

# Online Learning in Mathematics Higher Education during the COVID-19 Pandemic: A Survey Study of Portuguese Students

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**Abstract**—Coronavirus pandemic has impacted the whole education system. Suddenly, presential classrooms are replaced by online learning, leaving students and teachers to deal with various problems without any specific preparation. This research study examines the perceptions of 78 students from a Portuguese Higher Education (HE) institution towards online learning during the Coronavirus disease 19 (COVID-19) pandemic. Two months after the implementation of the online learning, they responded to a survey whose responses were analyzed by using descriptive statistics and independent Chi-squared tests. The findings of this study reveal the difficulties that the students encountered, like the lack of familiar/spatial conditions at home, the failures of Internet connection, and the fear of clarifying doubts in this context. The preference for face-to-face classes was also expressed. However, the selected platform used for the online classes, the appropriate development of the explanations and the digital contents made available by the teachers were appreciated by the students. The present research also investigates the factors that affected the study motivation of the students and the future plans regarding their studies.

**Index Terms**—COVID-19, online learning, higher education (HE), mathematics, Portugal.

## I. INTRODUCTION

The Coronavirus disease 19 (COVID-19) was declared by the World Health Organization (WHO) as a pandemic on 11th March 2020. Originated in Wuhan city of China in December 2019, COVID-19 has quickly widespread with confirmed cases of the virus in numerous countries and territories worldwide. In order to combat the spread of the COVID-19 pandemic, countries took several measures like quarantines, travel restrictions, closing of schools, workplaces, stadiums, theatres, or shopping centres [1].

In particular, the closure of educational institutions led to several challenges for the teachers who had to adapt their face-to-face classes and to implement online learning by developing new digital contents and using technological tools [2], [3]. However, a large part of the educators was not effectively prepared and had not had the required experience to switch to online teaching [4], [5]. On the other hand, students also found difficulties during this period such as lack of Internet facilities, lack of interaction with the teacher and

absence of social interactions with colleagues [6]. Although online learning was found as the best solution to minimize the impact of the pandemic on education, there is no doubt that the obstacles are numerous, for all actors of the learning process [7]–[9].

In the twenty years that preceded this crisis, there had been an increasing use of new Information and Communication Technologies (ICTs), due to the rapid progress of the Internet and mobile technologies. Either as a support for distance courses, or as a complement to traditional classes, the use of ICTs shown to be positive for students, concerning their motivation, autonomy and learning outcomes [10]. Particularly in Mathematics, where most students have shown difficulties and lack of motivation, these technologies can be one of the strategies to improve the learning process and change the perception of this science [11], [12]. However, teachers' difficulties in using technology in education were already mentioned in the literature, such as lack of advanced computer skills and experience [13], and opinion about technologies [14]. On the other hand, a few studies also reported negative aspects for the students, such as the preference for the traditional face-to-face classrooms [15], [16] and the existence of technical problems [17], [18]. The obstacles found by students and educators were even more difficult to overcome with the pandemic, since the use of technology went from an option to the main way of learning.

Some research work has been performed about online learning during the pandemic, intending to conclude about the students' perception. Alawamleh and co-workers (2020) explored the effect of online learning on communication between instructors and students, by examining the responses of 133 students from the American University of Madaba to an online survey. This quantitative research study showed that most students still prefer face-to-face classes compared with online classes, due to the lack of motivation, feeling of isolation, and decrease in communication between students and the instructor [19]. Laili and Nashir (2021) used a descriptive method to analyze 103 responses from Higher Education (HE) students of Stikes Banyuwangi who joint Intensive English class in the 2020/2021 academic year. The flexibility of online learning was pointed out as a positive aspect but many constraints were also indicated such as unstable Internet access and reduced motivation. As concluded in the previous study, most students (91%) also showed a preference for face-to-face classes [20]. On the other hand, Michał Bączek and co-workers (2021) used routine statistical software to analyze the responses of 804 Polish medical students to a questionnaire. They concluded that there was no statistical difference between face-to-face

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and online learning to increase knowledge from the opinions of students, and 73% rated distance learning as enjoyable. The lack of interactions with patients and the technical problems were referred to as the main disadvantages. However, in a global conclusion, this study shows that online learning is a beneficial method to teach medical students [21]. These differences in results show that the success of online learning systems depends on various factors, such as the education area, the school level, the students' and teachers' characteristics, and mainly, the infrastructure and system quality [22].

Portugal has not escaped the pandemic. On 12th March 2020, Prime Minister Antonio Costa announced that all schools and universities in Portugal will be closed from 16th March 2020, due to the ongoing outbreak of COVID-19. In the present study, the students' perception of online learning during the pandemic is investigated. For this, 78 students from a HE institution in Portugal responded to a survey two months after the implementation of the online learning. The responses were analyzed by using descriptive statistics and independent Chi-squared tests, which allowed concluding about the students' perceived online learning outcomes and satisfaction during the pandemic of COVID-19.

After the description of the research methods in Section II, this paper includes a third section where all results are analyzed and discussed. The conclusions are presented in the last section IV.

## II. RESEARCH METHODS

### A. Sample

The 78 student participants in this research were enrolled in the first year Applied Mathematics II course of the Business Sciences degree, in a HE institution in Portugal. The syllabus of this course is composed of Methods of Integration, Topics of Differential Equations, Matrix Calculus and Systems of Linear Equations. The 78 respondents are aged between 17 and 54 years, with the majority (75.6%) aged between 17 and 25 years and only 5% aged between 45 and 54 years.

It should be noted that the curricular unit under analysis, Applied Mathematics II, takes place in two regimes (working hours – labour - versus after-working hours – post-labour) and that the profile of students differs between these two regimes. In our sample, 63.1% of the students attend the working regime and 35.9% the post-labour regime.

### B. Methodology

In March 2020, in-person learning is interrupted. Online classes mediated by the ZOOM platform were established and digital contents were made available on the institutional Moodle platform. Microsoft Word or digital pen were used to complete the explanations, and proposals for correction of the exercises were made available. The students also had the possibility to review the theoretical contents with the *b-Mat@plicada* videos [23].

Created in 2015, *b-Mat@plicada* is a b-learning Mathematics course for HE students and is composed of 34 educational videos on four topics (functions of a real variable,

differential calculus, integration methods, and matrix calculus). In the first year of implementation, 89 students completed a satisfaction survey and expressed a positive opinion respecting their quality and effectiveness [24]. Later, two experiments were performed with two *b-Mat@plicada* videos. In the first, the video on Matrix Multiplication was used as a substitute for the traditional face-to-face explanation. Then, 49 HE students were asked to solve individually an exercise, and respond to a survey assessing attitudes, perception, and satisfaction. The results showed the importance of using videos as complementary tools and the adequacy of the selected video [23]. Later, in a second study, 63 HE students participated in a similar experiment with the *b-Mat@plicada* video on the Laplace Expansion Theorem [25]. The quality of the video in terms of image, sound, clarity and usefulness was appreciated by the students, and most of them achieved the learning objectives after its visualization. The titles, objectives and links of the videos that the students used during the period of online learning are shown in Table I.

TABLE I: TITLE, OBJECTIVES AND ONLINE ADDRESS OF THE B-MAT@PLICADA VIDEOS

Title and Objective(s)	Online address
<i>Integration of rational functions – Resolution Methods.</i> - Identify the resolution method (decomposition method, polynomials division or immediate integration) to calculate the integral of a rational function.	<a href="http://youtu.be/kNOZtbiahgE">http://youtu.be/kNOZtbiahgE</a>
<i>Integration of rational functions - Polynomial division method.</i> - Divide two polynomials; - Use the polynomials division to integrate a rational function.	<a href="http://youtu.be/uwN56H0EK-4">http://youtu.be/uwN56H0EK-4</a>
<i>Integration of rational functions – Decomposition Method (real roots).</i> - Understand and use the decomposition method to integrate a rational function.	<a href="http://youtu.be/s04RHhxIeLY">http://youtu.be/s04RHhxIeLY</a>
<i>Differential Equations – Applications.</i> - Understand the importance of differential equations in solving a real practical case; - Use a differential equation to solve a cooling problem.	<a href="http://youtu.be/swFS6J7s_eY">http://youtu.be/swFS6J7s_eY</a>
<i>Matrix Multiplication.</i> - Identify whether multiplication of two matrices is possible; - Multiply two matrices.	<a href="http://youtu.be/VDFqhkYdyM">http://youtu.be/VDFqhkYdyM</a>
<i>Matrix Equations.</i> - Understand and use the techniques of resolution of the matrix equations.	<a href="https://youtu.be/MVcKpsrouU">https://youtu.be/MVcKpsrouU</a>
<i>Rank of a matrix.</i> - Understand and apply the Jacobi operations; - Determine the rank of a matrix.	<a href="http://youtu.be/9WHSaCej25o">http://youtu.be/9WHSaCej25o</a>
<i>Determinants (Order 2).</i> - Calculate a determinant of order 2;	<a href="https://youtu.be/PxPdayfrilk">https://youtu.be/PxPdayfrilk</a>

*Determinants (Order 3).*  
 - Use the Sarrus Rule to calculate a determinant of order 3. <https://youtu.be/LDBdVmupQk>

*Determinants (Order n).*  
 - Use the Laplace Theorem to calculate a determinant. <https://youtu.be/vk5U6rbJRAU>

*Solving a system of linear equations by determinants.*  
 - Apply the techniques of solving a system of linear equations by determinants. <http://youtu.be/h3QfA0scDaw>

*Cramer's rule.*  
 - Solve a system of linear equations by using the Cramer's rule. <https://youtu.be/v5qbahz-y3w>

*Implicit formulation matrix.*  
 - Describe the strategy that allows converting from the implicit form to the explicit form. <https://youtu.be/rVdIlxlyzek>

*Diagonal, scalar and identity matrix.*  
 - Define and exemplify diagonal, scalar and identity matrix.  
 - Use the definition of diagonal matrix to solve a problem. <https://youtu.be/W3vedrZZ4LM>

*Matrix dimensions and operations.*  
 - Verify if matrix operations are possible;  
 - Given a set of matrix operations, deduce the dimensions of the resulting matrix or matrices involved in the operations so that the operations are possible. <https://youtu.be/56xxnwq4sEI>

### C. Procedure

After two months of online learning, the students responded to a questionnaire available on the Google forms in order to collect their opinions.

### D. Data Analysis

Descriptive statistics were applied to investigate the responses of the students, and, due to the nominal nature of the variables, independent Chi-squared tests were implemented to test the association between perceptions, where the null hypothesis of no association was tested with a 5% level of significance. The analysis was performed using the statistical software IBM SPSS V.28.

### E. Ethical Issues

The questionnaire used for this research is anonymous and confidential. Moreover, the participation in this study was voluntary and the participants were previously informed about the purpose, benefits, risks and funding. Finally, the results of this work are free of research misconduct.

### F. Research Questions

Five research questions guided the questionnaire in the present study:

1) Had the students a good quality Internet connection and appropriate conditions at home during the online learning?

- 2) Which are the strategies adopted by the students to study?
- 3) Which is the opinion of the students about the strategies, the technological tools and the digital contents used to support the online learning?
- 4) Is the online learning efficient for their study, compared with the traditional face-to-face classes?
- 5) Which factors affected their study motivation and future plans regarding their studies?

## III. RESULTS

### A. Quality of Internet Connection and Home Conditions

Concerning the physical conditions of participation in the online classes during quarantine, all students (100%) indicated having a computer at home and only 2 students (2.6%) indicated not having Internet at home. However, these two students did not take advantage of the mobile operators' offer of 10GB mobile data that ran during the pandemic. In fact, only 24.4% ( $n = 19$ ) of the respondents made use of this offer.

The vast majority (97.4%) used a computer to participate in the online classes and only 2 respondents indicated that they used a tablet or mobile phone.

With regard to family and space conditions to participate in the online classes, only 47.4% ( $n = 37$ ) indicated that they always have the conditions to be in a quiet place to concentrate, and more than half (53.6%) indicated that sometimes it is complicated, or they never manage to be in a quiet place. Of the respondents, 52.6% ( $n = 41$ ) indicated that sometimes there were connection failures during distance learning, 37.1% ( $n = 27$ ) that they never or rarely had connection failures, but 10.3% ( $n = 8$ ) indicated that they always or often had connection failures. This technical problem has been referred to in other previous similar studies [20], [26].

### B. Strategies Adopted by the Students to Study

Regarding the students' perception of the Mathematics curricular units, 77% indicated that they consider their performance in Mathematics as Good or Very Good, and only 3.9% considered their performance as Poor or Very Poor. It should be noted that the surveyed students had already had in the first semester the curricular unit of Applied Mathematics I, face-to-face, with the same teachers.

The following characterization answers to the second research question regarding the strategies adopted by the students to study. In the first semester, 64.1% ( $n = 50$ ) of the respondents used the *b-Mat@plicada* videos, nonetheless in the second semester, 83.3% ( $n = 65$ ) assumed that they would use the videos more often, which means that they identified the videos as an important strategy.

Of all the respondents, 89.7% ( $n = 70$ ) consider that the explanations given in the online classes of Applied Mathematics II have an adequate development, only 2.6% ( $n = 2$ ) consider that they are too slow, leaving a lot of time to wait, and the remaining 7.7% ( $n = 6$ ) consider that they are too fast, making it difficult to follow.

Examining the way students participate in class, the majority (94.9%) responded that they used the notebook and

pencil to take notes and/or solve the exercises. Only 3.8% ( $n = 3$ ) answered not writing anything, as they were only concentrating on the lesson. Only one student (1.33%) assumed not to write anything, trying to listen to the class but doing other things at the same time.

*C. Opinion of the Students about the Strategies, the Technological Tools and the Digital Contents Used in the Online Learning*

Considering the platform used for online transmission of the classes - the ZOOM platform - the vast majority (65.4%) classifies it as Good or Very Good. Only 9% ( $n = 7$ ) classify it as Poor or Very Poor, and 25.6% ( $n = 20$ ) as Moderate. This positive opinion on the ZOOM platform is in agreement with other previous research works [27], which reinforces that this platform is an appropriate tool for online learning.

The opinion regarding how the teachers of the institution have generally managed to adapt their teaching strategies to be able to teach at a distance, is slightly equally distributed in the categories “Disagree” (23.1%), “neither disagree nor agree” (25.6%) and “Agree” (28.2%). In the extreme opinions of “I totally disagree” and “I totally agree”, the latter has more weight (6.4% and 16.7%, respectively).

Most of the students (98.7%) consider that the material available on the Moodle platform to support online classes (resolution of exercises, slides and videos) is sufficient. These answers give light to the third research question.

*D. Comparison between Online Learning and Traditional Face-to-Face Classes*

Concerning the clarification of doubts in online classes, 61.5% ( $n = 48$ ) do not usually ask questions, mainly because the doubts of colleagues are the same ones they have (45.8%) and because they do not feel comfortable in this context to question the teacher.

Comparing the face-to-face classes with the online classes in terms of learning performance, 75.6% ( $n = 59$ ) consider that the face-to-face classes are more effective in terms of learning. However, 16.7% ( $n = 13$ ) consider that in the videoconference classes they learn more and are more concentrated, and only 7.7% ( $n = 6$ ) consider that there is no difference between the two regimes. Thus, regarding the fourth research question, we can understand that students do not find online learning more efficient than traditional face-to-face classes. This conclusion is in accordance with most previous research works [19], [20]. However, as referred to in the introduction, the preference for online learning is not always deduced [21], which reinforced the idea that this depends on several aspects, like the educational area, the education level, types of students, educational habits etc.

*E. Factors Affected Their Study Motivation and Future Plans Regarding Their Studies*

We consider that motivation for study and future plans for the academic path are two important indicators to measure the effectiveness of the teaching process in a HE institution during the pandemic period. As such, and to answer the fifth research question, students were questioned regarding these two aspects. Observing the motivation to study subjects in general in the exceptional period of confinement (Fig. 1), the

majority (61.5%) assumed to be a little unmotivated but making efforts to try to achieve success; 14.1% ( $n = 11$ ) answered to be completely unmotivated and lost; 10.3% ( $n = 8$ ) considered to be more motivated than usual, and 14.1% ( $n = 11$ ) indicated that they maintain the same study habits, making no difference to them.

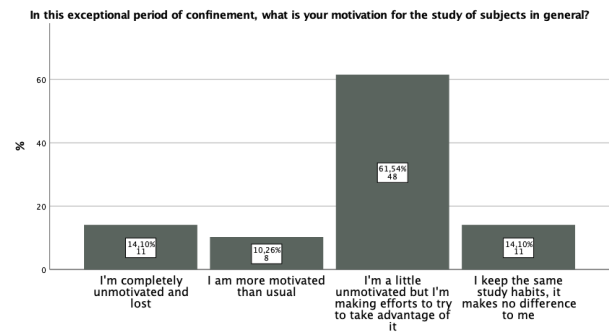


Fig. 1. Students' motivation for study.

With regard to future plans for the academic path (Fig. 2), 87.2% ( $n = 68$ ) replied that they maintain the same objectives, that is, to continue and finish the course, however 10.3% ( $n = 8$ ) indicated that they are confused and hypothesize to pause their studies until the pandemic period ends; 2.6% ( $n = 2$ ) assumed to interrupt their studies for a while until the situation is normalized.

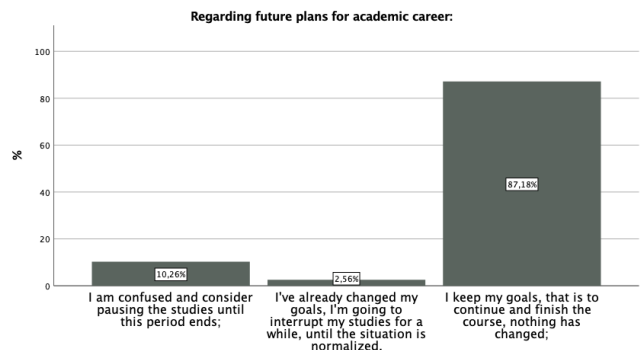


Fig. 2. Students' future plans for the academic career.

Aiming to understand whether the distribution of perceptions regarding the motivation to study during the exceptional period and future plans are related to inherent characteristics of the students; to the students' perception of the Mathematics curricular unit and its resources; or to the exceptional situation of online classes, the two variables abovementioned were crossed with the various questions of the survey, using the Chi-square test of independence (Table II).

From the results presented in Table II we realize that the perception that students have of the ZOOM platform is associated with study motivation. In fact, analyzing the crossable (not presented due to space restrictions, but made available upon request), we understand that students who rate the platform as bad or very bad are those who are more demotivated.

TABLE II: RESULTS FOR THE INDEPENDENCE QUI-SQUARE TEST

Question:	Motivation		Future Plans	
	p-value	Fi	p-value	Fi
Q1. Age	0,111		0,534	

<b>Q2.</b> Regime in which you attend Applied Mathematics II classes?	0,368		0,136	
<b>Q3.</b> Do you have Internet at home?	0,49		0,86	
<b>Q4.</b> All mobile operators offered 10GB of mobile data. Thus, through the smartphone, as a hot spot, students can have access, on their computers, to the Internet, via Bluetooth. Did you use this offer?	0,984		0,69	
<b>Q5.</b> What mechanism do you use to participate in online classes? When you participate in an online class, do you have the conditions (family, space...) to be in a quiet place and thus be able to concentrate?	0,195		0,99	
<b>Q6.</b> Do connection failures occur during distance classes?	0,753		0,001	0,568
<b>Q7.</b> On a scale of 1 to 5, where 5 represents "Very good" and 1 represents "Very poor", how do you rate the Zoom - Colibri platform for distance classes?	0,023	0,551	<.001	0,750
<b>Q8.</b> On a scale of 1 to 5, where 5 represents "totally agree" and 1 represents "totally disagree", comment on the following statement: "In general, the teachers of the institution were able to adapt their teaching strategies to be able to teach at a distance."	0,045	0,524	0,334	
<b>Q9.</b> On a scale of 1 to 5 where 5 represents "Very good" and 1 represents "Very poor", how do you rate your performance in Mathematics?	<.001	0,664	0,003	0,5470
<b>Q10.</b> How do you participate in Applied Mathematics II classes?	0,016	0,448	<.001	0,878
<b>Q11.</b> In particular, in Applied Mathematics II, how do you qualify the material available in Moodle to support distance learning (exercises, slides, videos...)?	0,104		<.001	0,703
<b>Q12.</b> In the 1st semester, did you use the educational videos of the "b-Mat@plicada" course?	0,547		0,609	
<b>Q13.</b> This semester, do you intend to use the educational videos of the "b-Mat@plicada" course more often?	0,184		0,197	
<b>Q14.</b> Comparing face-to-face classes with online classes in terms of use, do you consider that presential classes are more effective?	<.001	0,767	0,616	

The teachers' adaptation, in general, of their teaching strategies is also a demotivating factor, with the students who disagree that the teachers have managed to adapt their strategies being the ones who are completely or somewhat demotivated. Students' own performance in Mathematics is related to motivation and, in fact, the only two students who responded that they perform very poorly in Mathematics indicated that they are totally unmotivated or lost. A relationship was also found, as expected, between opinions regarding face-to-face and online classes.

Similar results were found for future plans, however in this case, adding associations with variables related to the Mathematics curricular unit itself. In fact, the only student who thinks the materials available on Moodle platform are insufficient, indicated that he has changed his future plans and will interrupt his studies.

Overall, for these two variables, it is not the students' characteristics that are related to their motivation or change of future plans, but their perception of the platform used, the way teachers have changed their learning strategies and the performance they have of the Mathematics curricular unit. All associations found are moderate, since the *F<sub>i</sub>* statistic, which quantifies the degree of association, is close to or just above 0.5.

#### IV. CONCLUSIONS

The pandemic of COVID-19 had and still have major repercussions in our life, among others in the educational field. The present study investigates the opinions of 78 students from a Portuguese HE institution about the online classes, during the confinement period that started in March 2020. As reported in other similar studies in the literature, the unstable Internet connection is one of the constraints of the online learning. In the present research, the lack of appropriate conditions at home and the fear of questioning the teacher in this context were appointed as additional limitations. Moreover, the preference for presential classes was expressed by these students, compared with distance learning.

However, some positive aspects were deduced: the ZOOM platform used for the online classes, the strategies adopted to support the explanations were appreciated by the students, as well as the digital contents made available by the teachers such as the *b-Mat@plicada* educational videos.

Finally, the responses to the questionnaires also allowed for investigating the factors that affected their study motivation and future plans regarding their studies. The perception of the platform used, the adjustments in the learning strategies of the teachers and the performance they have of the Mathematics curricular unit showed to be related to their motivation or change of future plans.

#### CONFLICT OF INTEREST

The authors declare no conflict of interest.

#### AUTHOR CONTRIBUTIONS

Ana I. Borges and Sidonie F. Costa conducted the research; Ana I. Borges analyzed the data; Ana I. Borges and Sidonie F.

Costa wrote the paper; both authors had approved the final version.

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