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THE DISCIPLINE OF DIFFERENTIAL AND INTEGRAL CALCULUS IN ENGINEERING COURSES: OBSERVING THE REALITY AT FEDERAL TECHNOLOGICAL UNIVERSITY OF PARANÁ, PATO BRANCO CAMPUS

A DISCIPLINA DE CÁLCULO DIFERENCIAL E INTEGRAL NOS CURSO DE ENGENHARIA: A REALIDADE OBSERVADA NA UNIVERDIDADE TENOLÓGICA FEDERAL DO PARANÁ CAMPUS PATO BRANCO

LA DISCIPLINA DE CÁLCULO DIFERENCIAL E INTEGRAL EN LOS CURSOS DE INGENIERÍA: OBSERVANDO LA REALIDAD EN LA UNIVERSIDAD TECNOLÓGICA FEDERAL DE PARANÁ, CAMPUS PATO BRANCO

Micheli Cristina Starosky Roloff[1] [0000-0001-5901-6312]

Luis Mauricio Martins de Resende[2] [0000-0003-4151-0843]

Christian Joseph Antoine Mercat[3] [0000-0002-5921-1801]

Juliana Castanon Xavier[4] [0009-0002-8931-2758]

Edinéia Zarpelon[5] [0000-0002-4715-1450]

[1] *Federal Technological University of Paraná, Brazil, micheli.roloff@gmail.com*
[2] *Federal Technological University of Paraná, Brazil, lmresende@utfpr.edu.br*
[3] *Université Claude Bernard – Lyon 1, France, christian.mercat@univ-lyon1.fr*
[4] *Federal Technological University of Paraná, Brazil, julianaxavier@utfpr.edu.br*
[5] *Federal Technological University of Paraná, Brazil, ezarpelon@utfpr.edu.br*

Abstract

This study delves into the Brazilian educational landscape by examining the practical application at the Federal Technological University of Paraná, campus Pato Branco. Throughout the second semester of 2023, four classes of Differential and Integral Calculus 1 were closely monitored, with four professors actively engaging in teaching and facilitating learning. The observation encompassed various teaching activities, including the duration spent by professors at the board, students tackling exercises independently, and whole-class discussions. Moreover, the professors' perspectives were captured through a questionnaire gauging the frequency of specific teaching methods and their perceived efficacy in enhancing student learning outcomes. By shedding light on pivotal elements like time allocation for problem-solving and the potential for student-centered instruction, this research seeks to inspire and guide transformative changes within the Brazilian educational framework, particularly in the realm of Engineering courses.

Keywords: differential and integral calculus, engineering education, teaching strategies, mathematics, undergraduate.

Resumo

Este estudo investiga o panorama educacional brasileiro, examinando a aplicação prática na Universidade Tecnológica Federal do Paraná, campus Pato Branco. Ao longo do segundo semestre de 2023, quatro turmas de

Cálculo Diferencial e Integral 1 foram acompanhadas de perto, com quatro professores envolvidos ativamente no ensino e facilitação da aprendizagem. A observação abrangeu várias atividades de ensino, incluindo a duração gasta pelos professores do conselho, os alunos abordando exercícios de forma independente e discussões em classe inteira. Além disso, as perspectivas dos professores foram captadas através de um questionário aferindo a frequência de métodos de ensino específicos e sua eficácia percebida na melhoria dos resultados de aprendizagem dos alunos. Ao lançar luz sobre elementos fundamentais como a alocação de tempo para a resolução de problemas e o potencial de instrução centrada no aluno, esta pesquisa busca inspirar e orientar mudanças transformadoras dentro do quadro educacional brasileiro, particularmente no âmbito dos cursos de Engenharia.

Palavras-chave: cálculo diferencial e integral, educação em engenharia, estratégias de ensino, matemática, graduação.

Resumen

Este estudio profundiza en el panorama educativo brasileño examinando la aplicación práctica en la Universidad Tecnológica Federal de Paraná, campus Pato Branco. A lo largo del segundo semestre de 2023, se monitorearon de cerca cuatro clases de Cálculo Diferencial e Integral 1, con cuatro profesores participando activamente en la enseñanza y facilitando el aprendizaje. La observación abarcó diversas actividades docentes, incluida la duración de la permanencia de los profesores en la junta, la realización de ejercicios por parte de los estudiantes de forma independiente y debates con toda la clase. Además, las perspectivas de los profesores se capturaron a través de un cuestionario que midió la frecuencia de métodos de enseñanza específicos y su eficacia percibida para mejorar los resultados del aprendizaje de los estudiantes. Al arrojar luz sobre elementos fundamentales como la asignación de tiempo para la resolución de problemas y el potencial de la instrucción centrada en el estudiante, esta investigación busca inspirar y guiar cambios transformadores dentro del marco educativo brasileño, particularmente en el ámbito de los cursos de Ingeniería.

Palabras-clave: cálculo diferencial e integral, educación en ingeniería, estrategias de enseñanza, matemáticas, graduación.

INTRODUCTION

Currently, engineering courses in Brazil primarily consist of foundational training during the first two years, with a high course load in mathematics and physics interspersed with a few introductory engineering subjects. The following three years focus on the specific field of study chosen by the student upon entering the program. Understanding this model, the authors aim in this paper to explore the current model by examining the reality at the Federal University of Technology – Paraná (UTFPR), Pato Branco campus, in the context of the Differential and Integral Calculus course. This research intends to identify which aspects might inspire changes and improvements in the Brazilian engineering course structure.To collect data, classroom observations were conducted, and questionnaires were administered to teachers and students. According to Reis (2011), classroom observation allows for an understanding of the teaching strategies and methodologies used, the activities developed, and the interactions between teachers and students, among other aspects, facilitating improvements in teaching quality and learning. To determine which aspects to observe and what questions should be included in the questionnaires, a literature review was conducted to understand the application of active methodologies in mathematics education within engineering and their impact on the teaching and learning process. Consequently, the observation guide and questionnaires were adapted from the instrument used by Ellis et al. (2014).

1 FEDERAL UNIVERSITY OF TECHNOLOGY – PARANÁ (UTFPR)

UTFPR is an institution with over 100 years of history. Currently, it has 13 campuses, one of which is in Pato Branco, inaugurated in 1993, where it offers 13 undergraduate courses, including 5 engineering programs: Cartographic and

Surveying Engineering, Civil Engineering, Computer Engineering, Electrical Engineering, and Mechanical Engineering. The engineering programs at UTFPR Pato Branco have a curriculum structure organized into four cores. The Basic Core is responsible for subjects in mathematics, physics, chemistry, and humanities, serving as the foundation for the development of other curricular units. The Professional Core encompasses scientific and technical subjects fundamental to engineering education. The Complementary Core includes advanced and elective subjects. Finally, the Practical Core involves the Final Course Project (TCC), the Mandatory Internship, among other activities. The courses have a duration of 10 semesters, with the Basic Core occupying between 30.8% (Civil Engineering) and 34.6% (Electrical Engineering) of the total course load. Subjects from this core are mainly concentrated in the first four semesters of the program.

This study focused on the Engineering programs in Computer, Civil, Electrical, and Mechanical Engineering. It examined the sequence of Differential and Integral Calculus subjects, which includes two units: Calculus in One Real Variable (90 hours and 6 weekly classes) and Calculus in Several Real Variables (60 hours and 4 weekly classes). The exception is the Civil Engineering program, which offers the Calculus sequence in 3 units of 60 hours each: Pre-Calculus, Differential and Integral Calculus 1 (equivalent to Calculus in One Real Variable), and Differential and Integral Calculus 2. The difference primarily lies in discussing Functions content in the Pre-Calculus subject. For analysis purposes, data collection and classroom observations were conducted in the Calculus in One Real Variable and Differential and Integral Calculus 1 subjects due to the number of offered sections, enrolled students, and similarity in syllabi.

1.1 Calculus 1

In the second semester of 2023, UTFPR Pato Branco offered three sections of Calculus in One Real Variable for students in the Computer, Electrical, and Mechanical Engineering programs who had failed the course in previous semesters. Additionally, one section of CDI1 (Differential and Integral Calculus 1) was offered for Civil Engineering students in the afternoon period.

Four instructors taught these courses. Classes took place in classrooms with a capacity of 60 students, large whiteboards, equipped with multimedia projectors, and air conditioning. The class sizes ranged from 23 to 29 students.

Teachers P1 and P2 taught on Mondays, Wednesdays, and Thursdays, between 3:50 PM and 5:30 PM. Professor P3 taught on the same days but from 10:20 AM to 12:00 PM. As for Professor P4, the sessions were held on Mondays and Thursdays, between 3:50 PM and 5:30 PM.

Table 1 shows the instructors and the number of sessions that were observed.

Table 1

Teachers and sessions observed

Teacher	Sessions observed
P1	3
P2	2
P3	5
P4	2

The number of sessions observed varied depending on the availability of the professors to accommodate the first author. Other academic activities, such as evaluations and the course's Academic Week, along with overlapping schedules, also made it challenging to observe a larger number of sessions with professors P1, P2, and P4.

Table 2 summarizes the key characteristics observed during the classes and the average time dedicated to each in minutes, noting that each session totals 100 minutes.

Table 2

Characteristics observed and distribution of time

Teacher	Time at the board	Time answering students	Class-wide discussion	Students working individually	Students working in groups	Use of softwares
P1	37,4	0,7	4,3	34,3	0	12,7
P2	62	1,5	3,5	9,5	0	0
P3	47,2	7,6	0,8	17,4	11,4	0
P4	57,5	6,5	4,5	8	0	0
Average	**51,3**	**4,1**	**3,3**	**17,3**	**2,9**	**3,2**

Teachers P2 and P4 are the youngest in the group, with 3 and 8 years of teaching experience, respectively. Although P2 spends 62% of class time at the board, his interaction with students differs somewhat, as he was in constant dialogue with them, posing questions and engaging in discussions. Professors P1 and P3 have 16 and 18 years of teaching experience, respectively. All the teachers began their classes by reviewing the content from the previous session.

Teacher P1 was the only one to use GeoGebra software and encouraged students to do the same, while Teacher P3 was the only one to ask students to solve exercises in groups. It was observed that when students were asked to solve exercises individually, some of them helped each other, and this was not discouraged. If we combine the time dedicated to students working individually and in groups, Teacher P3 spent 28.8 minutes on this activity and devoted slightly less than half the class time to the board.

Teacher P1 also spent less than half the class time at the board and encouraged students to work on exercises and other activities, indicating an effort to put students at the center of the learning process.

It is worth mentioning that Teacher P3 was the only one to provide supplementary materials on the Moodle platform during the observed sessions.

1.2 Teaching Methodology and Learning According to the Teachers

To complement the observations conducted, the professors were invited to respond to a questionnaire, and the first question addressed the frequency with which certain activities are employed in their CDI1 classes. The response options were: never (1), rarely (2), sometimes (3), often (4), and always (5). Table 3 shows the average of the responses. Activities with a frequency rating between "sometimes (3)" and "always (5)" are among the first ten listed.

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Table 3

Activities developed

Activity	Average (hours)
I answer questions at the board	4,3
I ask if students have questions	4,3
I solve exercises on the board	3,8
Students solve exercises individually	3,5
I hold discussions with the entire class	3,5
I ask a student to explain their reasoning	3,5
Lectures	3,3
I attend to students individually	3,3
I use some mathematical software	3,3
I ask students to solve exercises before class	3,0
Students work in groups	2,8
I recommend supplementary material	2,8
I propose a new problem before covering the content	2,8
Students solve exercises at the board	2,5
I address a real-world problem	2,5
A student explains their reasoning during an assessment	2,5
I provide pre-class material	2,3
A student explains an exercise to their peers	2,0
I use a platform with immediate feedback	1,8
A student gives a presentation to the entire class	1,3
I play a game with the class	1,3

The second question addresses student learning, considering the same characteristics, and asks the professor to identify the five they believe most contribute to improved learning. Table 4 lists the characteristics in descending order.

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Table 4

Students learn better when...

Activity	Average (hours)
Explains an exercise to a classmate	2,5
Teacher solves exercises at the board	2,3
Explains their reasoning	2,3
Asks questions about their doubts	1,8
Solve exercises at the board	1,5
Work in groups	1,3
Explains their reasoning in an assessment	1,0
Solve exercises before class	1,0
Solve exercises individually	0,8
Receives individual attention from the professor	0,8

It is intriguing that the professors identified "explains an exercise to a classmate (2.5)" as the most important activity, yet this activity was not observed during the sessions. "Professor solves exercises at the board (2.3)" and "the student explains their reasoning (2.3)" were also listed as activities undertaken by the professors and were observed during classes, particularly when the professor was working at the board.

2 DISCUSSION

The CDI1 course model developed at UTFPR Pato Branco resembles the model practiced at the Federal Institute of Santa Catarina (IFSC) and the Federal Institute of Catarinense (IFC), where the first author has previously taught. It contrasts with models presented by other authors, such as Gruber et al. (2021) and Hancock et al. (2021) in the United States, and Radzimski et al. (2021) in Canada, which describe a structure where a large class meets in an auditorium followed by smaller sessions for solving exercises. The difference lies in the number of hours dedicated to exercise-solving and the duration of each session.

Analyzing the observed sessions, there's a significant difference in the time dedicated to the board between professors P1 and P3, and P2 and P4. The former two spend less than half of class time at the board, dedicating more time to students working individually or in groups, while the latter two do the opposite. It seems that professors P1 and P3 are trying to place students at the center of the activities, as suggested by Bonwell & Eison (1991, p. 19), who stated, "active learning involves students doing things and thinking about what they are doing."

When the professors were asked about the activities they use in their CDI1 classes, we have "I answer questions at the board (4.3)" in first place, followed by "I solve exercises on the board (3.8)" in third place, and "I lecture (3.3)" in seventh place. These were grouped as the time the professor spends at the board during observations, reflecting the fact that this activity occupies, on average, half of class time, as seen in Table 2.

Activities like "I ask if students have questions (4.3)", the second most mentioned by the professors, "I hold discussions with the entire class (3.5)", and "I ask a student to explain their reasoning (3.5)" in fifth and sixth places, categorized with a frequency between "sometimes (3)" and "always (5)", were observed during the sessions but did not rank among the most observed activities, since asking students questions or holding a discussion does not require much time.

However, the activities "Students solve exercises individually (3.5)", the fourth most mentioned by the professors, and classified with a frequency between "sometimes (3)" and "often (4)", on average occupy 17.4% of class time. Professors P2 and P4 dedicate less than 10% of class time to this activity.

There are also differences between the activities that professors believe contribute to student learning and those they claim to use in their classes. "Explains an exercise to a classmate" and "Solve exercises at the board", identified as the first and fifth most important activities for learning, did not rank among the top 10 activities most commonly used by the professors, and were also not observed during the sessions.

FINAL CONSIDERATIONS

We can observe that it is possible to reduce the time professors spend at the board and increase the time students are working, either individually or in groups. This time dedicated to solving exercises provides some flexibility, particularly in terms of the teaching methodology used, even if it's just during part of the classes, as reported by Bénéteau et al. (2016), Gruber et al. (2021), Hyland et al. (2021), Krause et al. (2021), Ng et al. (2020), Olson et al. (2011), Reinholz (2015), Villalobos et al. (2021), among others.

Activities where students "Explain an exercise to a classmate" and "Solve exercises at the board" could be further explored by professors, especially given their belief in these activities' importance to the learning process, particularly when combined with the activity where a student explains their reasoning. Likewise, activities where students work individually on solving exercises, if converted into group activities, could lead to significant discussions, according to Talbert (2014), potentially leading to real progress towards students becoming lifelong self-regulated learners.

This would align with a more student-centered teaching approach, as recommended by the National Curriculum Guidelines for Undergraduate Engineering Courses (BRASIL, 2019), and as noted by Albalawi (2018), who emphasizes the importance of self-regulated learning and student-centered learning, where students are actively engaged in the learning process, taking on responsibilities that make them lifelong learners.

For future perspectives, continuing this work will allow for an analysis of students' perceptions regarding the teaching methodology employed by the professors and their perceptions of learning, enabling comparisons between observed sessions, professor feedback, and student perceptions.

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