THE IMPACT OF DISTANCE LEARNING ON THE TEACHING-LEARNING PROCESS OF MATHEMATICS IN HIGHER TECHNICAL EDUCATION

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ABSTRACT

This study evaluates the impact of distance learning in the teaching-learning process of mathematics in Higher Technical Professional courses. The results reveal that a positive evaluation of the functioning of the online support platform, as well as a positive attitude of teachers and students, has a positive impact on the evaluation of the functioning of mathematics classes. The functioning of the classes in the distance learning modality has a positive impact on the evaluation of the mathematics teaching-learning process. The evaluation of the platform and the students' attitude also indirectly influence the evaluation of the teaching-learning process.

Keywords: online teaching; higher education; teaching-learning process; students' attitude; teachers' attitude; mathematics.

INTRODUCTION

With the COVID-19 pandemic, new terms have entered the daily vocabulary and new realities have become routine, such as distance learning (Cao et al., 2020; Händel et al., 2020; Owusu-Fordjour et al., 2020). The number of homeschoolers due to school and university closures has surpassed 1.5 billion worldwide (UNESCO, n.d.). Many studies focused on how schools responded and how online classes worked (Ali, 2020; Bao, 2020; Kapasia et al., 2020).

Mathematics is a mandatory subject in the school curriculum around the world and has come to be taught and learned at a distance. However, it is one of the education areas where students have the most difficulty, even in higher education. Therefore, many studies have sought to understand their difficulty from different perspectives and to propose new solutions to facilitate the teaching and learning of mathematics (Langoban, 2020). Many new methodologies have been implemented that allow a better understanding of its concepts and, ultimately, boost the students' learning success.

Thus, this study aims to assess the impact of distance learning of mathematics in Higher Professional Technical Courses (TESP), which are offered in Portuguese higher education. In the 2019/2020 academic year, 15,500 students were enrolled in these types of courses (Direção Geral do Ensino Superior, 2020), which are differentiated by their learning model, where collaboration with companies is fundamental and where the curricular units are taught with a strong connection to the business environment. Their students come mostly from vocational education and have large gaps in mathematics, which made teaching this subject online even more challenging. Thus, this study focused on evaluating the inputs that affect the distance teaching-learning process of mathematics, namely, the quality of the online platform, the attitudes of teachers and students, and the functioning of the teaching sessions. Distance learning was widely implemented during the Covid-19 pandemic, forcing institutions, teachers, and students to familiarize themselves with a new model of teaching and learning and to rapidly adapt to the new model while facing many obstacles. In disciplines such as mathematics where, traditionally, more conventional and less interactive methodologies were used—combined with the difficulties inherent to the area of the study itself—even more teaching obstacles emerged.

This empirical study, in addition to being a new contribution to the existing literature on mathematics teaching and distance learning, presents the novelty of having been carried out during the Covid-19 pandemic, and therefore, is an important contribution to its impact on teaching. On the other hand, this study focused on students in TESP, for whom there are still very few studies.

LITERATURE REVIEW

Distance Learning in Higher Education

The Covid-19 pandemic imposed important changes in the teaching-learning process at all educational levels, which modified the relationship between students and teacher from face-to-face teaching to fully distance learning during periods of lockdown while following government decisions to continue previously defined study plans. This change was supported by internet-based teaching methodologies that altered the attitudes of students and teachers towards the teaching and learning process (Abou El- Seoud, et al. 2014).

In the case of higher education, several studies have shown that there are some advantages of this teaching modality for these students, such as greater flexibility, greater interaction, the fact that it allows the simultaneous use of synchronous and asynchronous activities (e.g., email, chats, videoconferencing) during the learning process, the ease of sharing content, the control of time spent on the learning, and the possibility of adapting to the defined objectives and the needs of the target audience (Adnan & Anwar, 2020; Dhawan, 2020; Marinoni et al., 2020; Suresh et al., 2018). The use of online learning tools in classes increases students' interest and satisfaction towards the distance learning method (Kaddoura & Al Husseiny, 2021).

The success of distance learning has been discussed over the years and shows that low satisfaction rates are related to a lack of time for completing activities by students, a lack of motivation, problems with the technology chosen, a lack of technological support for students, the poor graphics of the platforms, a lack of competence by teachers for distance learning, a lack of customization of the platforms, and the lack of adequacy of the content to be used in distance learning (Frankola, 2001; Selim, 2003; Wang, 2003). These determinants of distance learning success have begun to be categorized and Selim (2007) grouped these factors into four dimensions: teachers, students, information technology, and university support. Sun et al. (2008) identified six dimensions (students, teachers, courses, technology, design, and environment), Liaw et al. (2007) two dimensions (students and teachers), Ozkan and Koseler (2009) six dimensions (system quality, service quality, content quality, students' perspective, teachers' attitudes, and support offered), and Machado-Da-Silva et al. (2014) three dimensions (information quality, system quality, and service quality). Cidral et al. (2018) identified as drivers of satisfaction in distance education the quality of information, the quality of the technological system, the attitude of teachers, the diversity of assessment, and the student's perception of interaction with others. In summary, the main obstacles that affect the distance learning process are related to the technological platform used, the students' attitudes, and the teachers' attitudes.

Regarding the technological platform, ease of use is the main characteristic for accepting the technology supporting distance learning as being effective and efficient (Selim, 2003), along with the ease of access and the interface design being appealing (Selim, 2007; Volery & Lord, 2000), the level of interaction that the platform allows between students and learners in virtual classes (Volery & Lord, 2000), the quality of the systems, the quality of the service, and the quality of the internet connection (Chiu et al., 2007; Moreno et al., 2017; Ozkan & Koseler, 2009; Roca at al., 2006; Wang & Wang, 2009). Thus, platforms that have a greater number of the mentioned characteristics have a positive impact on online classes.

Regarding students, distance learning has proven to be a process that decreases their motivation, increases the isolation and distance between students and teachers and accentuates the delay between teaching and learning, since teachers are not available whenever students need them (Yusuf & Al-Banawi, 2013). Coman et al. (2020) reported that these obstacles are compounded if learning is exclusively online and they also identified that accessibility, connectivity, lack of appropriate devices, and social problems were the main challenges encountered by students in the transition from traditional to distance learning. Motivation is considered one of the most important variables that affects the performance of online students (Castillo-Merino & Serradel-López, 2014); that is, positive student attitude has a positive impact on the functioning of distance classes.

On the other hand, distance learning has also posed obstacles to the attitude of teachers because specific methodologies are required for this type of teaching that differ from traditional ones. This combined with a very short adaptation time and the fact that many of the teachers have never taught in the distance modality were big obstacles. These obstacles are minimized when teachers are already familiar with distance learning platforms and new information technologies (Kisanga, 2016; Krishnakumar & Rajesh Kumar, 2011), technological tools (hardware and software), and didactic approaches appropriate to distance learning, and they have greater pedagogical skills and a positive motivation to encourage better interaction with students (Tuparova et al., 2006). Thus, better preparation of teachers for distance learning positively impacts their attitude, which, in turn, positively influences the functioning of distance classes.

Distance Learning in Mathematics and Related Areas

Mathematics education and knowledge play an essential role in the development of the individual and society. Students often exhibit considerable anxiety associated with mathematics (Dillon, 1982). Besides, negative experiences when learning this area of knowledge are associated with lower demand for STEM fields—Science, Technology, Engineering, and Mathematics (Petrillo, 2016), which has a future impact on the labor market. The difficulty in learning mathematics is associated, according to Nordin (1992), with the animosity that students feel, which stem from fear, resistance, perseverance, and other underlying factors. Also, the lack of connection between syllabi and their applicability in real-life situations, as well as some little concern that teachers may show for individual differences in students, limits the learning (Nordin, 1992). Other factors such as attitude, interest, peer influence, and perception of teacher preparation are correlated with the success of the mathematics teaching and learning process (Abu Bakar et al., 2009; Leng, 2006; Tew, 2004.

TESP students have major gaps in their mathematical training. The areas where they have the greatest need for reinforcement of learning are Algebra, Geometry, and Functions, and these difficulties are worse among students who come from vocational courses (Monteiro, 2020). It is known that if students feel challenged, motivated, and interested, the level of effort they will put into learning mathematical content is greatly increased (Ahn & Edwin, 2018). Coupled with the difficulty already experienced in learning mathematics are all new dynamics imposed by distance learning. Distance learning technologies allow students to study independently and organize a continuous learning process (Bobyliev & Vihrova, 2021). Studies reveal that student satisfaction with distance learning courses is associated with the teaching-learning environment, teaching resources used, student-teacher interaction, individual attitude, and teaching methodologies (Goh et al., 2017; Topal, 2016). Therefore, it is crucial to understand the impact of distance learning on the teaching-learning process of mathematics to better prepare students in the future.

Previous experiences involving the use of new technologies, either by distance learning or by using previous videos—the so-called flipped learning model, show a positive impact on the success of learning this subject. This new model has a positive effect on teaching-learning compared to the traditional one since the percentage of time available in the classroom for the practical component increases and the introduction of new knowledge and the respective feedback are done in real time. On the other hand, the biggest challenges facing the flipped teaching model have to do with the students' unfamiliarity with the methodology and the initial preparation effort required of teachers (Lo et al., 2017).

Akugizibwe and Ahn (2020) show that

the effective integration of elearning tools in mathematics teaching in higher education makes this area of knowledge more attractive to students, awakening in them a predisposition to perform individual tasks for which, before the use of these tools, there was no interest and to use different applications in the different curricular units of mathematics. Among the main results of the adoption of elearning in developed countries are an increased understanding of the studied topics, the ability to solve problems and apply the learned knowledge, and a greater willingness for self-learning. The elearning method leads to improvement in adult mathematics students and is effective for its implementation in adults (Moreno-Guerrero et al., 2020).

Regarding the adoption of new technologies in Algebra classes, students value the time that the use of these technologies offers and the possibility of learning at one's pace (Braun et al., 2014; Clark, 2015; Murphy et al., 2016). On the other hand, the availability of these tools allows students to grasp the concepts and to identify doubts that can later be clarified with the teacher or with other classmates (Carney et al., 2015; Kirvan et al., 2015; Ogden, 2015). In the Statistics' area, previous research shows that final grades increased when virtual learning of statistical concepts was used (Cilli-Turner, 2015; Gundlach et al., 2015; Haughton & Kelly, 2015), and that this teaching typology fostered feelings of greater self-confidence and success and a better understanding of concepts and their application in real-life situations (Kraut, 2015; Kuiper et al., 2015), all because elearning is more engaging and students are more satisfied with the subject (McBride, 2015; Peterson, 2016; Touchton, 2015). In applied mathematics classes, students appreciate the new role that the lecturer assumes as a facilitator of learning and not a sole figure in transmitting knowledge. Moreover, they recognize that they have a greater responsibility in the individual teaching-learning process and that online resources motivate them (D'addato & Millet, 2016; Muir & Geiger, 2016; Schroeder et al., 2013).

The use of elearning tools in this area of knowledge increases students' engagement with themselves, their performance, and their acquisition of mathematical knowledge (Mulqueeny et al., 2015). The use of the so-called social regulation-based online learning framework increases students' learning behaviors and their self-modification and notes organization, and it leads to a higher knowledge construction (Hwang et al., 2021). Some models in which elearning has been implemented as a teaching model have brought interesting results in this area and bring to light the importance of teaching-learning methods in the development of new pedagogies using new technologies. The MCIEC Method (motivation, context, interactivity, evaluation, and connectivity) increases the students' level of engagement and their level of effort for understanding mathematical concepts (Ahn & Edwin, 2018). The WCM (working memory capacity) method, on the other hand, results in a clear improvement in performance and in the ability to grasp a wide variety of mathematical concepts (El Mamoun et al., 2018).

The predictors of satisfaction with the use of elearning tools are the quality of the internet services, the effective use of tools for content development and the perceived individual problem-solving ability (Akugizibwe & Ahn, 2020). Poor internet access, inflexible class schedules, and inadequate computer equipment significantly affect student learning and achievement (Msomi & Bansilal, 2018). The quantity and quality of the prepared online materials leads to high levels of student satisfaction (Pócsová et al., 2021). Mathematics teaching during Covid-19 lock down in the spring of 2020 revealed that online teaching had a positive influence on motivation, autonomy, application of concepts, achievement, and the grades obtained by adult students (Moreno-Guerrero et al., 2020).

CONCEPTUAL MODEL

Considering the literature review, a conceptual model was created, as shown in Figure 1. This model focuses on five latent variables: Teaching and Learning Process and Functioning of Online Classes, endogenous latent variables, and the remaining exogenous latent variables (online platform, student attitudes, and attitude of the teachers). Thus, the latent variable Teaching and Learning Process will be directly and indirectly influenced by the other latent variables—online platform, functioning of online classes, teachers' and students' attitudes, and the latent variable Functioning of Online Classes will also be influenced by the latent variables' online platform and teachers' and students' attitudes.

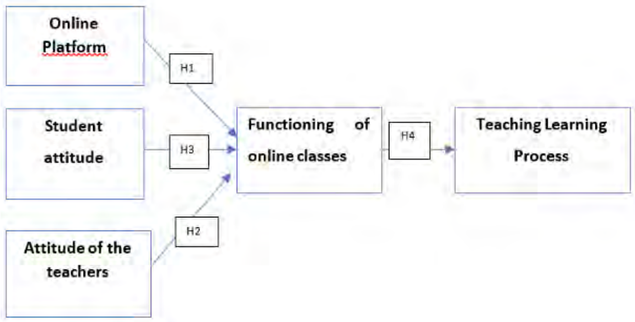

Figure 1. Structural Model

Given the conceptual model, the following hypotheses (shown in Figure 1) were formulated and tested in this study:

H1: A positive evaluation of the platform used in online mathematics classes has a positive impact on the evaluation of the functioning of mathematics classes;

H2: A positive attitude of mathematics teachers in online classes has a positive impact on the evaluation of the functioning of mathematics classes;

H3: A positive attitude of students in online mathematics classes has a positive impact on the evaluation of the functioning of mathematics classes;

H4: A positive evaluation of the functioning of these classes has a positive impact on the teaching and learning process in online mathematics classes.

METHODOLOGY AND DATA

Bearing in mind the main objective of assessing the impact of distance learning in the teaching and learning process of mathematics in the case of Higher Professional Technical Courses, this study uses a quantitative methodology. The sample of this case study is composed of 97 valid responses collected through a questionnaire made available online to TESP students from the Technical Higher Professional School of the Polytechnic Institute of Cávado and Ave. This is the first higher school in the country dedicated to TESP.

The applied questionnaire has 50 questions that are divided into six groups: (1) the evaluation of the online platform used in mathematics classes with eight questions; (2) the attitude of mathematics teachers with eight questions; (3) the students' attitude in online math classes with four questions; (4) the operation of online math classes with nine questions; (5) the teaching and learning process in online mathematics classes with 16 questions; and (6) the sociodemographic characteristics of the respondents with five questions, namely gender, age, education, employment situation, and municipality of residence.

All responses to the questions were measured using a 5-point Likert scale, with the exception of the group of questions related to sociodemographic characteristics. The group of questions for the evaluation of the platform used in online mathematics classes used the scale from 1—very bad to 5—very good; the groups of questions about the attitude of mathematics teachers, the attitude of students in online math classes, and the teaching and learning process in online math classes used the scale 1—strongly disagree to 5—strongly agree; the group of questions related to the functioning of online mathematics classes used the scale from 1—very bad to 5—very good.

RESULTS AND DISCUSSION

The statistics on the sociodemographic characteristics of the respondents were calculated using IBM SPSS Statistics v25 and are shown in Table 1. It should be noted that 95.9% of the respondents were men and the average age was 21.16 years, with a minimum age of 18 years and maximum of 43 years. Regarding their professional situation, 80.4% were students and 19.6% were student workers.

TABLE 1. STATISTICS OF SOCIODEMOGRAPHIC VARIABLES

Variable		Frequency	Valid Percent	Cumulative percent
Gender	Men	93	95.6	95.6
	Women	4	4.1	100
Age	Under 20 years	68	70.1	70.1
	21–30 years	24	24.7	94.8
	Above 31 years	5	5.2	100
Professional situation	Student	78	80.4	80.4
	Student Worker	19	19.6	100

TABLE 2. MEAN AND STANDARD DEVIATION OF ANSWERS TO QUESTIONS FROM GROUPS G1 TO G5

	Mean	Std. Deviation
G1—Evaluation of the online platform		
Q1-- Access	4.06	0.788
Q2—Ease and comfort of use	3.93	0.893
Q3-- Features	3.82	0.829
Q4—Graphic appearance	3.68	0.884
Q5—Motivation of the platform for its use	3.32	1.295
Q6—Suitability of the platform to UC	3.47	1.200
Q7—Difficulty and complexity of the learning process using the platform	3.24	1.188
Q8—Overall satisfaction	3.55	0.979
G2—Evaluation of the functioning of online mathematics classes		
Q9—Adequacy of measures/strategies	3.68	1.114
Q10—Interaction between teacher and students	3.86	1.080
Q11—Quality of the teaching-learning process	3.49	1.234
Q12—Adequacy of UC workload outside class hours	3.42	1.383
Q13—Classes were on schedule	4.04	1.298
Q14—The classes had the expected duration	4.10	1.246
Q15—Satisfaction with the way the UC was presented	3.75	1.242
Q16—The assessment was adequate for the course unit	3.67	1.264
Q17—The evaluation tests were adequate	3.54	1.308
G3—Teacher's attitude		
Q18—The teacher motivated and encouraged participation	4.08	1.017
Q19—The teacher supported the clarification of doubts	4.15	1.083
Q20—The teacher was available to accompany the students, outside the class period	4.00	1.216
Q21—The teacher was attentive to the students' difficulties	3.98	1.199
Q22—The teacher was clear in the exposure of the contents	4.01	1.113
Q23—O promoted interaction between all	3.71	1.414
Q24—The teacher valued the participation of students in the proposed online activities	3.97	1.220
Q25—The teacher was assiduous and punctual	4.07	1.460
G4—Student attitudes		
Q26—During the online classes I actively participated and answered the professor's questions	3.65	1.242
Q27—I carried out the proposed activities within the defined deadlines	4.08	1.133
Q28—Did it interfere with my physical and/or mental well-being	3.10	1.510
Q29—I felt involved with distance activities	3.39	1.319
G5—Teaching and learning process in online math classes		
Q30—Online mathematics teaching is more efficient than face-to-face teaching	2.25	1.339
Q31—Online mathematics teaching is more attractive than face-to-face teaching	2.31	1.357
Q32—My participation in online Mathematics classes was higher when compared to participation in classroom	2.43	1.399
Q33—I felt more inhibited in distance classes	2.89	1.322
Q34—I felt more motivated with distance classes	2.37	1.349
Q35—I am more distracted by distance learning	3.47	1.542
Q36—I felt more autonomous and self-taught	2.80	1.328
Q37—I missed direct contact with the teacher	3.56	1.266

TABLE 2. MEAN AND STANDARD DEVIATION OF ANSWERS TO QUESTIONS FROM GROUPS G1 TO G5 (CONT.)

Q38—I missed collaborative work with my colleagues	3.36	1.430
Q39—I became more involved with distance activities	2.56	1.283
Q40—With distance classes, my use of Mathematics has improved	2.63	1.325
Q41—The teacher supported students more in clarifying doubts, with distance classes	3.05	1.365
Q42—The teacher was more attentive to the students' difficulties, with the distance classes	3.08	1.412
Q43—The teacher motivated students more, with distance classes	3.14	1.346
Q44—The teacher valued students' participation more, with distance classes	3.28	1.405
Q45- The contents made available in distance classes were better than those made available in face-to-face classes	2.58	1.345

Regarding the group of questions on the assessment of the online platform used in mathematics classes, the attitude of students in online mathematics classes, the functioning of online mathematics classes and the teaching, and the learning process in online mathematics classes, the mean and standard deviation of the answers are described in Table 2.

The surveyed students rated the online platform (1—very bad to 5—very good) used in distance classes, in average terms, as good (3.6) with an overall satisfaction of 3.55. The most valued aspects were access (4.06), ease and comfort in use (3.93), features (3.82), and the graphic aspect (3.68). In relation to the group of questions about the evaluation of the functioning of online mathematics classes, the average value of the answers was 3.73. The issues that merited greater agreement were compliance with the expected duration of classes (4.10), operation on schedule (4.04), interaction between students and teachers (3.86), and satisfaction with the unit curriculum presentation (3.75).

The questions related to the teacher's attitude in online math classes had an average response of 3.99. The issues that generated the greatest agreement (1—strongly disagree to 5—strongly agree) were support for clarifying doubts (4.15), motivation and incentive to participation (4.08), the fact that the teacher is assiduous and punctual (4.07), clear exposure of the contents (4.01), and availability to accompany students outside the class period (4.00). In the student's attitude, the questions of greatest agreement among respondents were the performance of the proposed activities within the defined deadlines (4.08) and active participation in online classes (3.65). In the group of questions about the teaching and learning process in online mathematics classes, the answers had an average value of 2.86, and the lack of direct contact with the mathematics teacher was the question with the highest agreement (3.56). The question of online mathematics teaching being more efficient than face-to-face teaching was the one that generated the least agreement (2.25), as seen with questions related to online mathematics teaching being more attractive than face-to-face teaching (2.31), students feeling more motivated in online classes (2.37), participation in online math classes is higher when compared to face-to-face participation (2.43), and the feeling of being more autonomous and self-taught (2.80).

Considering the hypotheses to be tested and the conceptual model in Figure 1, this model was estimated for the data sample collected by Partial Least Squares (PLS) in the Smart PLS 3.0 software. This is still widely used for small samples, as is the case in this study, and the validation of the sample size implies the fulfillment of one of the following conditions: (1) ten times greater than the number of indicators or (2) ten times greater that the number of structural paths directed to a latent variable in the structural model (Hair et al., 2019). The size of our sample is 97 observations, ten times greater than the number of paths directed to a latent variable (for the latent variable Teaching and Learning Process has a total of four paths, three indirect and one direct). Thus, we concluded that the sample size fulfills the conditions for applying the PLS method.

The initial Theorical Path Model inserted in SmartPLS and based on the conceptual model is presented in Figure 2. The Theoretical Path Model contains 45 indicators (represented in the rectangles), which are the answers to the 45 questions in Table 2, and the five latent variables created—

Online Platform, Student Attitudes, Attitude of the Teachers, Functioning of Online Classes, and Teaching and Learning Process (represented as circles). The relationship between the latent variables is in accordance with the formulated conceptual model. Also shown in Figure 2 are path coefficients between latent variables and indicators.

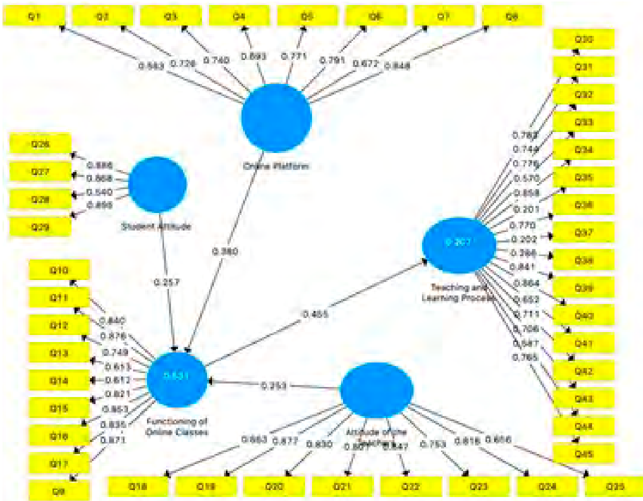

Figure 2. The Application of the PLS Algorithm to the Structural Model Defined in Figure 1

Based on the values of the path coefficients obtained in Figure 2, the statistically significant relationships between the indicators and the latent variables were determined. We concluded that the relationship between Teaching and Learning Process and questions Q35, Q37, and Q38 are of little significance, with these questions explaining only 0.201, 0.202, and 0.286, respectively, of the Teaching and Learning Process. Thus, they were removed from the sample to calibrate the model, using the Global-Minimum Error Uninformative-Variable-Elimination for PLS method as suggested by Andries et al. (2017). Thus, as shown in Table 3, the total number of indicators of the latent variables used to estimate the model is 42 and the new Theorical Path Model estimated by PLS is shown in Figure 3.

TABLE 3. NUMBER OF INDICATORS FOR EACH LATENT VARIABLE

Latent Variables	Initial Number of Indicators	Final Number of Indicators
Online Platform	8	8
Students Attitudes	4	4
Attitudes of the Teachers	8	8
Functioning of Online Classes	9	9
Teaching and Learning Process	16	13
Total	45	42

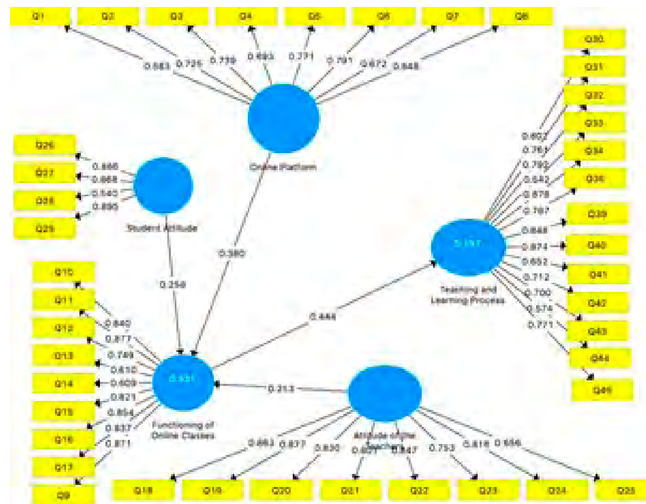

Figure 3. Application of the PLS Algorithm to the Calibrated Model

Path coefficients establish significant relationships between latent variables. As shown in Figure 3, a variation of 1% in the latent variables Online Platform, Student Attitudes, and Attitude of the Teachers have an impact of 38%, 25.8%, and 25.3%, respectively, in the latent variable Functioning of Online Classes, and a variation of 1% in the latent variable Functioning of Online Classes has an impact of 44.4% in the latent variable Teaching and Learning Process.

The validation of the estimated model implies the use of measures of reliability and validity, which implies an analysis of the reliability of each latent variable at the indicator level and the convergent validity and discriminant. The validation in the model of this study showed that all latent variables have high outer loadings (greater than 0.540). The reliability coefficients of latent variables must be greater than 0.70 (Hair et al., 2019). In this model, the values obtained for the reliability coefficients of the latent variables are higher than the reference value (Attitude of the Teachers > 0.937; Functioning of Online Classes > 0.937; Online Platform > 0.901; Student Attitudes > 0.881; Teaching and Learning Process > 0.943). In this way, the reliability coefficients are "satisfactory to good" and all latent variables are above the acceptable values for the outer loadings, reliability, and validity of the estimated model. Cronbach's

Alpha calculates the internal consistency that allows assessing the degree of reliability of the model, with an indicative value of 0.700 (Hair et al., 2019). All latent variables have Cronbach's Alpha values higher than the reference value (Attitude of the Teachers > 0.923; Functioning of Online Classes > 0.924; Online Platform > 0.875; Student Attitudes > 0.819; Teaching and Learning Process > 0.933), so there are higher levels of reliability. The Average Variance Extracted (AVE) is equivalent to the commonality of a latent variable, with the reference value for the AVE being 0.50 (Hair et al., 2019), which means that, on average, the latent variable explains more than half of the variance of its indicators. All latent variable strokes are greater than 0.5.

The Fornell-Larcker criterion was also used as a measure of Discriminant Validity. This criterion analyzes the cross-loadings that are indicators of the discriminant validity of latent variables. As we can see in Table 4, each AVE of the latent variables (elements in the main diagonal that are in bold) are superior to all the square correlations of the latent variables (elements outside the diagonal), thus establishing the discriminant validity of each of the five latent variables.

In short, we concluded that the model shown in Figure 3 complies with the measures of reliability and validity and of discriminant validity, and, therefore, it is a valid model. The validation of the predictive precision of the model was performed through the R Square (R2) values of the endogenous (dependent) latent variables, that is, Functioning of Online Classes and Teaching and Learning Process. According to Chin (1998), the recommended R2 values for the endogenous latent variables are 0.67 (substantial), 0.33 (moderate), and 0.19 (weak). According to this criterion, the PLS algorithm calculated an R2 moderate of 0.531 for the latent variable Functioning of Online Classes and an R2 moderate of 0.197 for the latent variable Teaching and Learning Process, as shown in Figure 3.

A bootstrap analysis was also carried out to assess its statistical significance (95% confidence interval). Table 5 shows the results of this significance test. We concluded that the latent variables Student Attitudes, Online Platform, and Functioning of Online Classes are statistically significant at $p < 0.05$ and the variable Attitude of the Teachers is significant at $p < 0.1$.

The results revealed that the online platform positively influences ($\beta = 0.380$, $p < 0.05$) the functioning of online classes, confirming the first hypothesis, as found by Akugizibwe and Ahn (2020), Lo et al. (2017), Moreno-Guerrero et al. (2020), Hasan et al. (2015), and Mulqueeny et al. (2015). A variation of 1% in the evaluation of the online platform has a direct impact of 38.0% in the evaluation of the functioning of the classes.

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TABLE 4. RESULTS OF FORNELL-LARCKER CRITERION

	Attitude of the Teachers	Functioning of Online Classes	Online Platform	Student Attitudes	Teaching and Learning Process
Attitude of the Teachers	0.808				
Functioning of Online Classes	0.567	0.792			
Online Platform	0.399	0.609	0.732		
Student Attitudes	0.631	0.606	0.495	0.811	
Teaching and Learning Process	0.491	0.444	0.513	0.651	0.751

TABLE 5. SIGNIFICANCE TESTING RESULTS OF THE STRUCTURAL MODEL PATH COEFFICIENTS

	Original Sample	P Values
Attitude of the Teachers → Functioning of Online Classes	0.253	0.069*
Functioning of Online Classes → Teaching and Learning Process	0.444	0.000**
Online Platform → Functioning of Online Classes	0.380	0.001**
Student Attitudes → Functioning of Online Classes	0.258	0.015**

Note: *p<0.1; ** p<0.05

research hypothesis, we found that a positive attitude of Mathematics teachers towards online classes has a positive impact (β =0.253, $p < 0.1$) in the functioning of these online classes, as found by Abu Bakar et al. (2009), Leng (2006), Nordin (1992), and Tew (2004). A variation of 1% in the evaluation of the Attitude of the Teachers has an impact of 25.3% in the evaluation of the functioning of the distance classes.

The positive attitude of students during mathematics classes positively affects (β = 0.258, $p < 0.05$) the functioning of online classes, supporting the third research hypothesis, as concluded by Abu Bakar et al. (2009), Leng (2006), Nordin (1992), and Tew (2004). A variation of 1% in the self-assessment of the students' attitude has an effect of 25.8% in the evaluation of the functioning of the classes in this modality.

The fourth research hypothesis is also confirmed, with a positive assessment of the online functioning of the classes having a positive impact (β = 0.444, $p < 0.05$) on the mathematics teaching-learning process, in accordance with the results obtained by Ahn and Edwin (2018), Akugizibwe and Ahn (2020), Lo et al. (2017), Moreno-Guerrero et al. (2020), and Msomi and Bansilal (2018). In addition, when the evaluation of the functioning of the classes varies by 1%, the evaluation of the teaching-learning process varies by 44.4%.

In addition to the direct path coefficients, the model also allowed estimating three indirect paths of the effects of Attitude of the Teachers, Online Platform, and Student Attitudes on the Teaching and Learning Process, as shown in Table 6. The values are obtained, as an example, for Online Platform → Functioning of Online Classes → Teaching and Learning Process (0.169), results from the combination of the influence Online Platform → Functioning of Online Classes (0.380) and the influence Functioning of Online Classes → Teaching and Learning Process (0.444). This means that a variation of 1% in the evaluation of the Online Platform has an indirect impact of 16.9% in the Teaching and Learning Process. As can be seen in Table 6, all indirect effects are statistically significant with $p < 0.1$ for 95% bootstrap, except for the Attitude of the Teachers variable. All total effects are also statistically significant with $p < 0.01$ and $p < 0.05$ for 95% bootstrap, except for the total effect of the Attitude of the Teachers → Teaching and Learning Process variable, which is not significant.

Considering the direct, indirect, and total effects, the four hypotheses tested in this study are confirmed. That is, in addition to the tested and confirmed hypotheses of the present study, it was also concluded that the evaluation of the online platform has a significant indirect effect on the teaching-learning process, with a 16.9% impact on the evaluation of this process for every 1% that the platform rating varies. The attitude of the students also impacts, in an indirect and significant way, the evaluation of the teaching-learning process, with a contribution of 11.4% in their evaluation by variation of each percentage point in the evaluation of their own attitude. The assessment of the teachers' attitude does not have a significant impact on the teaching-learning process.

TABLE 6. INDIRECT AND TOTAL EFFECTS ESTIMATION RESULTS

		Original Sample	**P Values**
Indirect Effects	Online Platform → Functioning of Online Classes → Teaching and Learning Process	0.169	0.000**
	Attitude of the Teachers → Functioning of Online Classes → Teaching and Learning Process	0.112	0.151
	Student Attitudes → Functioning of Online Classes → Teaching and Learning Process	0.114	0.058*
Total Effects	Attitude of the Teachers → Functioning of Online Classes	0.253	0.069*
	Attitude of the Teachers → Teaching and Learning Process	0.112	0.151
	Functioning of Online Classes → Teaching and Learning Process	0.444	0.000**
	Online Platform → Functioning of Online Classes	0.380	0.001**
	Online Platform → Teaching and Learning Process	0.169	0.000**
	Student Attitudes → Functioning of Online Classes	0.258	0.015**
	Student Attitudes → Teaching and Learning Process	0.114	0.058*

Note: *p<0.1; ** p<0.05

CONCLUSION

The aim of this study was to assess the impact of distance learning on the teaching and learning process of Mathematics in Higher Professional Technical Courses. The important factors in evaluating the platform from the students' perspective are access, ease and comfort in its use, its graphic aspect, and general satisfaction with the platform. In the domain related to teacher evaluation, it is important to highlight punctuality and attendance, the willingness to meet with students outside of class hours, the support given in clarifying doubts, and the attention given to the difficulties presented by students. On the other hand, still in the student's domain, there was a high adherence to the proposed activities and compliance with the defined deadlines. About the operation of online classes, the interaction between teacher and students and compliance with the timetable and duration of the classes stand out. In assessing the teaching-learning process, students assumed that they are more easily distracted and that they miss both direct contact with the teacher and collaborative work with colleagues. On the other hand, they highlight the support and monitoring by teachers and their ability to motivate them for this type of teaching.

From the work developed, it can be concluded that the perception that the online classes functioned in a positive way is influenced by the assessment made of the online platform, by the appreciation of the teachers' attitude, and by the students' own attitudes. On the other hand, the operation of classes in the distance learning modality has a significant impact on the evaluation of the teaching-learning process. Finally, albeit indirectly, the evaluation of the platform and the attitude of the students influence the evaluation of the teaching-learning process. For future work, there is a need for studying the impact of the evaluation of the attitude of teachers in the teaching-learning process, which in the present study was not significant.

This study contributes to the existing literature and provides a better understanding of the impact that distance learning has on the teaching and learning process of Mathematics in general and in Higher Professional Technical Courses in particular. On the other hand, it explores some of the consequences of the pandemic on the teaching and learning process in higher education. In terms of future implications, adopting a platform for distance classes that is easy to use and access, has an appealing design, and allows greater interaction between teacher and students will positively influence the teaching-learning process. It is necessary to motivate students with synchronous and asynchronous activities in the teaching of mathematics, which brings students and the teacher closer together. Regarding teachers, investing in continuing technological and pedagogical training to support distance learning positively influences their attitude and the success of the teaching and learning process.

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