

Emotional impact of online assessment strategies in engineering mathematics during COVID-19 confinement: A study in Mexico City



Elena Fabiola Ruiz-Ledesma *, Lorena Chavarría-Báez, Juan Jesús Gutiérrez-García

Instituto Politécnico Nacional Escuela Superior de Cómputo, Mexico City, Mexico

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ABSTRACT

This study looks into how online testing methods in engineering math classes at a university in Mexico City affected students' emotions during the lockdown caused by the COVID-19 pandemic. It seeks to understand which specific testing techniques increased feelings of frustration, anger, anxiety, sadness, shame, and boredom among students. The research used a quantitative approach, focusing on describing and predicting outcomes, and gathered data from 324 university students chosen randomly. It examined which testing methods were most linked to negative feelings using correlation analysis and built models using ordinary least squares. The findings showed that traditional paper exams and the requirement to keep cameras on during video calls were the biggest sources of negative emotions. On the other hand, interactive methods like chat and forum participation, as well as making information organizers, had little to no emotional impact. The research also found that project-based assessments were emotionally neutral for students. When comparing these results with other studies, there's agreement that written and oral exams cause more stress in online settings. The study suggests using a variety of testing methods to avoid depending too much on any one way of assessing students and recommends making exams count for less. These suggestions aim to help improve the educational experience for students in similar situations.

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1. Introduction

Usually, emotions are sparked by something happening inside or outside of a person that they see as good or bad. Emotions and moods are different. Emotions are stronger but don't last as long. It's noted that students experience a wide range of emotions related to both school and other aspects of their lives (Koppad et al., 2023).

Because of the COVID-19 health crisis during the pandemic years, traditional in-person teaching had to shift to online learning and, in some situations, to a blend of online and in-person (hybrid) methods. This change meant that both students and teachers needed to adjust to new ways of learning and teaching involving the use of technology (Basilaia and Kvavadze, 2020; Xie et al., 2020).

Studies have demonstrated that public health concerns, such as the COVID-19 pandemic, may cause psychological problems for students; its presentation includes a spectrum of anger, fear, anxiety, hopelessness, and boredom (Pelikan et al., 2021; Cao et al., 2020; Khan et al., 2022).

Online learning from home does not have the same level of teacher oversight, support from classmates, or the structured setting of a classroom. This situation can make it harder for students to focus compared to learning in person at school. Furthermore, this method of teaching needs virtual platforms and systems to arrange digital educational materials, learning tasks, quizzes, and tools for communication and social interaction between students and teachers (García-Peñalvo, 2022).

On the other hand, Students' emotional engagement in classrooms has always been regarded as a crucial factor influencing educational outcomes. Emotionally engaged students are highly motivated to attend classes and participate actively in discussions. Conversely, emotionally disengaged students are habitual truants and/or often misbehave in classrooms (Subramainan et al., 2016).

A study by Sosa-Flores et al. (2022) found that the most common feelings among students were

* Corresponding Author.

Email Address: eruilz@ipn.mx (E. F. Ruiz-Ledesma)

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Corresponding author's ORCID profile:

<https://orcid.org/0000-0002-1513-8243>

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worry and tiredness, which were generally negative. This research also offered ways to tackle the adverse effects of the COVID-19 pandemic. Cobos et al. (2013) explored whether there were any connections between the grades students received, either from their peers or teachers, and the emotions detected in their writing. They discovered a relationship between grades and emotions, both at the high and low ends of the grading spectrum.

Research by Karasmanaki and Tsantopoulos (2021) showed that distance learning during lockdown did not yield the best academic outcomes, with many students experiencing negative emotions like frustration, despair, sadness, distress, and anxiety, as supported by findings from Gervacio Jiménez and Castillo Elías (2022), Khodabakhshi-Koolae (2020), and UNESCO (2021). These studies also pointed out that mathematics was a subject where below-average performances were particularly evident.

Given these insights, it's clear that now is a crucial time to think about the future direction of education and how students are evaluated. Therefore, this study focused on how different assessment methods in mathematics affected undergraduate students' negative feelings. The goal was to pinpoint which assessment techniques heightened negative emotions by analyzing the link between these methods and negative feelings using the least squares method. The ultimate objective is to help address the challenges faced by higher education as we move into the post-pandemic era. The findings of this paper could be especially valuable for higher education administrators looking to enhance educational effectiveness during this transition period.

2. Literature review

Educational evaluation is described as an ongoing process that rates both teaching and learning on a specific scale. Its goal is to assess how much knowledge students have gained and how well they have developed their skills. For teachers, this evaluation helps to understand how effectively they have conducted their classes, according to García et al. (2020). To achieve this, it's important to implement strategies that ensure the educational goals for each level are met.

Assessing students is a key part of education, as noted by Wanzer (2021). Qian-Khoo et al. (2022) described this assessment as a continuous effort to track students' progress in learning and skill development through their involvement in teaching and learning activities. Educational evaluation involves gathering evidence to measure and show a student's level of learning and to decide if they have successfully met the requirements for a particular subject, according to Wang and Yu (2021).

Harskamp and Suhre (2007) suggested that online assessments should include methods like project-based learning, contextual problem-solving,

and the integration of knowledge with the aid of digital technologies.

In mathematics, the evaluation can cover various student activities that are part of their learning. This includes assessing how well students can convert problems into mathematical terms, understand necessary concepts, solve exercises and problems, or apply what they've learned to new scenarios. Teachers need to choose what to evaluate and set clear criteria for assessment. For problem-solving tasks, criteria could include extracting problem data, understanding how variables relate, organizing the information, following a logical approach to find a solution, using the correct formulas, finding the answer, and verifying the solution, among others. These evaluation strategies are particularly relevant for remote learning, as discussed by Thomas and Graham (2019) and Jiang et al. (2023).

Tiwari et al. (2021) described evaluation strategies as tools and methods used to assess and quantify students' knowledge, skills, and abilities, especially as they apply these in solving problems. These strategies, particularly during periods of lockdown and in remote learning settings, fall into two categories: synchronous and asynchronous evaluations. Synchronous evaluations happen live during a class session, while asynchronous evaluations are done independently by students at their own pace.

Synchronous evaluations include various types, such as written tests conducted over video conferencing platforms like Zoom or Microsoft Teams, where students are expected to keep their cameras on. Oral exams are also part of this category, where students verbally present solutions to problems or discuss specific topics, again with the requirement to have the camera on. Another form of real-time assessment involves solving exercises and problems in a notebook during the class session. Additionally, timed quizzes are administered through applications like Kahoot, where students respond to questions online, as noted by Muscalagiu et al. (2009).

Asynchronous evaluations involve activities outside of regular class hours, like completing assignments (Grande-de-Prado et al., 2021), working on exercises and problem sets independently using tools like Google Forms or Moodle, engaging in online discussion forums, and creating organizational tools such as concept maps (Setiawan et al., 2020). Discussion forums serve as platforms where participants from various locations can share and discuss their views on specific topics at different times (Nitsche et al., 2022). Additionally, chat functions are used as an assessment tool that supports instant communication and encourages thoughtful reflection (Kim and Sun, 2021).

A research study by Salmela-Aro and Upadyaya (2014) found that evaluations can lead to emotions like stress, distress, anxiety, and frustration in students. Mu and Guo (2022) noted that high-stress levels in students can negatively affect their

academic performance and may lead to symptoms of burnout.

Abaalkhail et al. (2018) described emotions as responses to internal and external triggers. Historically, emotions were considered separate from thinking processes. However, later studies revealed that emotions or moods can significantly affect how we learn. Loewenstein and Lerner (2003) highlighted that emotions play a role in various cognitive functions, including focus, understanding, and recall. Leung and Cheng (2023) further explored how emotions could either positively or negatively impact student learning.

Current educational theory views emotions as complex phenomena that encompass physical reactions, motivations, and expressions (Forsblom et al., 2022). For instance, a student's anxiety about a math exam might involve concern over the possibility of not sitting for the exam (thought-related), feeling uneasy (emotional response), an increase in heart rate (physical reaction), a desire to avoid the exam (motivation), and showing worry through facial expressions (expression) (O'Leary et al., 2017).

Bleakley et al. (2020) emphasized the importance of students' emotions in the learning process, noting their significant interaction with cognitive activities. Lin et al. (2014) found that negative emotions could impact cognitive functions like concentration, memory retention, and recall, leading to poorer academic performance.

Thus, emotions are integral to the learning process, influencing students' ability to evaluate and sustain the effort needed to complete tasks.

Negative emotions are feelings that arise in a person due to bad experiences or difficult situations, such as anger, anxiety, and sadness. Khasawneh et al. (2021) explained that academic anxiety is a type of negative emotion that involves stress, worry, or intense pressure felt by students when they encounter a task they find challenging or feel they cannot manage.

During the COVID-19 pandemic lockdown, students faced numerous challenges that led to negative emotions. These included worries about their health, the grief of losing loved ones, and the uncertainty of their circumstances. Their academic efforts were also hindered by issues like unstable internet access or inadequate computer equipment, as well as distractions from home life during online classes. These conditions made students more susceptible to mood changes, affecting how they responded to different assessment methods used in their education (Chadwick and McLoughlin, 2021). Research by König and Frey (2022) indicated that students felt anxiety, frustration, discomfort, insecurity and had a diminished sense of self-worth during this period.

Research has shown that evaluations can lead to feelings of distress, stress, anxiety, frustration, anger, and sadness among students. Tang et al. (2023) observed that students in science and engineering expressed dissatisfaction with online learning,

particularly with aspects related to communication and questions-and-answers sessions. They also felt that online learning was not very effective and struggled to grasp the material taught.

This research aims to explore how assessments impact the emotions of advanced students in their mathematics courses during the lockdown period. It seeks to understand how different types of evaluations influence the negative emotions experienced by students. The structure of this paper is organized to discuss these elements in a systematic order.

3. Methodology

A quantitative and descriptive methodology of Hernández and Mendoza (2018) was used, considering a random sample of 324 students. The students were registered in the Computer Systems career at the Public Education Institution of Mexico City.

The study included 324 students from the Computer Systems program at the Escuela Superior de Cómputo (ESCOM) of the Instituto Politécnico Nacional (IPN). During the semester from August to December 2021, these students were enrolled in various mathematics courses: 22 in Calculus, 67 in Discrete Mathematics, 93 in Applied Calculus, 18 in Linear Algebra, 45 in Differential Equations, 55 in Probability and Statistics, and 24 in Advanced Mathematics. The survey used in this study had 15 questions organized into three parts. The first part collected basic information such as the participants' ages, the math courses they were enrolled in if they had contracted COVID-19, and if they had been infected during times when assessments were being conducted. This information helped begin to understand the participants' emotional states. The second part included five open-ended questions aimed at exploring the overall impact of technology on the assessment process. The third part of the survey featured 12 questions related to the specific topic of each question with options on a Likert scale ranging from 1 (representing a very negative response) to 5 (indicating a very positive response).

The survey's reliability was verified using Cronbach's alpha, a statistical measure used to assess the consistency of a questionnaire. The document includes Table 1 that details the questions from the first two parts of the survey. The findings and discussions based on these questions are also provided.

Cronbach's alpha was used to measure the reliability of the questionnaire used during the research. The formula used is shown in Eq. 1.

$$\alpha = \left[\frac{k}{k-1} \right] \left[1 - \frac{\sum_{i=1}^k S_i^2}{S_t^2} \right] \quad (1)$$

where, α is Cronbach's Alpha coefficient. k is the number of items in the questionnaire. S_i^2 is the variance of each item in the questionnaire. S_t^2 is the total variance of scores from all items combined.

Table 1: Questionnaire

ID	Item	Response choices
E1	Age	
E2	What math course are you enrolled in?	
E3	Male or female or other?	
E4	Have you had COVID?	Yes No
E5	Have you had COVID during any evaluation period?	Yes No
E6	Were your grades affected by online exams?	0-10 11-20 21-30 More than 30
R1	During the pandemic, have you taken online tests?	Yes No
R2	How many online exams did you take during the August-December 2021 semester?	Traditional camera-on examination Test to go Google Forms Microsoft Forms Edmodo Moodle Kahoot
R3	Select the platform or tool you have used in your math assessments	Traditional camera-on examination Test to go Google Forms Microsoft Forms Edmodo Moodle Kahoot
R4	Which of the assessment strategies caused you to stress?	Traditional camera-on examination Test to go Google Forms Microsoft Forms Edmodo Moodle Kahoot

4. Results and discussion

4.1. Results and analysis of the first block of questions

Table 2 shows the values obtained for the variables in Eq. 1, with an alpha coefficient of 0.7, representing a good consistency among the questions that made up the questionnaire.

Table 2: Values obtained from the survey results questionnaire

Parameter	Value
K	324
k-1	323
k/k-1	1.003
Adding of variances	8.07
The variance of the sum	37.5

The students in the sample ranged between 18 and 23 years. Table 3 shows that 84% of the students had suffered from COVID-19, and 40% suffered from it in evaluation periods from August to December 2021, when the study was conducted. Nevertheless, 100% mentioned that the disease affected their evaluation, as shown in Table 3 of the data obtained.

Table 3: Average of control values obtained

Question ID	Rank in evaluation
E1	18-23 years
E2	Math course
E3	39 women (12%) /285 men (88%)
E4	259 infections
E5	103 infections
E6	100% of those infected

Figs. 1 to 4 show the percentages obtained from the second block of questions through the graphs obtained from Excel after data processing. Fig. 1

shows that about 80% of the students in the sample had submitted between 11 and 30 online exams during the school year from August to December 2021, which shows that one of the instruments most frequently used by teachers to evaluate their students in some mathematics subject was the written exam. According to the literature reviewed (O'Leary et al., 2017), this is one of the instruments that generates the most stress in the student.

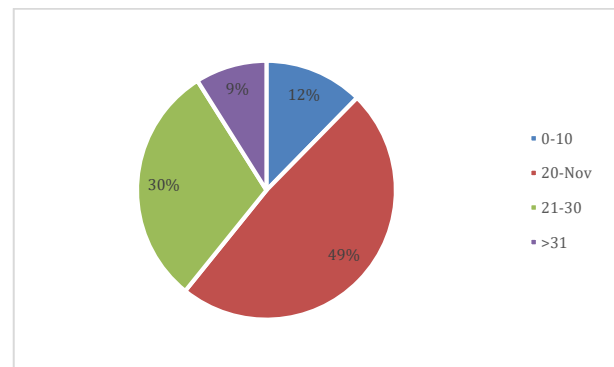
**Fig. 1: The number of examinations performed during the August-December 2021 semester**

Fig. 2 shows it is perceived that more than half of the students were emotionally affected by the evaluations performed online during the semester from August to December 2021, which contributed to the emotional imbalance experienced by the students during the confinement period. Also, Fig. 3 shows a high percentage (58%) that their grades were affected by the type of evaluations performed.

Figs. 3 and 4 show that, within the context of the respondents, the most used forms of evaluation were the traditional exams with the camera on and using a videoconferencing platform. In this regard, it was found that the former are still the ones that generate

the most stress, followed by those performed by the Kahoot platform. This may be due to the pressure due to the reduced time and the presented internet failures, as already studied in other research (Iman et al., 2021). At the same time, the student solved it, generating stress because of the reduced time or the internet failures that had, among other factors (Fig. 4).

It can be noted that the online evaluations caused the students in the sample constant nervousness and stress and accentuated their negative emotions, such as anger and anguish, anxiety, frustration, and sadness.

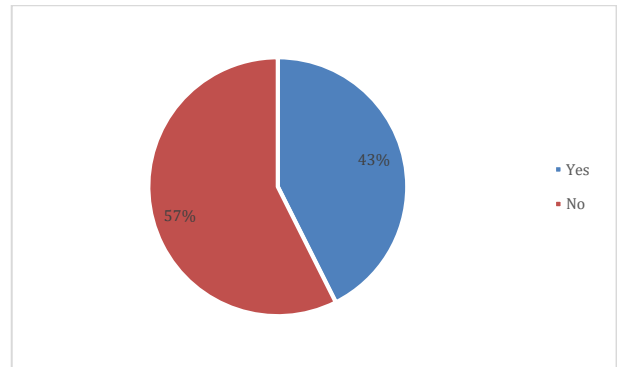


Fig. 2: Perceived impact of online evaluations

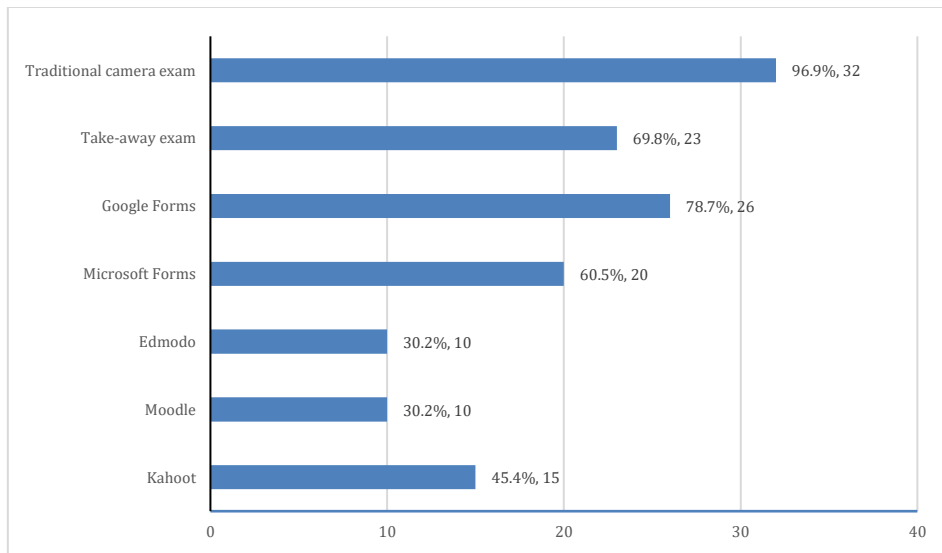


Fig. 3: Platforms and tools used to perform examinations

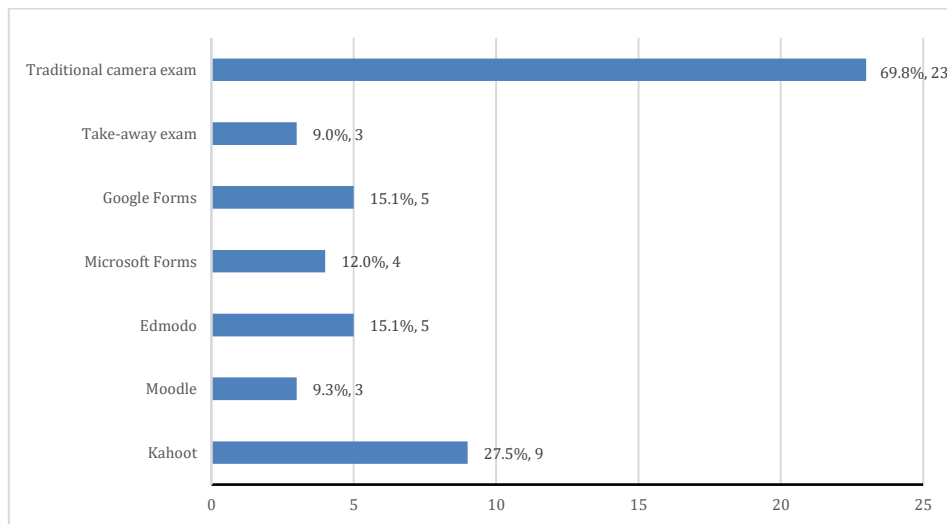


Fig. 4: Perceived stress on the platforms during online evaluations

4.2. Results and analysis of the third block of questions

SPSS software was used to analyze the data obtained from the third block of questions of the questionnaire. The data were correlated around negative emotions (dependent variable), which were produced by the type of evaluation used (independent variables): Online written exams with the camera on and teacher supervision, oral exams, online quiz solving using Kahoot, solving a problem

in the digital pencil, offline quiz solving using Google forms and Moodle, solving exercises and problems in the virtual classroom, random questions in class, extra class activities, exercise lists, projects, essay writing, and information organizers.

These variables were used to elaborate a predictive model related to the level of negative emotions (low and high) caused by the type of evaluation used in mathematics subjects. The numerical scale was for low level >1 and high level <1. Table 4 contains the variables and their description.

Table 4: Study variables for developing a predictive model of negative emotions

Variable	Description
Negative emotion level (Y)	Low and high
Organizes (X ₁)	Schematic presentation of information obtained from bibliographic sources
Projects (X ₂)	Application of mathematical knowledge to the resolution of a social, physical, or economic situation
Online quiz Kahoot (X ₃)	An application that presents questions with four answer options or with two options: False and true It gives a time limit to answer and assigns a score
Traditional written exams with the camera on (X ₄)	Knowledge test of the topics covered in class and has a time limit. The processes used in solving the problems must be written down and must be legibly written
Offline questionnaire (X ₅)	Questions are usually multiple-choice, true-false, or short-answer
Randomized questionnaire (X ₆)	Directed questions from the teacher to the students through educational platforms
Solve a problem on a digital Whiteboard (X ₇)	The student solves a problem proposed by the teacher, using the digital whiteboard of the educational platform
Solve exercises online session (X ₈)	Problem-solving and exercises
Oral examination (X ₉)	Real-time of questions and problems, using an educational platform
Chat (X ₁₀)	Participation in chat about class topics on educational platforms
Forum participations (X ₁₁)	Opinions are given by students on the topic being worked on

Scale: 1 = Very poor, 2 = Poor, 3 = Fair, 4 = Good, 5 = Excellent

4.3. Model

The theoretical model of the increase in the average with the variables presented in Table 2 is described in Eq. 2.

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \dots + \beta_{11} X_{11} + u \quad (2)$$

Table 5 presents the results of the predictive model proposed in Eq. 2, whose dependent variable is the level of negative emotions.

The results showed that the variables with the most significant influence on negative emotions such as anguish, anxiety, and stress were the traditional written exams, employing the camera turned on in

any of the video platforms (0.248), as well as the use of timed quizzes online such as Kahoot (0.238), and offline such as Google forms or Moodle (0.238), oral exams (0.268), randomized questions (0.234), solving a problem on the digital whiteboard (0.228), and solving exercises in their notebook, during class (0.187). On the other hand, participation in the chat (0.009), as in the forum (0.009), as well as the elaboration of information organizers (0.015) had a value close to zero, which implies that these three evaluation strategies did not cause negative emotions in the students. Project development (-0.023) was also an assessment strategy that did not cause negative emotions in students (-0.023).

Table 5: Results of the predictive model (level of negative emotions)

	Coefficient	Standard deviation	Statistic t	p-value
Independent term	0.304	0.052	5.863	<0.0001***
Development of organizers	0.015	0.007	2.2349	0.0264**
Projects	0.023	0.009	-2.550	0.0114**
An online questionnaire (Kahoot)	0.238	0.049	4.8637	<0.0001***
Traditional written examinations	0.248	0.050	4.9625	<0.0001***
Offline questionnaires (Google Forms and Moodle)	0.238	0.049	4.8144	<0.0001***
Randomized questions	0.234	0.050	4.6804	<0.0001***
Solving a problem on the whiteboard	0.228	0.051	4.5032	<0.0001***
Solve exercise online session	0.187	0.052	3.6222	0.0004***
Oral examinations	0.268	0.057	4.7400	<0.0001***
Chat	0.009	0.005	1.7900	0.0747*
Participation in the forum	0.009	0.005	1.8759	0.0619*

*: p < .05; **: p < .01; ***: p < .001

The predictive model presented in Eq. 2, with the results of Table 5, is presented in Eq. 3.

$$Y = 0.304 + 0.015 (\text{Organizers}) - 0.023 (\text{Projects}) + 0.238 (\text{Online quizzes}) + 0.248 (\text{Written exams}) + 0.238 (\text{Offline quizzes}) + 0.234 (\text{Randomly questions}) + 0.228 (\text{solving problems on the digital whiteboard}) + 0.187 (\text{Solving exercises in the notebook}) + 0.268 (\text{Oral exams}) + 0.009 (\text{chat}) + 0.009 (\text{Forum participation}) \quad (3)$$

The model's accuracy was confirmed using an F test score of 4.93 with a p-value of 0.000, indicating it is statistically significant. It also showed appropriate coefficients and t-values, suggesting a statistically significant increase in negative emotions among students. The research looked into how different technological and academic factors predict an increase in negative emotions in university students based on the assessment methods used in

their math courses. Key findings revealed that certain activities, including online quizzes (Kahoot), traditional written exams monitored via webcam, offline quizzes (Google Forms and Moodle), being selected to answer questions in a virtual classroom, solving problems on a digital whiteboard, participating in chat during online sessions, completing exercises in their notebook during an online session, and oral exams, contribute to increasing negative emotions in students, with increases noted as 0.238, 0.248, 0.238, 0.234, 0.228, 0.187, and 0.268, respectively.

Conversely, activities such as creating graphic organizers and participating in chats and forums showed minimal impact on students' negative emotions, with values close to zero (0.015, 0.009, and 0.009, respectively). This indicates these activities did not heighten negative emotions and may even have elicited some positive feelings. Furthermore, working on group projects had a

slightly positive effect, reducing negative emotions by -0.023, suggesting that these activities can help mitigate negative feelings among students.

Math teachers employed various methods of assessment to determine the best ways to evaluate how students approach problem-solving. However, traditional written exams (Loewenstein and Lerner, 2003), online quizzes using platforms like Kahoot, and spoken exams have been linked to causing negative feelings among students, supporting findings by Iman et al. (2021). The use of randomly chosen questions as a testing strategy also led to negative emotions, primarily due to the anxiety and stress students felt from the uncertainty of not knowing the answers to potential questions, as noted by Tang et al. (2023).

In this research, it was found that the variable corresponding to the evaluation strategy "develop projects" did not harm students, which means that when students develop projects, they feel at ease and can think better when making a decision. This coincides with García et al. (2020), who pointed out that working on school projects allows them to live together and discern a situation to make a decision, causing positive emotions in the student.

The strategies of participation in the chat, the forum (Nitsche et al., 2022), and the tasks where the student elaborates graphic organizers, such as diagrams or concept maps, which allow him/her to synthesize the information reviewed (Kwon et al., 2018), also did not generate negative emotions.

According to Crawford et al. (2020), the virtual discussion forums present in some educational platforms encourage interaction among students as they participate by writing down their reflections on the task or activity developed.

5. Conclusions

The study involved 324 students studying Computer Information Systems who were participating in online courses from August to December 2021, a change prompted by the COVID-19 health crisis. The predictive model revealed that certain assessment methods, including written exams monitored via webcam, oral exams, online quizzes like Kahoot, questions asked directly by the professor during class, and solving math problems in front of the class using a digital whiteboard, led to negative feelings. These feelings, including anxiety, distress, frustration, and anger, impacted the students' learning experiences.

Some assessment methods chosen by teachers, like forums, chats, and using diagrams for summarizing information or project development, did not cause negative emotions in students. The study concludes that employing a variety of evaluation strategies in mathematics is crucial. This variety allows for assessing students' abilities, knowledge, and skills from different angles and helps balance their emotional states. Therefore, it's important to encourage teachers to move beyond traditional exams and explore diverse assessment

options. Meetings among educators should be organized to discuss evaluation strategies. Moreover, educational institution authorities should focus on supporting the physical, social, and emotional well-being of students.

On the other hand, it is essential to promote self-regulatory strategies and their effective use in different areas (Ospina and Serrano, 2021). These are based, in turn, on metacognitive strategies, resource control, management strategies, and motivational strategies.

The quality standards for online exams and student participation in online courses must be established to ensure quality in teaching, learning, and assessment (Xie et al., 2020). The massive adoption of online learning in higher education due to the pandemic is most likely to cause changes in conventional forms of education and trigger a broader adoption of online learning in the post-COVID-19 world (Gervacio Jiménez and Castillo Elías, 2022). The limitations of this study have to be stated. The study was conducted only in one university department in Mexico City, and thus, the study is composed of a unique perspective of students' experience with COVID-19 and student satisfaction with both in-person and online education. It is possible that the situation described through the results presented in this paper would be different in other departments.

In addition, while traditional education is mainly associated with the value of learning, satisfaction with online education could be defined as learners' attitude, which stems from their evaluation of the educational experience, facilities, and services (Weerasinghe and Fernando, 2017). It is thus more complicated and affected by factors such as communication, participation in online discussions, flexibility, technological support and feedback, flexibility, individual enthusiasm for online learning, technical problems, study load, the marketing construct of university reputation, and interactions among learners (Elshami et al., 2021; Weerasinghe and Fernando, 2017; Parahoo et al., 2016; Wei and Chou, 2020).

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Compliance with ethical standards

Conflict of interest

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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