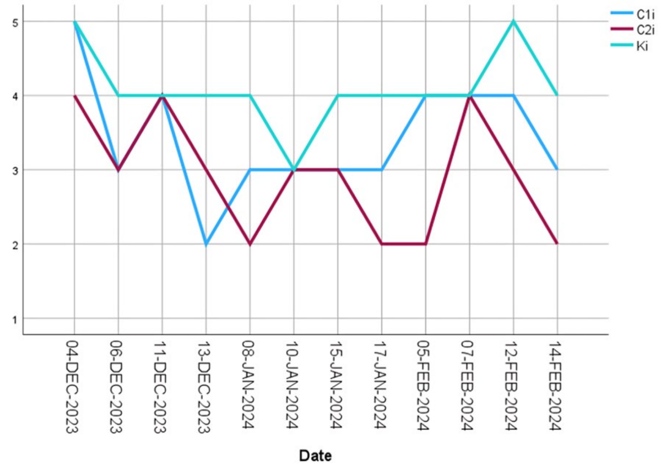

Figure 4. Time series plot of student peer interactions (Source: Authors' own illustration)

Table 8. Friedman test on confusion ratings

Ranks	
	Mean rank
C1c	2.13
C2c	2.67
Kc	1.21
Test statistics[a]	
N	12
Chi-square	16.474
df	2
Asymptotic significance	< .001

[a] Friedman test

Table 9. Wilcoxon signed-rank tests on confusion ratings

Ranks				
		N	**Mean rank**	**Sum of ranks**
C2c-C1c	Negative ranks	0[a]	.00	.00
	Positive ranks	5[b]	3.00	15.00
	Ties	7[c]		
	Total	12		
Kc-C1c	Negative ranks	9[d]	5.78	52.00
	Positive ranks	1[e]	3.00	3.00
	Ties	2[f]		
	Total	12		
Kc-C2c	Negative ranks	11[g]	6.00	66.00
	Positive ranks	0[h]	.00	.00
	Ties	1[i]		
	Total	12		

[a] C2c < C1c, [b] C2c > C1c, [c] C2c = C1c, [d] Kc < C1c, [e] Kc > C1c, [f] Kc = C1c, [g] Kc < C2c, [h] Kc > C2c, [i] Kc = C2c.

Test statistics[a]			
	C2c-C1c	Kc-C1c	Kc-C2c
Z	−2.236[b]	−2.547[c]	−2.989[c]
Asymptotic significance (2-tailed)	.025	.011*	.003*

[a] Wilcoxon signed ranks test, [b] Based on positive ranks, [c] Based on negative ranks.
Note: Bonferroni adjusted significance level = .05/3 = .017

compared to everyone else. The following section examines the observation ratings related to the behavioral aspect of "confusion."

Confusion

C2 demonstrated the highest levels of confusion during the limits sessions, which corresponded with a decrease in participation and engagement levels reported in the preceding analysis (**Figure 3**). K1–K21 maintained low confusion levels across all calculus sessions, indicating either a stronger prior foundation or better adaptation to the course. C1, like C2, initially showed a high level of confusion during the limits sessions but experienced a noticeable decline in confusion by the derivatives phase. Both C1 and C2 were able to clear their confusions through support from the course instructor and interacting with their peers. However, the rate of adaptation was slower for C2 than C1.

The Friedman test showed a statistically significant difference in students' confusion levels ($\chi^2(2) = 16.474$, $p < .001$) (**Table 8**). The mean ranks for C1 and C2 are higher than the mean rank for K1–K21. This result has significant pedagogical implications for instruction in calculus courses at universities. Although students entering university are expected to have mastered the prerequisite knowledge necessary for success, some may require additional support. Therefore, differentiated instruction, tailored to meet the individual learning needs of students, may be necessary even at the university level.

Post-hoc analysis using Wilcoxon signed-rank tests with a Bonferroni correction applied to the significance level showed a statistically significant difference in confusion ratings between K and C1 $(Z = -2.457, \mathrm{p} = .011)$, as well as between K and C2 $(Z = -2.989, \mathrm{p} = .003)$ (**Table 9**). However, there was no statistically significant difference between the confusion ratings for C2 and C1 $(Z = -2.336, \mathrm{p} = .025)$.

An analysis of the confusion ratings reveals that C1 and C2 had identical confusion levels in seven out of twelve observations. C1 exhibited higher confusion levels than K1–K21 in nine of the twelve observations. Additionally, the confusion ratings for C2 were higher than those for K1–K21 in eleven out of twelve observations. The following section will explore the observation ratings related to the behavioral aspect of "peer interactions."

Peer Interactions

The time series plot in **Figure 4** shows that student interaction ratings were higher during the functions and derivatives sessions and lower during the limits sessions. Interestingly, the peer interaction ratings for K1–K21 were higher than those for C1 and C2 in seven of the twelve observations. The high interaction ratings correspond with improved engagement and reduced confusion, emphasizing the importance of peer support in adaptation and learning. During the third to sixth week, C2 exhibited low peer interaction, which may have

Table 10. Friedman test on peer interaction ratings

Ranks	
	Mean rank
C1i	1.92
C2i	1.42
Ki	2.67
Test statistics[a]	
N	12
Chi-square	14.250
df	2
Asymptotic significance	< .001

[a] Friedman test

Table 11. Wilcoxon signed-rank tests on peer interaction ratings

Ranks				
		N	**Mean rank**	**Sum of ranks**
C2i-C1i	Negative ranks	6[a]	4.08	24.50
	Positive ranks	1[b]	3.50	3.50
	Ties	5[c]		
	Total	12		
Ki-C1i	Negative ranks	0[d]	.00	.00
	Positive ranks	7[e]	4.00	28.00
	Ties	5[f]		
	Total	12		
Ki-C2i	Negative ranks	0[g]	.00	.00
	Positive ranks	9[h]	5.00	45.00
	Ties	3[i]		
	Total	12		

[a] C2i < C1i, [b] C2i > C1i, [c] C2i = C1i, [d] Ki < C1i, [e] Ki > C1i, [f] Ki = C1i, [g] Ki < C2i, [h] Ki > C2i, [i] Ki = C2i.

Test statistics[a]			
	C2i-C1i	Ki-C1i	Ki-C2i
Z	−1.897[b]	−2.530[c]	−2.739[c]
Asymptotic significance (2-tailed)	.058	.011*	.006*

[a] Wilcoxon signed ranks test, [b] Based on positive ranks, [c] Based on negative ranks.
Note: Bonferroni adjusted significance level = .05/3 = .017

increased their confusion during the limits and derivatives sessions. This challenge is likely due to linguistic and/or personality barriers.

The Friedman test showed a statistically significant difference in students' peer interaction levels ($\chi^2(2) = 14.250$, $p < .001$) (**Table 10**). The mean rank for K1–K21 is higher than the mean ranks for C1 and C2. This result highlights potential areas for intervention, such as promoting more collaborative learning experiences among university students, addressing linguistic challenges, and breaking cultural barriers that impede interactions and learning.

Post-hoc analysis of peer interaction ratings using the Wilcoxon signed-rank test with a Bonferroni correction applied to the significance level showed a statistically significant difference between K and C1 ($Z = -2.530, p = .011$), as well as between K and C2 ($Z = -2.739, p = .006$) (**Table 11**). However, there was no statistically significant difference between the peer interaction ratings for C2 and C1 ($Z = -1.897, p = .058$). The peer interaction patterns for C1 and C2 were largely similar.

An analysis of the peer interaction rankings indicates that the K1–K21 group outperformed C1 in seven out of twelve observations and student C2 in nine of those observations. Furthermore, the rankings show that C1 and C2 never surpassed K1–K21 in any of the twelve peer interaction observations. In terms of ties, C1 and C2 had the same ratings in five observations, while C1 and K were tied in five observations, and C2 and K only tied in three observations. The primary point emerging from this analysis is that some students faced challenges interacting with their peers during the calculus learning process. The students with low peer interactions exhibited high confusion levels during the limits sessions. While students who come to university are often regarded as adults who can manage their own learning styles, universities can help students who are not accustomed to interacting with peers adjust and get along with others to survive in a university learning environment. The following section examines the observation ratings related to the behavioral aspect of "instructor-student interactions."

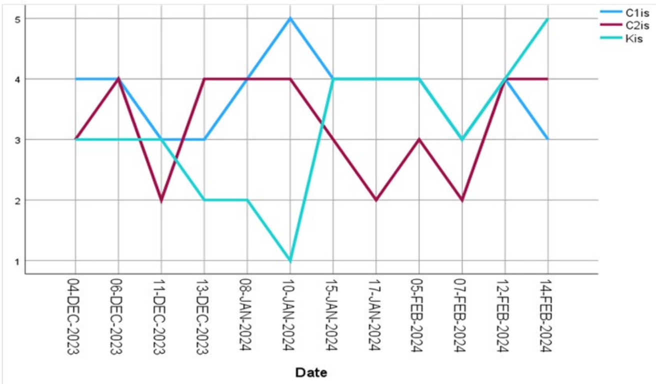

Figure 5. Time series plot on instructor-student interactions (Source: Authors' own illustration)

Table 12. Friedman test on instructor-student interactions

Ranks	
	Mean rank
C1is	2.38
C2is	1.71
Kis	1.92
Test statistics[a]	
N	12
Chi-square	3.722
df	2
Asymptotic significance	.155

[a] Friedman test

Instructor-Student Interactions

C1 exhibited a steady and moderate level of interaction with the instructor, demonstrating a balanced approach to seeking assistance (**Figure 5**). In contrast, students K1–K21 had minimal interaction with the instructor during the functions sessions; however, their engagement gradually increased during the limits and derivatives sessions. This trend suggests that as calculus concepts became more challenging, students' need for instructor support increased. C2 showed spikes in interaction with the instructor during periods of high confusion, particularly during week 3 and week 4, but subsequently reduced this interaction. The reduced interaction with the instructor by C2 is concerning, given that this student exhibited the highest levels of confusion compared to their peers. Probably, it was due to frustration or a reduction in confidence. Alternatively, cultural differences in seeking help from authority figures could explain these trends.

The Friedman test revealed a nonsignificant difference in instructor-student interaction levels ($\chi^2(2) = 3.722$, $p = .155$) (**Table 12**). Therefore, a post-hoc analysis is not needed. The mean ranks are quite close to each other. All students required assistance from the instructor at some point while learning the calculus course. C1 and

C2 required more support from the instructor than K1 through K21 during the functions and limits sessions, which suggests they had deficits in their prior knowledge.

The observed behavior patterns of the students indicate that previous differences in curriculum, language medium, individual student characteristics, and cultural norms significantly influenced their calculus learning trajectories. Although students C1 and C2 had similar backgrounds, they adapted to the new environment in different ways. In contrast, students K1 through K21 displayed a clear growth curve as they gained familiarity and confidence over time. In the following section, we review and summarize the findings from the field notes.

FIELD NOTES

Analysis of field notes confirms the ratings assigned to the students during the observation period. Student C1 raised their hand 3 to 4 times during the functions sessions, 1 to 3 times during the limits sessions, and 3 to 5 times during the derivatives sessions. The student's participation can be categorized as moderate to high during functions, very low to moderate during limits, and moderate to very high during derivatives. Student C2 raised their hand 3 to 4 times during the functions sessions, 1 to 3 times during the limits sessions, and 2 to 4 times during the derivatives sessions. The student's participation rates can be categorized as moderate to high during functions, very low to moderate during limits, and low to high during derivatives. Overall, the participation rates of C1 and C2 appear to follow a similar pattern. Students K1 to K21 raised their hands 3 to 5 times during the functions sessions, 4 to 5 times during the limits sessions, and at least 5 times during the derivatives sessions. These students participated at moderate to very high rates during function sessions, high to very high rates during limits sessions, and very high rates during derivatives sessions. Students K1 to K21 had the highest average participation rates throughout the calculus sessions.

In terms of attention and note-taking, C1 was observed paying attention and taking notes 3 to 4 times during the functions sessions, 2 to 3 times during the limits sessions, and 4 to 5 times during the derivatives sessions. The student's attention and note-taking behaviors were moderate to high during functions sessions, low to moderate during limits sessions, and high to very high during derivatives sessions. C2 was noted paying attention and taking notes 3 to 4 times during the functions session, at most twice during the limits sessions, and 2 to 4 times during the derivatives sessions. The student's attention and note-taking behavior were moderate to high during functions sessions, low during limits sessions, and low to high during derivatives sessions. Students K1 to K21 were observed paying attention and taking notes 4 to 5 times during the functions sessions, 4 to 5 times during the limits sessions, and 4 to 5 times during the derivatives sessions. These students' attention and note-taking behavior were high to very high across all sessions. This shows that K1 to K21 maintained consistent attention and note-taking behavior throughout all sessions.

C1 showed confusion 1 to 3 times during the functions session, 3 to 5 times during the limits sessions, and 1 to 3 times during the derivatives sessions. The student's confusion rates can be categorized as very low to moderate during functions sessions, moderate to very high during limits sessions, and very low to moderate during derivatives sessions. The concept of limits was more challenging for this student than the other two concepts. C2 exhibited confusion 2 to 3 times during the functions sessions, 4 to 5 times during the limits sessions, and 2 to 3 times during the derivatives sessions. The student's confusion rates can be categorized as low to moderate during functions sessions, high to very high during limits sessions, and low to moderate during derivatives sessions. This indicates that the concept of limits was more challenging for student C2 compared to functions and derivatives. In contrast, students K1 to K21 displayed confusion a maximum of two times during the functions sessions, twice during the limits sessions, and twice during the derivatives sessions. The confusion rates of these students are low for all three calculus concepts. Overall, these students experienced the least confusion throughout all the calculus sessions.

C1 interacted with peers 2 to 5 times during the functions sessions, up to three times during the limits sessions, and 3 to 4 times during the derivatives sessions. The student's peer interaction patterns vary from low to very high during functions sessions, moderate during limits sessions, and moderate to high during derivatives sessions. C2 interacted with peers 3 to 4 times during the functions sessions, 2 to 3 times during the limits sessions, and 2 to 4 times during the derivatives sessions. The student exhibits moderate to high peer interaction during functions sessions, low to moderate interaction during limits sessions, and moderate to high interaction during derivatives sessions. Overall, C2 appeared to maintain average interactions with peers across all sessions. K1 to K21 engaged with their peers a minimum of 4 times during the functions sessions, 3 to 4 times during the limits sessions, and 4 to 5 times during the derivatives sessions. The peer interaction rates of these students were high during functions sessions, moderate to high during limits sessions, and high to very high during derivatives sessions. Students K1 to K21 exhibited the highest rates of peer-to-peer interaction overall.

Regarding interaction with the course instructor, C1 interacted with the instructor 3 to 4 times during the functions sessions, 4 to 5 times during the limits sessions, and 3 to 4 times during the derivatives sessions. The student's interaction patterns with the instructor can be classified as moderate to high during functions sessions, high to very high during limits sessions, and moderate to high during derivatives sessions. Notably, the increased interaction between the student and instructor during the limits sessions highlights the need for additional support during this period. C2 interacted with the instructor 2 to 4 times during the functions sessions, 2 to 4 times during the limits sessions, and 2 to 4 times during the derivatives sessions. The student's interaction patterns with the instructor ranged from low to high across all sessions. Students K1 to K21 interacted with the instructor 2 to 3 times during the functions sessions, 1 to 4 times during the limits sessions, and 3 to 5 times during the derivatives sessions. The students' interactions with the course instructor varied from low to moderate during the functions sessions, from very low to high during the limits sessions, and from moderate to very high during the derivatives sessions. Unlike C2, who maintained a moderate level of interaction with the instructor during all sessions, interaction levels with the instructor varied for students K1 to K21 based on the complexity of the concepts. These results coincide with the patterns and trends described in the time series plots.

During the observation, specific areas of difficulty in calculus topics were noted. Under the topic of functions, some students struggled with transformations and function composition. They incorrectly applied shifting and scaling techniques and misjudged the order of transformations, such as when to apply shifting versus scaling.

Additionally, they confused function composition with multiplication. For example, they misinterpreted the composition of functions $(f \circ g)(x)$ as $f(x).\,g(x)$. When learning about trigonometric functions, students often misinterpreted periodic behavior and phase shifts. For example, some students thought that if the period of $f(x) = \sin(x)$ is 2π, then the period of $f(x) = \sin(2x)$ would be $2 \times 2\pi = 4\pi$, which is incorrect. Regarding the phase shift, students misinterpreted $y = \sin(x + \pi/2)$ as a horizontal translation of the graph of $\sin(x)$ by $\pi/2$ units to the right, instead of to the left. Fortunately, the instructor was knowledgeable about technology and utilized digital tools such as Desmos and Symbolab to clarify and debunk some of these misconceptions.

During the limits sessions, common issues included the improper application of limit laws, particularly with indeterminate forms, as well as understanding the language of the topic. Regarding indeterminate forms ($0/0$ or ∞/∞), most students thought these are just "undefined" rather than signaling the need for further algebraic simplification or application of L'Hôpital's rule. Additionally, there was a common misconception that if a function is not defined at a specific point, it cannot have a limit, thereby failing to recognize a removable discontinuity. Students were confused by informal terms like 'turns to' and had difficulty understanding more precise language, such as 'approaches' or 'tends toward' in the context of limits. They thought the limit was the value of the function at a point, rather than the value the function approaches as the input gets arbitrarily close to that point. As a result, they faced challenges with one-sided limits. They confused one-sided limits with continuity, incorrectly assuming that left- and right-hand limits must always be equal, even when a function is not continuous at that point. Consequently, students occasionally claimed that the limit does not exist, even when it does.

During the derivatives sessions, students faced several difficulties. They often misinterpreted the graph of the derivative function and were confused about where the derivative does not exist, particularly in cases involving cusps, corners, and vertical tangents. Additionally, there were instances of misapplying the product, quotient, and chain rules. Lastly, students frequently overlooked the importance of simplifying expressions before differentiating.

The instructor was an expatriate Doctor of Mathematics Education from Turkey. His native language was Turkish, and he used English as the medium of instruction according to the university's policies. Having worked in the region for over 20 years, he had also mastered basic Kurdish expressions to facilitate communication with his students. He could switch between English and Kurdish when necessary and received assistance from Kurdish-speaking students when occasional Arabic translations were needed. This support significantly helped to reduce language barriers and linguistic challenges in the calculus course. Additionally, the instructor was tech-savvy, which allowed him to address some misconceptions that students faced, such as those related to translating and scaling graphs of functions, periodicity, and the effects of phase shifts. He utilized lecture notes, PowerPoint slides, digital tools, such as Desmos, Mathway, and simulators to enhance the students' learning experiences.

DISCUSSION

This section discusses the main findings from a study examining the learning of calculus by first-year university students at a private international university in the KRI. The discussion explores the notable disparities observed in student performance and engagement, examines the factors contributing to these differences, such as individual student characteristics and the impact of instructional approaches, and situates these findings within the existing body of literature. Moreover, the section highlights the unique contributions of the study to the existing body of knowledge.

The study revealed significant variations in the learning behaviors of students from central Iraq, specifically those from Baghdad, compared to their counterparts from the KRI. Students from the KRI (designated as K1 through K21) consistently demonstrated elevated levels of participation, active engagement, and collaborative efforts among peers. In stark contrast, the two students from central Iraq (referenced as C1 and C2) exhibited a more inconsistent and generally lower performance across all assessed metrics. This divergence was particularly pronounced during the instruction of limits, a topic often viewed as abstract and linguistically challenging for many students.

One key reason behind the struggles faced by students from central Iraq is their lack of foundational knowledge in calculus concepts, which can be traced back to curricular reductions during their high school education, particularly as a consequence of the COVID-19 pandemic. For instance, the critical concept of limits was entirely excluded from the secondary school curriculum in central Iraq, placing these students at a significant disadvantage as they transitioned to university-level mathematics (Al-Saadi, 2022). Additionally, the university's medium of instruction was English. While the KRI students had prior exposure to learning in English, students from central Iraq encountered considerable difficulties with technical vocabulary and abstract calculus terminology (Adler, 2001; Ling & Mahmud, 2023). Misunderstandings were particularly common with terms such as "approaches" and "tends to," leading to further complications in their comprehension of the concept of limits in calculus.

The behaviors of students C1 and C2 demonstrated limited engagement with peer support and a reluctance to seek help, likely stemming from power-distance cultural norms that discourage questioning authority figures (Hofstede, 2001). One of the students consistently preferred to work independently despite facing evident challenges, which ultimately diminished their opportunities for collaborative and peer-supported learning. Notably, the differences in behavior between C1 and C2 highlighted the influence of student self-regulatory traits on learning outcomes. Over time, C1 demonstrated adaptability, showing increased participation and a reduction in confusion, while C2 continued to struggle with confusion and showed erratic levels of engagement.

The instructor, an experienced educator fluent in English and possessing basic proficiency in Kurdish, employed various digital tools and peer translation strategies to promote students' understanding of calculus concepts. However, his limited ability to effectively communicate with Arabic-only speakers potentially intensified the difficulties experienced by C1 and C2 during instruction. Instructors who are multilingual and can speak their students' native languages may achieve better learning outcomes than those who teach only in English.

The findings of this study resonate with broader global research focused on the challenges of learning calculus. Numerous studies have identified weak secondary education as a contributing factor to difficulties in higher education mathematics (Alam, 2020), highlighting issues such as inadequate conceptual understanding (Rach & Ufer, 2020) and an excessive focus on procedural skills. Additionally, language challenges in mathematics education are well-documented (Adler, 2001; Celik & Kara, 2022). Furthermore, this research supports the increasing consensus that active learning strategies and differentiated instructional methods are significantly more effective than traditional lecture-based approaches in fostering student engagement and understanding (Freeman et al., 2014; Laursen & Rasmussen, 2019).

This study is notable for being among the first to examine calculus learning in Iraq through a lens of regional disparity, specifically addressing the curricular fragmentation between the Kurdistan Region and central Iraq. Employing naturalistic observation over an extended six-week period along with behavioral scoring rubrics has allowed for a nuanced and detailed exploration of student participation and engagement trends. Additionally, the research underscores the importance of instructor multilingualism and technological proficiency in alleviating learning barriers within multilingual educational settings. Through these insights, the study contributes to a deeper understanding of the dynamics of calculus learning in diverse contexts and paves the way for future inquiries into effective instructional practices.

CONCLUSION AND RECOMMENDATIONS

The study underscores the multifaceted challenges faced by students in learning calculus, particularly those from under-resourced or linguistically disadvantaged backgrounds. It calls for a unified and inclusive curriculum, enhanced teacher training, and a shift toward culturally responsive and technologically supported pedagogies to ensure equitable learning opportunities across Iraq.

The findings contribute to broader educational theories such as Vygotsky's sociocultural theory by illustrating the pivotal role of language, peer interaction, and instructional scaffolding in mathematical development. In this context, the data affirm that cognitive development is culturally mediated and dependent on meaningful communication and guided participation. The results also challenge the universality of constructivist approaches that assume a level playing field in learner preparedness and access to prior knowledge. The discrepancies observed between central and KRI students suggest that context-sensitive adaptations to constructivist pedagogy are necessary when dealing with linguistically and culturally diverse populations. Furthermore, these findings support and extend Hofstede's cultural dimensions theory by linking high power-distance behaviors with reduced classroom interaction and limited help-seeking, even in inquiry-based learning environments.

Based on the findings outlined above, we recommend that the Iraqi Ministry of Education reform the secondary school curricula across all regions to introduce a standard core curriculum. This reform should ensure alignment with university requirements and provide aspiring university students with a solid foundation in the fundamentals of calculus. Additionally, international universities should implement measures to support students from diverse backgrounds who may not have mastered the prerequisite knowledge and skills necessary for success at the university level. Introducing mathematics modules taught in local languages in private universities could help facilitate a smoother transition from secondary school to university for speakers of Arabic or Kurdish. Another possible solution is to offer bridge courses. Valuable lessons can be learned from countries such as South Africa, Australia, Singapore, and Canada, where programs exist to address the knowledge and skill disparities between high school and university.

Furthermore, university instructors should be trained to adapt their teaching methods to accommodate the diverse learning needs and individual differences of students. In this regard, the use of digital technologies could serve as an effective intervention strategy. Technology has the potential to provide necessary support and experiences for students from diverse cultural backgrounds who prefer independent learning, thereby helping them succeed (Kurudirek et al., 2024; Taher & Abdul, 2019). Conversely, collaborative learning approaches that encourage peer-to-peer interaction benefit students who prefer group or team learning. On the other hand, students need to receive training on embracing cultural differences and integrating with individuals from diverse backgrounds. This training should be introduced and prioritized at earlier levels of education, long before students reach university. By doing so, we can help students navigate the challenges of collaborative learning at the university level, regardless of their cultural backgrounds and prior educational experiences.

The study focused on only two students from central Iraq, which limits its generalizability. Conducted at one private university in Erbil, the findings may not accurately reflect broader trends across Iraq. Observational methods, while rich in context, lacked triangulation with other data collection methods such as interviews and performance tests. Differences between male and female students were not addressed. Future research should include students from multiple universities and regions to enhance generalizability. Incorporating interviews, surveys, and performance assessments would improve triangulation. Future researchers should examine how gender influences calculus learning behaviors in Iraqi contexts. Studies comparing teaching styles, languages, and digital tools could yield insights into effective instruction. Investigating the impact of remedial or preparatory courses on reducing regional disparities would also be beneficial

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Declaration of interest: Authors declared no competing interest.

Data availability: Data generated or analyzed during this study are available from the authors on request.

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