Didactic Innovation in Mathematics Using Technologies

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Abstract: The continuous progress of society requires all the actors to be dynamic and constantly updated, both in terms of monitoring as well as in the need to adapt. Regarding education, no matter how updated we are in relation to the contents, didactic strategies, and technological resources, we are still inevitably forced to adapt to new paradigms, leading us to reformulate traditional teaching methods. In this context, the contribution of e-learning platforms emerges, where teachers and students have at their disposal new means of empowering the teaching and learning process, since these platforms can be defined as a virtual teaching support environments. Currently, our students, in general, have many difficulties in problem-solving and mathematical reasoning, which often reflects in the performance of very simple tasks, with a growing disinterest towards Mathematics. It is also possible to argue that our students' "poor preparation" is a contributing factor in their failure (many did not attend Mathematics in Secondary Education and/or have not studied for several years, as is the case of those who entered through special contingents, as the “aged 23 and over”). In order to promote a distinct, alternative and supportive pathway that may help to solve this issue, a project on the Moodle learning management system (LMS) platform has been developed with the goal of assisting students in their study and the development of their skills in a way that is directly related to the curricular units (CU) in the scientific field of Mathematics, in an online learning environment. To increase students’ engagement into their learning process in a collaborative environment, a flipped model was employed into a Financial Mathematics/Financial Calculus Course (FCC). This paper's primary goal is to examine the effects of implementing the flipped classroom paradigm on students' performance, learning, and classroom instruction. The results from employing this approach have indicated a beneficial effect on the overall academic progress of students.

Keywords: Flipped classroom, Distance education, Higher education, Didactic innovation, Online learning, Mathematics education

1. Introduction

The rapid evolution of technology and the unstoppable shifting of societal needs, demand continuous adaptation and learning across multiple sectors, with education being a primary focus. In this case, it means embracing new paradigms and integrating technological advancements into traditional teaching methods (Crowley et al., 2023; Means et al., 2009; Shea & Bidjerano, 2013). Traditional classrooms, often limited by time and space, are being supplemented and even replaced by e-learning platforms that facilitate a more dynamic and flexible learning environment. One outstanding example of such platforms is Moodle, an open-source Learning Management System (LMS) that supports a wide range of educational activities. Moodle provides a versatile environment for enhancing the educational process by offering several tools and resources that support both teaching and learning (Lopes, 2011, 2014). These tools include discussion forums, quizzes, and assignments, which can be tailored to meet the specific needs of different courses and student populations Dougiamas & Taylor (2003). Research has shown that the use of Moodle can lead to improved student engagement and learning outcomes, as it encourages active participation and provides immediate feedback (Al-Ajlan & Zedan, 2008; Lopes & Soares, 2018b).

Moreover, the adaptability of e-learning platforms like Moodle allows for the implementation of diverse teaching strategies, such as the flipped classroom model. In this model, traditional lectures are replaced with online instructional videos and other support material that students can watch and use at their own pace, freeing up classroom time for interactive, hands-on activities. This approach has been shown to enhance students' understanding and retention of material, as it allows them to engage with the content more deeply and actively(Fung et al., 2021; Han et al., 2024; Lowell Bishop & Verleger, 2013; Nja et al., 2022; Rahmat et al., 2024; Walsh, 2024).

Even today, one of the most significant challenges in education continues to be the widespread difficulty students face in problem-solving and mathematical reasoning (OECD, 2019; Seepiwsiw & Seehamongkon, 2023; Szabo et al., 2024). This is particularly evident in their performance on simple tasks and their increasing

disinterest in Mathematics. Additionally, the inadequate preparation of many students, especially those who have been out of formal education for extended periods, exacerbates this issue. Research indicates that students often struggle with problem-solving and mathematical reasoning, which are critical skills for success in many fields, such for instance Financial Calculus (Indefenso & Yazon, 2020; Janicek Pavelova et al., 2023; Lopes & Soares, 2018a; Vilenius-Tuohimaa et al., 2008; Wangsa et al., 2023).

The main objective of this study is to explore the effects of implementing a flipped classroom model in a Financial Calculus Course (FCC) on student performance, learning outcomes, and classroom dynamics.

2. Methodology

2.1 The Flipped Classroom Model

The flipped classroom model represents a significant shift in traditional teaching methodologies. In this approach, instructional content is delivered outside of the classroom, often through online videos, readings, and other digital resources. The flipped classroom concept incorporates theories such as constructivism, active learning, and peer-assisted learning. In a flipped classroom, the instructor serves as a guide and facilitator, motivating students to construct their own knowledge, supporting them, and closely monitoring their learning outcomes. This model reserves in-class time for interactive, hands-on activities that promote active learning and deeper understanding of the subjects. Students could engage with the content at their own pace before class, allowing them to come prepared for more collaborative and application-based activities during class time (Akçayır & Akçayır, 2018; Jensen et al., 2015; Lopes & Soares, 2017; Sopamena et al., 2023).

Several studies have highlighted the impacts of the flipped classroom model. Lowell Bishop & Verleger (2013), conducted a comprehensive review of flipped classroom research and found that students in flipped classrooms performed better academically and reported higher satisfaction compared to traditional classroom settings. Lage et al. (2000), observed that students in a flipped classroom showed improved engagement and performance in economics courses, attributing this to the increased opportunity for active learning during class time. O'Flaherty & Phillips (2015), reviewed diverse studies and concluded that the flipped classroom model enhances student learning outcomes, engagement, and satisfaction across diverse educational contexts. Setren et al. (2021), conducted a randomized controlled trial at West Point to investigate the impact of the flipped classroom. They found that the flipped classroom produced short-term gains in math but had no effect in economics. Interestingly, the flipped model broadened the achievement gap, with effects driven by white, male, and higher-achieving students. While short-term gains were observed, the long-term average effects on student learning were not significant. Nouri (2016), studied students' perceptions of flipped classroom education in a university course on research methods. The results indicated that a large majority of students had a positive attitude toward the flipped classroom. Positive attitudes were strongly correlated with increased motivation, engagement, and effective learning. Notably, low achievers reported more positive perceptions compared to high achievers. Cabi (2018), investigated the impact of the Flipped Classroom (FC) Model on students' academic achievement. The results indicated that there were no statistically significant differences between the scores of the experimental group that included students learning through the FC Model, and the control group that included participants taught through traditional blended learning. The findings showed that the use of the FC Model does not yield significant impacts on increasing the students' academic achievement.

2.2 Implementation in Financial Calculus Course

The project was implemented using the Project MatActiva in Moodle LMS platform (see Figure 1), which provided a structured and interactive environment for the FCC. Video lectures, interactive lessons (see Figure 2), quizzes and tests (all with a proposed step-by step solution) were made available online for students to study independently. In-class time was dedicated to problem-solving sessions, discussions, and collaborative activities.

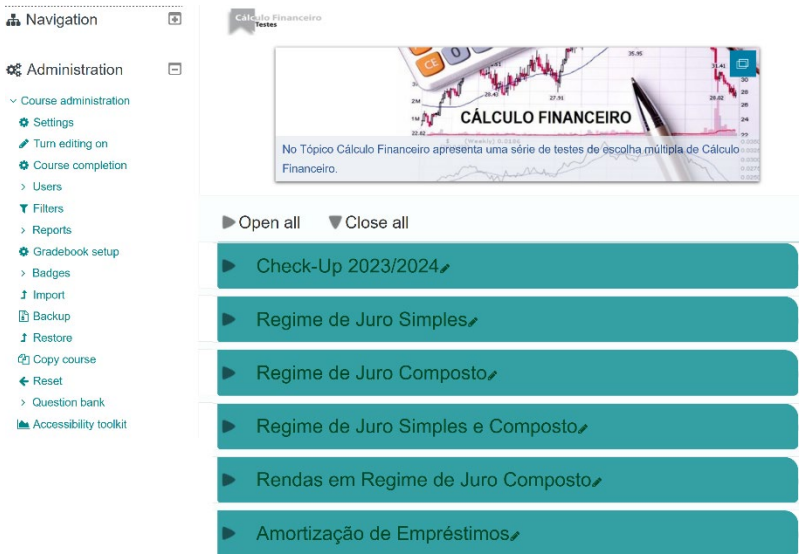

Figure 1: Print screen from the Main Page of FCC in MatActiva Project Moodle

Figure 2: Print screen of an interactive lesson about Discount at Simple Interest

A question pool, with more than 300 questions, based on the material covered in the FCC was built from scratch (see Figure 3) and afterwards organized into categories and subcategories. Each category's question combinations are chosen at random, creating a huge variety of online tests (quizzes) that students can solve whenever and wherever it is most convenient for them. The assessments facilitate many efforts, yielding automatically quantifiable outcomes, and promptly rectify each attempt. To assist students in understanding about their answer and with the underlying reasoning, the feedback provides a step-by-step proposed solution for each answer, encouraging self-evaluation and skills development.

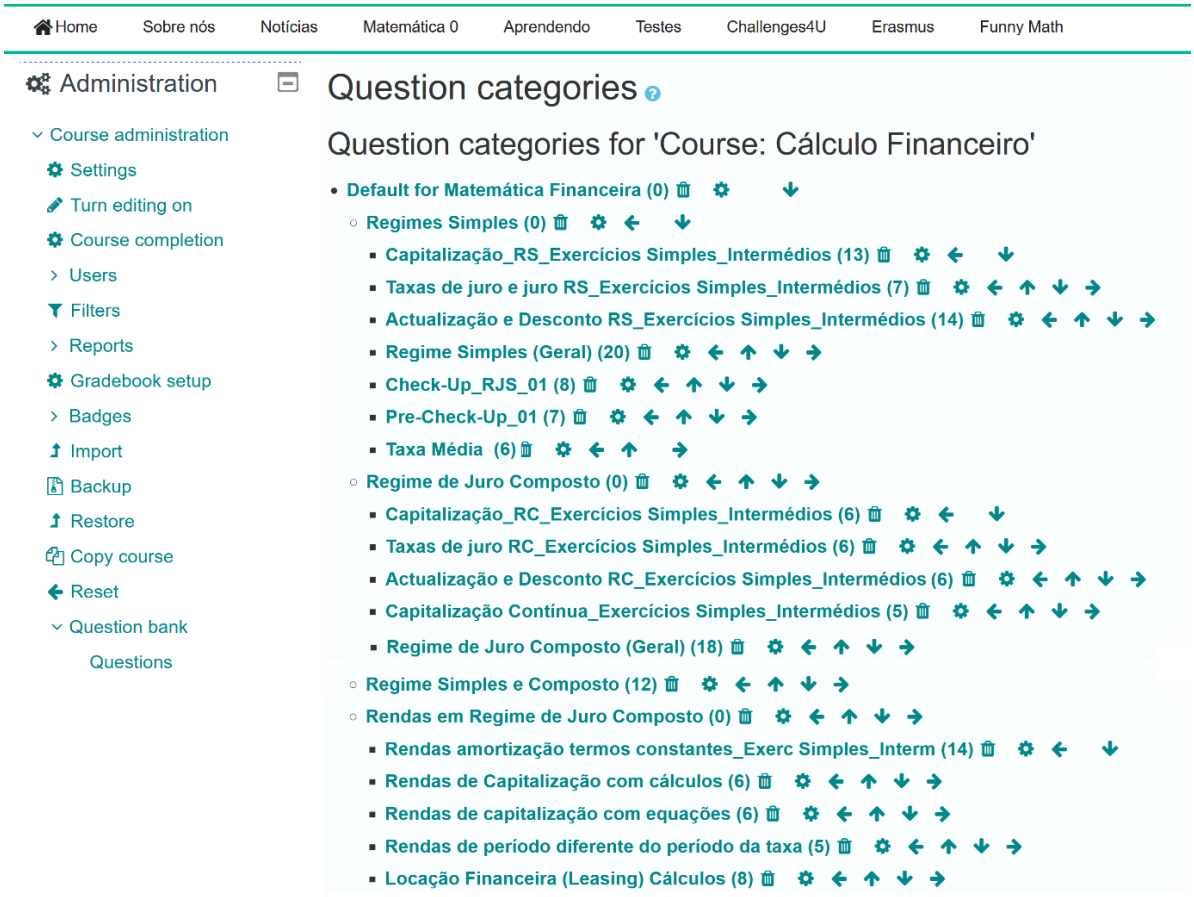

Figure 3: Print screen of some of the categories and sub-categories of the Question Bank (Question Pool)

2.3 Data Collection and Analysis

The sample for our study, conducted during the second Semester of the FCC at the Porto Accounting and Business School (ISCAP), which belongs to one of Portugal's largest and most prestigious public Polytechnic Institutes, the Polytechnic Institute of Porto (P.PORTO), in the 2022/2023 academic year, comprised 732 students. These students were divided into two groups: a flipped classroom group, included 64 students and a traditional teaching group. In both groups, around 80% of the students were attending the classes for the first time. The course covered four topics (Simple Interest, Compound Interest, Annuities and Loan Amortization) throughout the semester. Participants from flipped group could access to the Project Course Moodle (www.matactiva.com) where they can find video lectures, interactive lessons (see Figure 2), online exercises and quizzes related to each topic.

Accessing the Project Course Moodle (www.matactiva.com), participants could access all the available sections and they have at their disposal video lectures, interactive lessons, sets of online exercises and online quizzes, related with each topic.

Two classes each week, lasting one hour and thirty minutes, were part of the flipped classroom approach. Before this class period, students could study at their own pace using a set of interactive lessons (SCORMS) and quizzes that covered the course topics and were posted to Project Moodle. During the first twenty minutes of class, students' queries about any issues they were having trouble with were answered while skimming through the interactive lessons. The rest of the class period was allocated to working through the material through PowerPoint presentations, followed by individual or group work projects and problem-solving exercises. Every week students had a series of online tasks called "Financial Check-Up", deeply connected with the subjets they had learned, that should be completed outside of class. Therefore, online quizzes and activities were integrated to “test” what students have learnt. By receiving immediate quiz feedback and the possibility to repeat lecture segments enabled them to clarify some “grey” points in their thinking. These quizzes can also enhance learning because if students are “tested” before the class time, instructors have the additional opportunity to use feedback from these to tailor the content addressed in class.

The course performance data was collected and the results from both groups (flipped and traditional) were examined and compared. To further investigate the impact of the flipped classroom paradigm on the training, comprehension, and performance of FCC students, we have also created a survey. At the end of the semester, this survey was given to participants to analyze their overall opinions regarding the implementation of the flipped model in their classes.

3. Results/Discussion

For instructors, evaluating students' performance is always a difficult and demanding activity, especially in online learning contexts. Teachers that use online learning platforms often must modify and enhance their courses to ensure that their students do well and are able to learn. Access to learning analytics regarding students' quiz results and lesson completions should help educators gain a better understanding of, for instance: students' contributions to the course and their ability to follow and understand the materials, issues that students found challenging, students' knowledge transfer, as well as several other insights. The Moodle platform gives educators and administrators access to a variety of learning analytics tools that offer a wealth of information reports on the many activities that students complete in each subject, these can be very useful in enhancing and changing the subject matter Mwalumbwe & Mtebe (2017).

The grades chart in Moodle displays grade distribution for selected activities that helps both, teachers and students visualize performance, track progress, and identify areas needing improvement.

This chart (see Figure 4) tabulates grade results from assignments, quizzes, databases, forums, and other gradable activities from FCC. All tasks in which grades have already been awarded are listed below the chart and can be added to or removed from display in the chart. The chart displays the distribution of grades in the selected activities as a box plot.

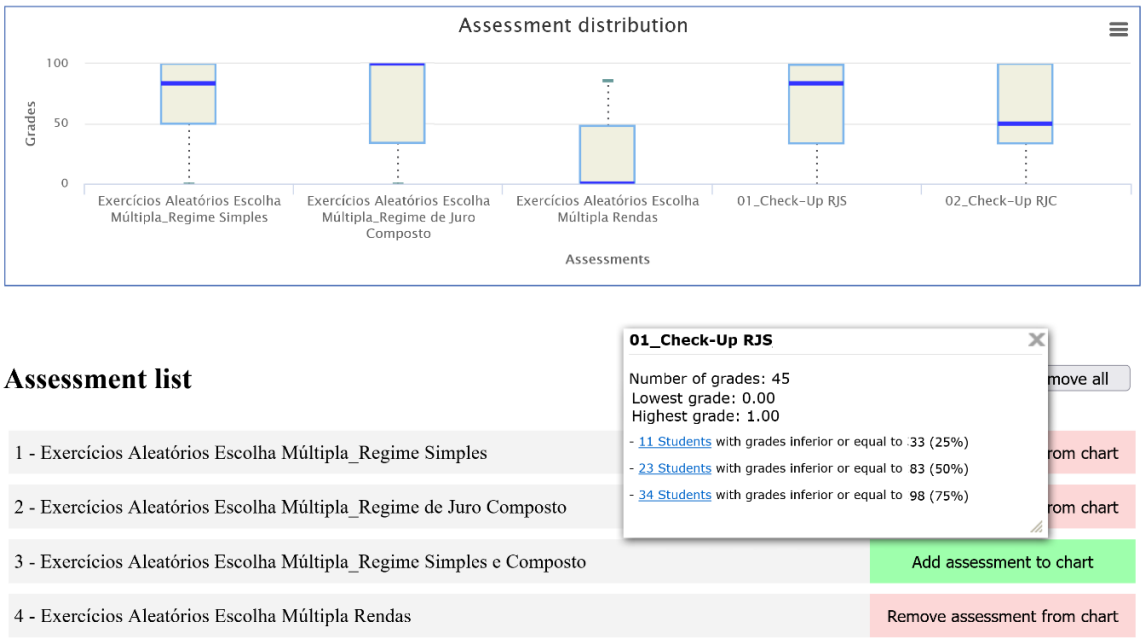

Figure 4: Print screen of the grades chart of FCC students in Moodle

When we click on the box plot for an activity, for instance first Check-Up about Simple Interest (see Figure 4), we can see a numerical breakdown of the grades, including the number of students below the quartiles and the highest and lowest grades. In this case, clicking the highlighted student numbers allows the direct message editing to be send to students who are below the quartiles in that group. A popup will appear, enabling to personalize the subject and text of the message. The default subject will include the unit's name and the assignment title. Additionally, we can choose to share the email with other teachers in the Moodle Course. It is very important to recognize students work and effort in a respectful and welcoming manner, since this will encourage positive self-esteem and motivation. This can be achieved by using their names, affirming their accomplishments, and tailoring comments based on our understanding of the individual performance. When students feel supported and respected, they are more likely to be receptive to feedback and motivated to act on it (Henderson & Phillips, 2015).

From Moodle Learning Analytics, the analysis revealed a significant improvement in students' problem-solving skills and overall performance in the FCC.

The final exam results have been used to measure the success of the flipped classroom model.

Table 1: Measuring the success of Flipped and the Traditional Classroom Groups

	2022/2023
Flipped Classroom Group success rate	73,6%
Traditional Classroom Group success rate	42,2%

Source: Own elaboration

Table 1 shows the results of the 2022/2023 FCC, in the traditional classroom group and flipped classroom group and it illustrates that the flipped classroom's success rate is higher than the traditional classroom's success rate in FCC.

Additionally, the average grade received by successful flipped students was greater than the average grade received by successful traditional class participants. In Financial Calculus, the average grade for students in flipped classrooms was 14.1, while the average grade for the students from traditional class was 12.6 (in a 0 to 20 scale).

The survey conducted at the end of the course showed a high level of student satisfaction with the flipped classroom model.

A big percentage (92,2%) of the students who took part in the experience said that the Interactive Lessons improved their understanding of the FCC subjects (see Table 2). No participants expressed any disapproval of the flipped classroom interactive lessons.

Table 2: Interactive lessons and students' preparation

Interactive lessons helped me understand the concepts studied in FCC	**Number**	**Percentage**
Strongly agree	37	57,8%
Agree	22	34,4%
Neither agree nor disagree	5	7,8%
Disagree	0	0%
Strongly disagree	0	0%

Source: Own elaboration

It's remarkable that nearly all of students (96,9%) who responded to the question "Online exercises enabled me to improve my Financial Calculus Course knowledge and skills" said that they performed better as a result of the randomly quizzes and detailed solution offered by all the online exercises.

Just 3.1% of participants had no opinion, were neutral, regarding the advantages of the flipped classroom's online exercises in terms of improving their performance (see Table 3).

Table 3: Students' Academic Achievement and Online Exercises

Online exercises enabled me to improve my FCC knowledge and skills	**Number**	**Percentage**
Strongly agree	44	68,8%
Agree	18	28,1%
Neither agree nor disagree	2	3,1%
Disagree	0	0%
Strongly disagree	0	0%

Source: Own elaboration

When asked about their preferences on the flipped classroom, 70,3% of the students in this study said they were in accordance with it. Of the participants, 12,5% preferred the traditional classroom, whereas 17,2% were neutral about their choices about the flipped classroom (see Table 4).

Table 4: Students' preferences in relation to the flipped classroom

A flipped classroom course is more attractive to me than a traditional classroom course.	Number	Percentage
Strongly agree	29	45,3%
Agree	16	25,0%
Neither agree nor disagree	11	17,2%
Disagree	8	12,5%
Strongly disagree	0	0%

Source: Own elaboration

In general, students reported feeling more engaged and motivated, citing the interactive and collaborative nature of the classroom sessions as particularly beneficial.

4. Conclusion

The development and implementation of a project, called MatActiva, on the Moodle platform has shown promising results in addressing students' weak skills in Mathematics. By directly aligning with the curricular unit of Financial Calculus Course in the scientific field of Mathematics, this project provides a structured and supportive online learning environment that enhances students' study practices and skill development.

The adoption of the flipped classroom model in this course has yielded significant improvements in student performance, engagement, and classroom dynamics. This innovative approach leverages e-learning technologies to deliver instructional content outside the classroom, thereby optimizing in-class time for interactive and applied learning activities. The flipped classroom model not only seems to foster a deeper understanding of mathematical concepts but also cultivates essential critical thinking and problem-solving abilities.

The positive outcomes observed in this project underscore the potential of e-learning platforms like Moodle to transform traditional Mathematics education. These platforms offer flexible and adaptive solutions that provide diverse learning needs and styles, thereby enhancing the overall educational experience.

Further research and development in this area can continue to improve educational methodologies and addressing the dynamic needs of students and society. Future studies should focus on exploring additional e-learning tools, refining the flipped classroom model, and integrating new technological advancements to sustain and enhance the efficacy of education.

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