

# Students' Pre- and Post-COVID-19 Perception of Mathematics Videos in Higher Education

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**Abstract**—Educational videos have been an increasingly used tool in education, accentuated not only by the rapid growth of the Internet and mobile technologies but also by the Coronavirus disease 19 pandemic. Following this trend, the b-Learning Mathematics course *b-Mat@plicada* was created in 2015 for Higher Education students and has evolved to extend the course and improve the quality of the available contents. This evolution was influenced by some studies that have been made since the first year of implementation. The main objective of this work is to evaluate the influence of the Coronavirus disease 19 pandemic on the students' perceptions and attitudes toward the learning videos available on the course *b-Mat@plicada* and, also, on the Internet. At the end of the year 2022, 104 higher education (HE) students responded to a satisfaction survey about the use of learning videos to study and the contents of the *b-Mat@plicada* course. By using descriptive statistics and independent Chi-square tests, the responses were analyzed and compared with other results obtained in 2015 and 2018, that is, before the pandemic. The findings indicate that there has been a rise in the demand for *b-Mat@plicada* educational videos and for videos available on the Internet in general. Also, students perceived an improvement in the quality of the videos since the pre-pandemic period. Additionally, students now consider online videos more useful than before the pandemic. However, they still view them as supplementary rather than a primary learning source.

**Index Terms**—Educational videos, b-learning, user satisfaction, higher education, mathematics, COVID-19, Portugal

## I. INTRODUCTION

The enormous importance that online videos hold in our present is incontestable. With the growing access to the Internet and the evolution of Smartphones, and more recently due to the Coronavirus disease 19 (COVID-19) pandemic, the amount of online videos has increased significantly. In 2020, the viewers spent seven hours and 55 minutes per week watching online videos, which corresponds to an increase of 85% since 2016 [1]. According to Cisco, it is estimated that, in 2022, 82% of the global Internet traffic came from video streaming and downloads [2].

This trend has been also observed in the educational field, where users increasingly resort to videos to learn. According to recent studies performed in 2020 and 2022, 58% of the respondents revealed using online videos to learn new skills [3], and the most common online learning contents used in K-12 classrooms are online educational videos [4]. In Higher Education (HE), the use of videos has grown rapidly [5, 6]

and their benefits in teaching have been reported in the literature [7, 8]. The students considered that these contents are effective learning tools and useful [9], but also enjoyable to watch [10], motivating [11] and easily accessible [12, 13]. Specifically, in Mathematics, where the difficulties of the students are frequent, the use of videos allows improving their perception of the exact science [14]. Some negative aspects have been also described, such as the technical problems [15] and the preference for face-to-face classes [16]. However, the number of studies that report benefits remains considerably larger [17].

The COVID-19 pandemic accentuated the growing use of videos in teaching. During this period, the closure of schools, colleges and universities led to a sudden transition from traditional face-to-face lectures to online learning and forced teachers to create a wide variety of digital content. The videos available on the YouTube platform, which is widely used by almost 2.5 billion people in 2022 [18], have been chosen in some institutions as learning material during the pandemic. In 2021, Nomura and co-workers evaluated the effectiveness of YouTube videos for teaching medical students CardioPulmonary Resuscitation (CPR), by analyzing the results of a study with 129 students divided into two groups. The authors concluded that using YouTube videos is a beneficial technology for teaching CPR during the COVID-19 pandemic [19]. In the same year, another research work with 85 students allowed deducing that YouTube videos can be used during the pandemic COVID-19 as English learning material to improve the students' speaking skills [20]. Moreover, some studies reported that the use of instructional videos during the confinement period can improve student learning outcomes [21, 22]. Concerning the perceptions of the students, Yeung and Yau [23] analyzed the responses of 145 HE students to an online questionnaire concerning the challenges they found in online learning, which kind of support they need and which strategies they used to overcome the difficulties. One of their conclusions is the great importance of lecture videos as a learning source. In the research work of Breslyn and Green [24], in which a comparison is made before, during and after the pandemic, the majority of the 1147 students who responded to the online questionnaire would like to continue to use the videos in a post-pandemic phase.

The existing research works on the use of videos during the COVID-19 pandemic have shown that the videos are useful, effective in the learning process and appreciated by the students. But will the students continue to appreciate videos to learn in the post-pandemic phase? Have their attitudes and opinions changed with the pandemic? The number of studies relating to the influence of the COVID-19 pandemic on the students' perceptions and attitudes toward the learning videos

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is still low. However, the forced online classes experience of the students during the period of confinement will have left marks on their future learning and study habits. Consequently, it is relevant to understand which marks the pandemic left, especially for the HE teachers who are concerned with providing students with educational content which is more appropriate for their learning.

This study aims to infer the HE students' perceptions of Mathematics videos and how these perceptions changed with the pandemic phase, that is if the experience of online learning modified the students' views and habits related to the instructional videos. The conclusions of this study can be also an orientation for HE teachers who usually recommend or produce videos as learning content to teach.

## II. THE *B-MAT@PLICADA* COURSE

*b-Mat@plicada* is a b-Learning Mathematics course created in March 2015. Implemented in a Portuguese HE Institution, this course was implemented with the aim of making Mathematics more captivating and giving the students the possibility of reviewing the contents anywhere and anytime. It is also a strategy to overcome the difficulties of students in Mathematics [25, 26], which has been seen as a real challenge for them [14]. Moreover, this course is particularly beneficial for working students who tend to have more delays and lower attendance due to their professional commitments. Finally, *b-Mat@plicada* follows the trend that has been seen in HE institutions, regarding the increase in demand for e-Learning courses [27].

The *b-Mat@plicada* course is mainly composed of educational videos available on the institutional page of the Moodle platform for all students to have access. The topics, creation dates, and online addresses of the 38 contents are described in Table I. All videos are substitutional, i.e., these contain all details of a specific topic, which allows students to supplement or replace face-to-face classes [28]. A methodology of five steps, composed of a set of orientation guidelines, was followed to create the videos [29]. The main characteristics of this methodology are: i) the minimization of the video length since the student engagement decreases as the video lengthens [30]; ii) the combined use of Microsoft Office PowerPoint and Audacity Software to maximize the image and the sound quality; iii) the inclusion of elements that support the audio explanation, such as arrows, different colours or underlines, to maximize the student's learning [31]. The objectives of this approach are to maximize the students' satisfaction and learning performance, to minimize the teacher's required time and computer skills to prepare the videos, and to minimize the costs of equipment.

TABLE I: TITLE AND ONLINE ADDRESSES OF THE *B-MAT@PLICADA* VIDEOS

Title (Chronological order)	Online address
2015	
1. Integration of rational functions – Resolution Methods.	<a href="http://youtu.be/kNOZtbiahgE">http://youtu.be/kNOZtbiahgE</a>
2. Integration of rational functions - Polynomial division method.	<a href="http://youtu.be/uwN56H0EK-4">http://youtu.be/uwN56H0EK-4</a>
3. Integration of rational functions – Decomposition Method (real roots).	<a href="http://youtu.be/s04RHhxleLY">http://youtu.be/s04RHhxleLY</a>

4. Differential Equations – Applications.	<a href="http://youtu.be/swFS6J7s_eY">http://youtu.be/swFS6J7s_eY</a>
5. Matrix Multiplication.	<a href="http://youtu.be/VDFqhkYdyM">http://youtu.be/VDFqhkYdyM</a>
6. Matrix Equations.	<a href="https://youtu.be/MVcKpsrouuU">https://youtu.be/MVcKpsrouuU</a>
7. Rank of a matrix.	<a href="http://youtu.be/9WHSaCej25o">http://youtu.be/9WHSaCej25o</a>
8. Determinants (Order 2).	<a href="https://youtu.be/PxPdayfrilk">https://youtu.be/PxPdayfrilk</a>
9. Solving a system of linear equations by determinants.	<a href="http://youtu.be/h3QfA0scDaw">http://youtu.be/h3QfA0scDaw</a>
2017	
10. Derivative rules: Basic rules.	<a href="https://youtu.be/U5Cq-xH3-sQ">https://youtu.be/U5Cq-xH3-sQ</a>
11. Derivative rules: General rules.	<a href="https://youtu.be/IO35cBZSMAM">https://youtu.be/IO35cBZSMAM</a>
12. Derivative rules: Product rule.	<a href="https://youtu.be/uUIMxJLQ8Bg">https://youtu.be/uUIMxJLQ8Bg</a>
13. Derivative rules: Quotient rule.	<a href="https://youtu.be/ibvP5bJhUeQ">https://youtu.be/ibvP5bJhUeQ</a>
14. Derivative rules: Power rule.	<a href="https://youtu.be/ABmSj8RhW4M">https://youtu.be/ABmSj8RhW4M</a>
15. Derivative rules: Exponential function rule.	<a href="https://youtu.be/YvOT5DUPOeg">https://youtu.be/YvOT5DUPOeg</a>
16. Derivative rules: Logarithmic function rule.	<a href="https://youtu.be/qMn85gvTT68">https://youtu.be/qMn85gvTT68</a>
17. Applications of the first derivative.	<a href="https://youtu.be/qYr9KxbFroc">https://youtu.be/qYr9KxbFroc</a>
18. Applications of the second derivative.	<a href="https://youtu.be/8b3YKbPy7eU">https://youtu.be/8b3YKbPy7eU</a>
19. Integration rules: basic rules.	<a href="https://youtu.be/4hn--lSYlUk">https://youtu.be/4hn--lSYlUk</a>
2018	
20. Determinants (Order 3).	<a href="https://youtu.be/LDBdVmupQQk">https://youtu.be/LDBdVmupQQk</a>
21. Determinants (Order n).	<a href="https://youtu.be/vk5U6rbJRAU">https://youtu.be/vk5U6rbJRAU</a>
22. Cramer's rule.	<a href="https://youtu.be/v5qbahz-y3w">https://youtu.be/v5qbahz-y3w</a>
2019	
23. Domain of a function.	<a href="https://youtu.be/P7w4kiQkCIE">https://youtu.be/P7w4kiQkCIE</a>
24. Partial derivatives of a multivariable function (1 <sup>st</sup> order).	<a href="https://youtu.be/W2wHxp-LrXs">https://youtu.be/W2wHxp-LrXs</a>
2020	
25. Maxima and minima of multivariable functions.	<a href="https://youtu.be/5vlbFLHK3ZI">https://youtu.be/5vlbFLHK3ZI</a>
26. Integration method by parts.	<a href="https://youtu.be/NH34U1FBF8A">https://youtu.be/NH34U1FBF8A</a>
27. Integration by method of substitution.	<a href="https://youtu.be/XTH6mcfRivE">https://youtu.be/XTH6mcfRivE</a>
2021	
28. Implicit formulation matrix.	<a href="https://youtu.be/rVdIlxlyzek">https://youtu.be/rVdIlxlyzek</a>
29. Diagonal, scalar and identity matrix.	<a href="https://youtu.be/W3vedrZZ4LM">https://youtu.be/W3vedrZZ4LM</a>
30. Matrix dimensions and operations.	<a href="https://youtu.be/56xxnwq4sEI">https://youtu.be/56xxnwq4sEI</a>
31. Function composition.	<a href="https://youtu.be/EKio_EbjIuw">https://youtu.be/EKio_EbjIuw</a>
32. Equation of tangent line.	<a href="https://youtu.be/XowrHZ2gtHc">https://youtu.be/XowrHZ2gtHc</a>
33. Equation of normal line.	<a href="https://youtu.be/OsvKuqzTLzo">https://youtu.be/OsvKuqzTLzo</a>
34. L'Hôpital's rule.	<a href="https://youtu.be/R3rNdX6ywyZ">https://youtu.be/R3rNdX6ywyZ</a>
2022	
35. Immediate integration: Power rule.	<a href="https://youtu.be/qbzpR251Zvw">https://youtu.be/qbzpR251Zvw</a>
36. Immediate integration: Integrals resulting in logarithmic functions.	<a href="https://youtu.be/lQtKWUJ19uk">https://youtu.be/lQtKWUJ19uk</a>
37. Immediate integration: Exponential function rule.	<a href="https://youtu.be/nFPwjKtHCL0">https://youtu.be/nFPwjKtHCL0</a>
38. Quadratic inequalities.	<a href="https://youtu.be/EPorqccu-GY">https://youtu.be/EPorqccu-GY</a>

Four months after the creation of the *b-Mat@plicada* course, 89 students responded to a satisfaction survey about the first 9 videos that had been included in the course. The opinions were generally very positive, mainly respecting the usefulness of *b-Mat@plicada*, and the image and sound quality of the videos [32]. The less positive views were observed regarding the inclusion of the musical introduction, the video length and the number of available contents. Finally,

the results of this study also confirmed the need for e-Learning content that has been referred to in the literature [33].

Later, in 2020, the usefulness of the *b-Mat@plicada* videos was also reported by 78 HE students who responded to an online survey, during the online learning originated by the COVID-19 pandemic [34].

Specific experiments in the classroom context were also performed with the *b-Mat@plicada* course. In the first study, the 49 participants solved a proposed exercise, after watching the *b-Mat@plicada* video on Matrix Multiplication and completed a satisfaction survey [29]. The insights obtained by this study allowed us to conclude that the selected video is an adequate tool to achieve the learning objectives. Moreover, the students appreciated the image and sound quality, the video length and the usefulness. This research also allowed concluding that the videos in HE are seen as useful but not as a substitute for the face-to-face classes, as reported in other studies of the literature [35, 36]. Finally, they chose the speech, the sound and the image as the main characteristics that have the highest influence on the quality of a learning video.

Later, a similar experiment was performed with the *b-Mat@plicada* video on the Laplace Expansion Theorem [37]. Despite the higher degree of difficulty of the topic, the 63 HE students who participated in this study were able to apply the Theorem after the video watching, which shows the adequacy of the content to achieve the learning objectives. As observed in the previous study, these students rated the video as useful and with a good quality of image and sound. Significant differences were only found respecting the inclusion of musical instruction and video animations. Moreover, educational videos are also seen by these students as a good complement to the face-to-face lectures, not as a substitute and, the speech, the sound and the image were also selected as the main aspects of a good learning video.

In the present study, the student's perceptions of the use of videos in teaching Mathematics and the *b-Mat@plicada* course are analyzed. For this, 104 HE Portuguese students responded to a satisfaction survey, three months after the start of the school year 2022/2023, that is, in a post-pandemic phase. The responses were analyzed and compared with the results obtained in the previous studies that were performed before the COVID-19 pandemic. The aim is to evaluate the influence of the pandemic on the students' perceptions of the use of videos in teaching Mathematics. For that, a descriptive analysis of the results was used, followed by an analysis of associations using the chi-square test for independence.

After the introduction and a detailed description of the studies related to the *b-Mat@plicada*, the research methods are described in the next section. The fourth section includes the analysis and the discussion of the results. Finally, conclusions are presented in the last section.

### III. RESEARCH METHODS

#### A. Participants

Participants were 104 HE Portuguese students enrolled in the first-year Applied Mathematics course of the Business

Sciences degree.

In this sample, we have a majority of students of the female gender (72.1%), with an age range varied from 17 and 47 years old (Age [17, 21] = 66.3%; Age [22, 33] = 26%; Age [34, 47] = 7.7%).

#### B. Procedure

The participants completed an online questionnaire available on Google Forms, three months after the start of the school year 2022/2023, that is, in a post-pandemic phase. The questionnaire includes questions about the use of Internet videos in general for their learning (like YouTube videos) and others relating to the quality and usefulness of the *b-Mat@plicada* videos to study Mathematics.

#### C. Data Analysis

As a preliminary analysis, the obtained responses were explored through descriptive statistics. Additionally, independent Chi-square tests were used to test the relationship between items, where the null hypothesis of independence (no association) was tested with a 5% level of significance. The statistical program IBM SPSS V.28 was utilized to conduct the analysis.

#### D. Research Questions

Four key research questions were addressed regarding the use of learning videos to support the students' study, in a pre and post-COVID-19 pandemic period:

- 1) What is the student's opinion about the use of videos in general (such as YouTube videos) to learn and, has this opinion changed due to the COVID-19 pandemic?
- 2) Is there a relation between using videos in general (such as YouTube videos) to learn and the degree of difficulties in studying Mathematics?
- 3) Is there a relation between the use of *b-Mat@plicada* videos and the degree of difficulties in studying Mathematics?
- 4) How did students rate the quality of the *b-Mat@plicada* videos and what is the difference with the first opinions on these, i.e., before the COVID-19 pandemic?

## IV. RESULTS AND DISCUSSION

#### A. Students' Opinion about the Use of Learning Videos to Study and the Effect of the COVID-19 Pandemic

The results of the questionnaire showed that most students occasionally (58.7%) or frequently (36.5%) resort to learning videos available on the Internet (for example, on YouTube) to understand or review content that is taught in class. Only 5 students (4.8%) indicate that they never use learning videos. In 2018, this last number was higher (14.3%), which shows a new study habit that students acquired during the COVID-19 pandemic.

Table II presents the results respecting the students' opinions on the quality of learning videos available on the Internet, such as YouTube videos, in a pre (2018) and a post (2022) COVID-19 pandemic phase. In 2022, more than half (57.7%) believe that the videos available on the Internet are very diverse and clear. But 37.5% indicate that the videos available on the Internet are not always of good quality,

depending on the research topic. Only 4.8% never look for educational videos to help them with their study. Comparing with the results obtained in 2018, we can observe an increase in the search for online videos to study and an improvement in the quality of the videos that are available on the Internet. This phenomenon can be explained by the occurrence of the COVID-19 pandemic: the increase in the number of videos led to generally better quality and the online learning imposed by the confinement forced the students to use another type of material to study.

TABLE II: FREQUENCIES RELATING TO THE OPINIONS ON THE QUALITY OF VIDEOS IN GENERAL TO LEARN

Item	2018 (N = 63)		2022 (N = 104)	
	n	%	n	%
- I never look for learning videos to help me with my study;	9	14.3	5	4.8
- Videos available on the Internet are not always of good quality, depending on the research topic;	26	41.3	39	37.5
- The videos available on the Internet are very diverse and clear;	24	38.1	60	57.7
- The videos never have quality;	4	6.3	0	0

Observing the results reported in Table III, where the student’s view on the usefulness of the learning videos is presented, the majority (97.1%) consider that the educational videos can be useful and beneficial in student learning, and only 2.9% do not have any opinion on that matter. The same conclusion has been obtained in 2018, but with a lower percentage (89.8%), which means that students consider videos more useful after the pandemic. This variation can be explained by the new study habits caused by online learning during the COVID-19 pandemic, so the students are more familiar with this type of content. Another possibility to explain this is the fact that some students were forced to use videos to study due to the confinement, so they had the opportunity of trying a new form of study and recognized their usefulness. This reinforces the positive aspects of the learning videos, reported in the literature [21–24].

TABLE III: FREQUENCIES RELATING TO THE USEFULNESS OF THE LEARNING VIDEOS TO STUDY

Item	2018 (N = 49)		2022 (N = 104)	
	n	%	n	%
- I have not opinion on the usefulness of the videos to learn;	4	8.2	3	2.9
- I consider that the learning videos are useful and positive to study;	44	89.8	101	97.1
- I consider that the learning videos are not useful and positive to study;	1	2.0	0	0

The effect of the COVID-19 pandemic on the use of videos to learn, observed in the last results (Tables II and III), was also confirmed in a question of the survey: 46.2% started

using educational videos more frequently to study since the pandemic and 47.1% indicate that the pandemic made no difference and that they use the learning videos just as often.

Despite the positive opinions of the students on the usefulness of learning videos, 100% consider that these can not substitute traditional face-to-face lectures. The same result was obtained in 2018. Even with the occurrence of the COVID-19 pandemic, students continue to view videos as complementary content. This indicates that the experience of online learning during the pandemic did not modify the importance that students give to face-to-face classes [35, 36].

Observing Table IV, we can conclude that all students inquired believe that, particularly in the area of Mathematics, the learning videos can complement (and not substitute) the classes. More than half considered that the main advantages that videos have about more “traditional” material are that: they allow clarifying doubts (68.3%) and allow to remember content (58.7%), which means that they rely on the videos after attending classes. Only 10.6% consider that the videos help to modernize teaching. These results align with previous analyses where the two most selected benefits were the clarification of doubts and the remembering of contents [37].

TABLE IV: FREQUENCIES RELATING TO THE ADVANTAGES OF LEARNING VIDEOS

Item	2018 (N = 63)		2022 (N = 104)	
	n	%	n	%
- The videos allow me not to be so impaired if I miss classes	21	33.3	47	45.2
- The videos allow clarifying doubts	48	76.2	71	68.3
- Videos allow you to remember content	38	60.3	61	58.7
- Videos help to modernize teaching;	10	1.9	11	1.6
- Sometimes I find less technical languages that help me to better understand	0	0.0	1	1.0

Table V shows the reasons why videos cannot replace face-to-face classes, according to the students’ opinions. The majority (76%) point out that videos cannot replace face-to-face classes because the space for dialogue and discussion between students and the Professor is essential. On this matter, almost half (48.1%) explain that to study only with the help of videos, a lot of self-discipline is required. Equally registered are the opinions that interactions with their peers are important in their learning (37.5%) and that going to face-to-face classes is more motivating than studying only with videos (38.5%). Only 3.8% pointed out that they do not like to use digital technologies, to study to justify why videos cannot replace face-to-face classes. Compared to the results of the pre-pandemic study [37], although the number one reason maintains its ranking, showing that the importance of the dialogue between the teacher it is still the number one reason, there was a shift in the ranking regarding the other aspects. For example, the interaction with the colleagues that ranked 2<sup>nd</sup> in the previous studies is now in the 4<sup>th</sup> position, changing positions with the self-discipline required to study only with the help of videos.

Table VI shows the three most important characteristics to

be considered in a learning video so that it has quality, according to the students' opinions. The three aspects most relevant for a learning video to have good quality are the quality of speech (76.9%), the sound quality (62.5%) and the image quality (57.7%). The timbre of the voice and the aesthetic aspects of the videos are the least relevant aspects (9.6% and 12.5%, respectively). Compared to the reported pre-pandemic study [37], the ranking of the most important aspects is maintained, with only an exchange between second and third places.

TABLE V: FREQUENCIES RELATING TO THE REASONS WHY VIDEOS CANNOT REPLACE FACE-TO-FACE CLASSES

Item	2018 (N = 63)		2022 (N = 104)	
	n	%	n	%
- The space for dialogue and discussion between students and the Professor is essential;	56	88.9	79	76.0
- Interactions with my peers are important in my learning;	30	47.6	39	37.5
- To study only with the help of videos, a lot of self-discipline is required;	18	28.6	50	48.1
- Going to face-to-face classes is more motivating than studying only with the videos;	23	37.5	40	38.5
- I don't like to use digital technologies to study;	4	6.4	4	3.8
- Other: In the videos, the examples are very simple and for this reason, I think that videos cannot substitute face-to-face classes	1	1.6	0	0.0

TABLE VI: FREQUENCIES AND RANKING OF THE MOST IMPORTANT ASPECTS FOR A LEARNING VIDEO TO HAVE QUALITY

Item	2018 (N = 63)		2022 (N = 104)	
	Ranking Place	%	Ranking Place	%
Quality of speech.	1 <sup>st</sup>	79.4	1 <sup>st</sup>	76.9
Quality of image	2 <sup>nd</sup>	71.4	3 <sup>rd</sup>	57.7
Quality of sound.	3 <sup>rd</sup>	57.1	2 <sup>nd</sup>	62.5
Video length.	4 <sup>th</sup>	34.9	4 <sup>th</sup>	32.7
Timbre of voice	5 <sup>th</sup>	19.1	7 <sup>th</sup>	9.6
Animations	6 <sup>th</sup>	14.3	5 <sup>th</sup>	14.4
Aesthetic aspects.	7 <sup>th</sup>	4.8	6 <sup>th</sup>	12.5
Others: "Many different examples."	8 <sup>th</sup>	1.6		

**B. Relation between the Use of Videos in General (Such As YouTube Videos) to Learn and the Degree of Difficulties in Studying Mathematics**

Examining the relation between the frequency of usage of educational videos on the Internet and the reported degree of difficulties in studying mathematics, a statistically significant association was found (Chi-square independent test p-value = 0.022), however in a moderate strength (Cramer's V = 0.272). Analyzing the graph in Fig. 1, we can observe that the students that frequently make use of the learning videos are,

indeed, the ones that admit to frequently having more difficulties in studying mathematics.

Relation between the usage of learning videos available in the Internet (eg, on Youtube) with degree of difficulties in studying Mathematics

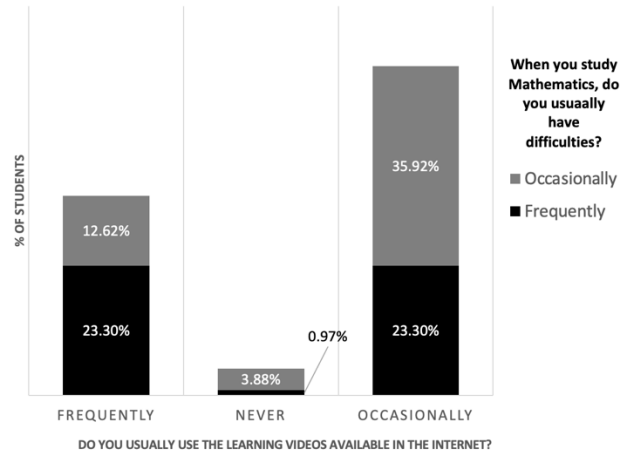


Fig. 1. Relation between using learning videos and the degree of difficulties in studying Mathematics.

**C. Relation between the Use of b-Mat@plicada Videos and the Degree of Difficulties in Studying Mathematics**

These are students that occasionally (51.9%) or frequently (47.1%) have difficulties studying Mathematics. Examining the relation between the frequency of usage of the learning videos and the reported degree of difficulties in studying mathematics, a statistically significant association was found (Chi-squared independent test p-value = 0.037), however in a moderate strength (Cramer's V = 0.253). Analyzing the graph in Fig. 2, we can observe that the students that frequently make use of the learning videos are, indeed, the ones that admit to frequently having more difficulties in studying mathematics.

Relation between the usage of learning videos created within the scope of b-Mat@plicada project with degree of difficulties in studying Mathematics

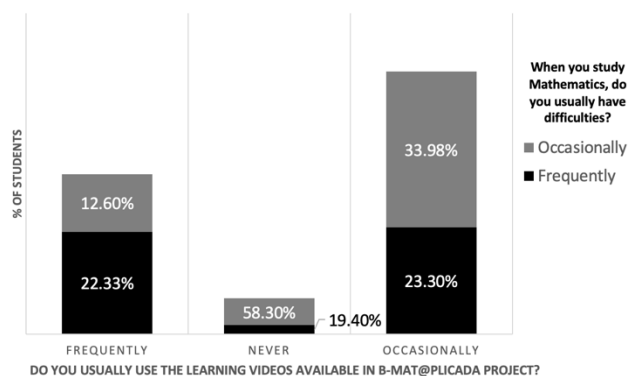


Fig. 2. Relation between using the b-Mat@plicada videos and the degree of difficulties in studying Mathematics.

**D. Students' Opinions on the b-Mat@plicada Videos**

Regarding the b-Mat@plicada course, these are students that occasionally (59%) or frequently (35.6%) use the videos created (Fig. 3). This result is, as expected, highly associated with resorting to learning videos available on the Internet (for example, on YouTube) (Qui-square independent test p-value < 0.001, and Cramer's V = 0.702), which indicates that the

frequency of usage of the *b-Mat@plicada* videos is associated with the reported frequency of usage of videos on the Internet.

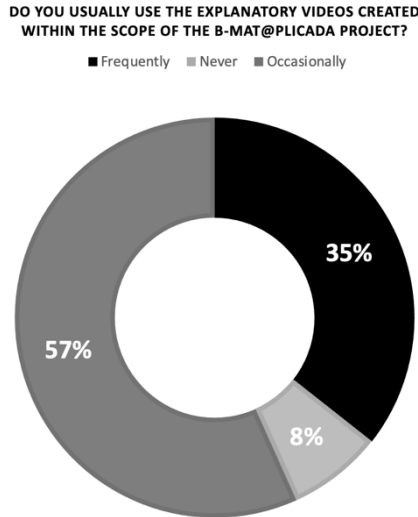


Fig. 3. Frequency of use of the *b-Mat@plicada* videos.

Table VII shows the students’ opinions regarding the learning videos created within the scope of the *b-Mat@plicada* course. These data were compared with the results obtained in a previous study performed in 2015, where the students rated the quality of the *b-Mat@plicada* videos [32]. In general, the opinions are positive. Comparing the results of 2015 and 2022, respecting the number of available videos: in 2015, only 9 videos were available, and the medium obtained for “the number of videos available was sufficient” is 3.9. In 2022, even with 38 *b-Mat@plicada* videos, the medium is even lower (3.74). The pandemic led to a higher demand for online learning videos, as concluded in other studies [23, 24].

TABLE VII: DESCRIPTIVE STATISTICS OF THE RATINGS ON THE QUALITY OF THE B-MAT@PLICADA VIDEOS (MEAN AND STANDARD DEVIATION)

Item	2015 (N = 52)		2022 (N = 96)	
	Mean	SD	Mean	SD
The videos are clear.	4.60	0.53	4.40	0.58
The videos were a good help during my study.	4.37	0.63	4.26	0.70
Videos have good image quality.	4.42	0.61	4.48	0.60
Videos have good sound quality.	4.35	0.74	4.29	0.71
I like the inclusion of music at the beginning and end of the videos.	3.71	0.96	3.91	0.81
The videos were well publicized.	4.19	0.86	4.2	0.89
The contents covered in the videos are adequate.	4.52	0.54	4.34	0.72
The video length is adequate	4.19	0.77	4.34	0.67
The amount of videos available was sufficient.	3.9	0.82	3.74	0.98
I liked the effects/animation of the videos, that is, the colors, arrows, circles that appear throughout the explanation.	Not included item in 2015.		4.16	0.72

## V. CONCLUSIONS

The present study investigates the answers of 104 students from a Portuguese HE institution regarding a satisfaction survey about the use of learning videos to study Mathematics and the contents of the *b-Mat@plicada* course. The survey was applied in the year 2022, in a post-COVID-19 pandemic phase. Results were compared to opinions collected and analyzed in the pre-pandemic phase, specifically in the years 2015 and 2018. In addition to the objective of making inferences regarding students’ opinions about the use of videos in general (such as YouTube videos) and the *b-Mat@plicada* videos to learn, we aim to understand if the opinions changed due to the COVID-19 pandemic. Furthermore, we intended to understand the relations between using videos in general to learn and the degree of difficulties in studying Mathematics, and between the use of the *b-Mat@plicada* videos and the degree of difficulties in studying Mathematics.

From the results, we perceived a growth in online learning video pursuits for educational purposes as well as an improvement in the quality of the videos that are readily available online. The COVID-19 pandemic’s occurrence can be used to explain this phenomenon: the increase in video production led to an overall improvement in quality, and the confinement-imposed online learning required students to use different types of study materials.

Most of the students who responded to the survey believe that educational videos can be helpful for students learning. Students now perceive videos as being more useful following the pandemic, according to the observed increase in this opinion frequency from 2018 to 2022. Again, this variation can be explained by the new study habits brought about by online education during the COVID-19 pandemic, which has given students more exposure to this type of material.

However, students still perceive online learning videos as supplemental content, despite the COVID-19 pandemic’s occurrence. The two most selected benefits were, in 2018 and 2022, the clarification of doubts and the remembering of contents. This demonstrates that students’ attitudes toward in-person instruction has not changed due to their online learning experiences during the pandemic.

The significant association found between the use of videos in general (such as YouTube videos), and the *b-Mat@plicada* videos, to learn, and the degree of difficulties in studying Mathematics, gives support to the necessity of this project to the range of students with more difficulties in the study of Mathematics. It was found that the students that frequently make use of the learning videos are, indeed, the ones that admit to frequently having more difficulties in studying mathematics.

Finally, the reported students’ opinions on the learning videos of the *b-Mat@plicada* project are positive. However, although the number of available videos in 2022 increased considerably, the students reported this number as insufficient. This result supports the idea that the pandemic led to a higher demand for online learning videos, as concluded in other studies from the literature.

### 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 approved the final version.

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