# Educational Computing
## in the COVID-19 Era

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# Introduction

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This book is made up of four chapters, which are derived from a part of the content developed in the Learning Unit (LU) of Educational Computing and Mobile Multimedia, which is taught in the Master of Mobile Computer Systems at the Higher School of Computation of the National Polytechnic Institute.

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In the January-July 2021 school semester, the subject of the use of technology in education during the COVID-19 pandemic was incorporated into the Educational Computing and Mobile Multimedia LU, because all sectors were affected in relation to the sanitary measures that were taken to prevent the spread of the SARS-Cov-2 virus. The main measure was confinement, which is why the face-to-face educational model was replaced by the distance model, thus technology has played an essential role within school performance, from the use of educational platforms through which teachers share teaching materials with their students, to virtual rooms to take online classes, and beyond, the use of virtual worlds.

Considering the use of technology in this stage of the pandemic, there have been four investigations that are presented in this book. Before providing an outline of said investigations, it is considered of utmost importance to carry out an analysis of the development of the role that computing has played in the field of education and to comment on the situations and the needs raised by teachers in relation to the incursion of computing technology in the education sector.

Since the appearance of computers, as more and more uses are outlined and new applications are conceived, there have been various experiences in education. Thus, in the decades of the 60s and 70s, Computer Aided Teaching (CAT) emerged, which was largely inherited from the modality of programmed teaching and which generally responded to very rigid paradigms. On the mainframes of that time, there were systems for CAT of great importance, among which PLATO (Programed Logic for Automatic Teaching Operation) is worth mentioning [1].

It is not enough to buy equipment for a school to start enjoying the benefits of the computer in teaching. This is one of the most serious mistakes that have been made, not only in our country, but also in many others, including technologically advanced countries [2] Introducing the computer into the teaching process produces a change as radical as the introduction of textbooks. For the books to be useful it was necessary for the students to have a much greater reading preparation than the students had before the introduction of the books (since it is possible to teach many subjects to illiterate people).

In the case of the computer, the situation is much more complex than in the stage of the introduction of books where it was only necessary to consider that the teachers had sufficient ability to read and write, but with the introduction of the computer, the majority of the teachers did not have enough preparation in the use of the computer to use it comfortably in teaching [3]. This requires intense training programs for both regular schools and practicing teachers, which can cost more than the hardware and software.

It is necessary to take into account that the way of teaching has also changed after the introduction of the books, because the dictation of notes was eliminated or worse still, the fact that the teacher had to write notes with figures and tables on the blackboard so that all students could copy them. Following this change, the teacher's ability as a speaker became less important. Much could be accomplished by reading the books.

With the computer, the changes in the teaching style must be greater than those mentioned. It is no longer necessary to fill out workbooks of the same exercises for everyone, which allows students to copy assignments among themselves. Computers can generate randomly different exercises for each student and the computer itself can score the answers if these were options to choose.

In this area, the teacher has the job of evaluating everything that requires intelligence, criteria and experience, such as tests, criticism and the true training of students. It has been shown with scientifically applied experimentation that the computer is an excellent means of teaching skills [4]. The arithmetic exercises of addition, division, etc., can be done with a calculator, with relatively little participation of the teachers. Posing problems, making decisions, and judging situations requires group discussions and intense teacher participation.

Today the world is dominated by information. Man has always handled information, but only until the 20th century this aspect has been given importance and sciences have been created such as Computer Science, Communication Theory, Automata Theory, Cybernetics, Artificial Intelligence and Cognitive Sciences that study the information and surrounding concepts in a deep and rigorous way. Information became one of the main commodities. These areas have important differences with past goods and services. Laws have had to be modified to regulate the handling of information such as The Copyright Law, the Patent Law, the Right to Public Information and the Right to Privacy.

In the decades of the 80s, 90s and in the 2000s, the following aspects were manifested, matured and consolidated:

- The paradigm of object-oriented programming [5].
- The software engineering canons.
- The limits of the scope of information structures with highly evolved databases and Datawarehouse.
- The evolution of the computing power of networks.
- Internet.

The schemes of virtual learning environments (VLE) emerge, which allow the management of courses covered by materials for them, the registration of students and their monitoring, the study of the courses by the students and the corresponding accreditation mechanisms , the management of teachers, as well as the facilities for sending and receiving emails, Chat and communication between the different users of the system.

In the last 30 years there has been the experience of different platforms for virtual education environments:

○ Blackboard
○ SOFÍA is a Web application, developed in Java and based on a three-layer architecture: user interface, computational logic and data [6].
○ Moodle
○ Classroom
○ Microsoft Teams
○ The use of the Web.
○ The distributed computation.

As well as new and versatile tools.

The Web [7] constitutes another part in the history of humanity and defines a new conception of information management, recovery and generation of knowledge, a conception in which in addition to using and receiving, the doing, participating, and sharing are fundamental.

The ICT Concept arises.

As well as in the field of pedagogy there are currents or tendencies, such as: Constructivism, behaviorism, eclecticism, social current, psychological current, etc .; In educational computer programs there are prototypes that are identified with these trends: tutorials, exercise, evaluation, simulation, etc., all useful at different moments of the learning process. The great importance of programs based on constructivist philosophy cannot, however, be overlooked.

The application of software to teaching / learning processes is one of the great technological contributions to the educational area.

This relationship between technology and education appears at an early moment in the history of software, especially as a support for distance education, so that educational software has evolved at the rate that technology requires or supports.

Tutorials, exercisers, expert systems and simulators were handled. The student-teacher relationship was through the same computer, a personal meeting where the expert was the teacher; the information was stored on floppy disks.

In some educational institutions, Laboratories were formed in which different software was used. Some allowed to simulate physical phenomena so that the teacher could explain concepts and present physics and mathematics problems, since the simulation allowed to design a model of a real system and experiment with it, in order to understand its behavior.

Based on the instructional theory of J. Bruner called *Learning by Discovery*, of the *Meaningful Learning* of D. Ausubel [8], and taking as main reference the mental mechanisms of learning that J. Piaget identified [9], has come to the conclusion that the best way to achieve this was through the development of computer programs that not only produced correct results, but also had a didactic design that allowed the student to carry out the above actions in an environment of exploration as free as possible.

Initially, each of these completed models were tested in the classroom. The operating scheme was "triangular": the keyboard, the screen and the students, who observed and made hypotheses, or were simply curious to see what was happening in the model if it gave a certain value to a variable.

When the institutional recognition arrived and together with it, the electronic blackboard, the scenario was changed and the inclusion of a keyboard on the model screen was forced. The students' enthusiasm increased when they began to interact "directly" with the model, which responded immediately to a touch of the electronic pen. The triangular scheme changed to a "point" scheme and the interaction was total and simple.

Computer systems grow and computer software libraries expand; Projects are developed in which programs are produced to diversify applications; Videos and games are linked to applications; The student-teacher relationship is made bi-directionally and universities acquire licenses to apply advancement within the classrooms.

Local and global area networks are booming; There are high-bandwidth digital communications and a growing demand for instant data access. It is counting on the advent and widespread use of microprocessors leading to a breakthrough in smart products.

The use of hypertexts, chat, emails is evidenced; The relationship between student - teacher (chat, mail) is diversified; Collaborative work is increased through networks; The information is stored through personal emails and is shared with the participants.

There are powerful personal machines controlled by sophisticated operating systems; There are global and local networks accompanied by advanced software applications; There is the use of content managers and virtual classrooms allow interactivity and participation through synchronous and asynchronous spaces; The information is stored in the web space.

COEEBA-SEP, Educational Informatics with Red Escolar, SEC21, EFIT-EMAT and Enciclomedia, have left their mark on the National Educational System [10].

Cognitivism and Constructivism posed the challenge of an intelligent use of computers. Among the pioneers were the United States, the United Kingdom, China, France, Israel and, later in the 1980s, Australia, Denmark, the Netherlands, Switzerland, Japan. In Latin America, countries such as Argentina, Colombia, Chile, El Salvador, the Dominican Republic, Uruguay and Ecuador, countries that showed progress in relation to the use of the computer in the fields of educational administration with a marked trend towards the total automation of management and administrative control systems.

The first project developed in Mexico was called Introduction of Electronic Computing in Basic Education and was known in the country as COEEBA-SEP. Its objective was to make the children of Mexico know and use the computer during their stay at school. [11-15].

The pedagogical model that would characterize the COEEBA-SEP project arose from the idea that there was something peculiar about computers that other media did not offer: the possibility of interacting with the student, which led to the idea of feedback and with it, to the empowerment of learning, however, it was necessary to take care not to lead the educational process through mechanization [15].

The model conceived the computer as a didactic resource, that is, as a tool that would be incorporated into the educational process as a support to the teacher, as a means for cognition, understanding that its role was to help learn and think and as a study purpose , therefore, as a workshop for the development of technology-specific skills [16-17].

In practical terms, the proposal of the model did not leave out word processors, simulators and expert systems, but it put as the central axis of all educational intentionality what was called at that time, Computer Educational Programs (PCE).

In the 90s the project called Enciclomedia appeared, which consisted in the construction of a database that organized a wealth of educational resources around textbooks, in order to offer a range of options to both teachers and students to complement the topics covered in the curriculum from very different points of view [18].

It was also considered as a didactic strategy based on an articulating system of learning resources, which, through the support of technology and the content of free textbooks, provided access to a series of links to still images, animations, videos , audio, interactive, exercises and complementary activities aimed at promoting higher quality training processes.

In terms of coverage, Enciclomedia began reaching elementary schools across the country at the end of the 2003-2004 school year and at the beginning of 2004-2005. In its first stage, the equipment was installed in at least twenty-one thousand classrooms of fifth and sixth grade, five hundred and forty-eight teacher centers, thirty-two normal schools, and forty-eight indigenous schools, for a total of twenty-one thousand four hundred thirty-four units installed [17].

The second phase of equipping included the 2005-2006 and 2006-2007 school cycles and was differentiated from the first phase by the change to a leasing model to equip Nearly one hundred and twenty-five thousand additional classrooms to cover the total number of primary public schools across the country. The technology package that was received in each classroom consisted of a Personal Computer, a projector, a printer, an interactive whiteboard, a power source, and a computer cabinet. With nearly one hundred and fifty thousand classrooms installed, an average of four million students were served each school year [17].

From recent years of 2010 to the present, many professors at the university level have used Information and Communication Technologies to distribute material such as notes, problem lists, presentations, either through the use of email, or by making use of an educational platform called LMS (Learning Management System), however in the area of mathematics, the blackboard, the textbook, as well as the projector for presentations have predominated. In 2020, due to confinement, online work has been forced, due to which the teacher of all educational levels has had to learn to use video conference rooms, LMS, educational programs, has had to produce educational videos, develop electronic books, among many other educational digital materials.

The first Chapter of this book shows an investigation on the use of virtual rooms, which highlights the importance that virtual rooms have acquired to carry out synchronous work and that is preferred by many students to asynchronous work. For which, teachers use videos and material that are sent through an LMS, although most of them continue to prefer face-to-face education.

In the second Chapter, it is reported the importance of evaluating the user experience of the different educational platforms used by the teachers of an Academic Unit of the IPN, which allows us to know their advantages, as well as their disadvantages.

In the third chapter a study is made to be able to know a specific work that is fundamental as part of the teaching-learning processes. This refers to distance assessment, which has represented a challenge that the mathematics teacher has faced. There are shown the strategies that have been used to lower the percentage that used to be assigned to the written exam during face-to-face classes.

The last chapter presents a practical example of the way in which a teacher can work with the students when teaching mathematics or how the subject of Artificial Intelligence (AI) is taught. Due to it is put into practice the knowledge of Mathematics and AI, specifically Machine Learning, for the construction of a model that estimates the number of people infected by COVID-19, as well as the hospital capacity in CDMX.

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# Index

# Chapter 1

## Use of virtual rooms in Distance Education during the COVID-19 pandemic

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**Abstract**

The purpose of this article is to review the opinion of students in relation to the way in which videoconferencing platforms are used by their teachers during the pandemic. A questionnaire was applied to a random sample of 220 students from an academic unit of the Instituto Politécnico Nacional. It was found that students prefer to take classes by videoconference instead of receiving the information by other means such as email and videos. Despite this, they consider that face-to-face classes help them in a better way in their learning process. Another result that was obtained was that due to the way in which videoconferencing platforms are used, it causes them boredom and stress. Based on what was obtained, a strategy for using the functionalities of the two most used platforms, Microsoft Teams and ZOOM, was proposed.

**Key words:** Distance education, higer level, students, videoconferencing platforms.

## 1. Introduction

Due to the current COVID 19 pandemic, videoconferences have had a greater impact either from the workplace [1], to give classes or to communicate with friends or family, they have become popular since they are an easy-to-use tool and help to communicate with people anywhere in the world. A videoconference can be defined as a telephone communication using the network, which serves to send and receive images, sounds, files, video and data. Videoconferencing has great benefits such as: it helps to promote teamwork, allows ubiquity, and can also be defined as the means of transportation of the future. However, video conferencing also has disadvantages, for example the lack of authentication. That is, there is no way to validate or verify the identity of the participants when participating in a video conference, particularly when the participant (s) have the microphone and camera turned off. There are many platforms that offer video conferencing services, among the most popular are: Zoom, Google Meet, Cisco Webex, Microsoft Teams. Depending on the use that will be given to videoconferences, different types of software can be used, whether they run on our device, or as a service through the web [2]. The problem addressed here is the massive use of platforms to teach distance learning, as a consequence of the current COVID 19 pandemic, in order to propose a support strategy for teachers and students to use the different tools provided by these platforms.

According to UNESCO [3], with the current COVID 19 pandemic until March 2021 around 148, 424,599 students have been affected, worldwide, with the closure of schools from basic to higher level.

Similarly, a report by the UN [4] shows that several countries in the world implemented online classes through ICT, requiring teachers to continue teaching. On the other hand, in some countries additional modalities were implemented through radio, television, printed materials and online.

With the current pandemic, schools from the basic level to the upper level have sought a way to continue with classes, either by using email, messages through WhatsApp, educational platforms or through videoconferences. In Mexico, according to the survey of academic continuity in HEIs [5], during the COVID-19 contingency it was discovered that teachers use at least one videoconferencing platform to continue with their classes, and the most used platform (31%) is Zoom, followed by the WhatsApp application (15%).

Also, an online survey carried out in 2019 to UNAM high school, university and postgraduate teachers [6], with a sample of 788 teachers, it was found that 75.2% use some resource such as Facebook, WhatsApp and email for communication with their students, while only 39.9% use a videoconferencing platform (Skype, Google Meet, Zoom, etc.). Similarly, some problems that teachers have when teaching online classes were expressed, where 39.7% have problems with the lack of knowledge with educational and videoconferencing platforms.

### 1.1 Objective

Identify the acceptance that students have towards videoconferencing platforms as support for distance classes to propose a support strategy for teachers and students when using videoconference rooms.

### 1.2 Theoretical aspects

The characteristics and functionalities of the main videoconferencing platforms were reviewed, which are shown in Table 1

Table 1: Characteristics of videoconferencing platforms

| Platform | Company | Screen sharing | Chat | Web browser compatibility | Board | Time limit | Mobile App |
|---|---|---|---|---|---|---|---|
| **Zoom** | Zoom Video Communications | ☺ | ☺ | ☺ | ☺ | ☺ | ☺ |
| **Google Meet** | Cisco Systems | ☺ | ☺ | ☺ | | | ☺ |
| **Microsoft Teams** | Microsoft Corporation | ☺ | ☺ | ☺ | ☺ | ☺ | ☺ |
| **Cisco Webex** | Google Inc | ☺ | ☺ | ☺ | | | ☺ |

## 2. Methods and Materials

The scope of the research is descriptive and correlational [7], for which a questionnaire was used to evaluate the effects that the use of videoconferencing platforms had on students in their distance classes. We worked with a random sample of 220 students, who were studying some of the nine semesters of the Computer Systems Engineering career in an Academic Unit of the Instituto Politécnico Nacional, whose ages ranged between 17 and 27 years.

The questionnaire consisted of ten questions, of which six were Likert-type options with a scale of one to five, two multiple-choice and two open. Google Forms was used for its application.
The questionnaire was validated using Cronbach's alpha coefficient [8], since it allowed the measurement of the homogeneity of the questions. Its interpretation is that the closer the index is to the unit, the better the reliability of the questionnaire, and it is considered acceptable reliability from .70. The formula for this coefficient is defined in (1):

$$\alpha = \frac{k}{k-1}\left[1 - \frac{\sum si^2}{st^2}\right], \qquad (1)$$

where:

K: The sample size
$\sum si^2$: Sum of item Variances
$st^2$: Variance of the sum of the items
$\alpha$: Cronbach's alpha coefficient

Data treatment was carried out in Excel, using the mean and standard deviation as statistics. Pearson's correlation coefficient was used to establish linear relationships between the study variables [9].

The methodology used is shown in the diagram in Figure 1, where it can be seen that it consists of five stages, which are described below.

- The first stage consists of the design of the questionnaire, according to the purpose, which consists of 10 questions, 6 of the liker type, 2 are open questions and the last 2 are multiple choice. The questionnaire was applied through Google Forms, in April of the current year.
- For the second stage of data collection, Excel and the graphs provided by Google Forms were used.
- In the third stage, for the statistical treatment the data were worked in Excel, taking the average, standard deviation and Pearson's correlation.
- In the analysis and results stage, the data obtained was taken in order to draw up the proposal.
- The last stage consists of creating a support proposal, on the tools that a videoconference room has.


Figure 1: Proposed methodology

## 3. Results

In relation to the platforms that are most used by teachers in teaching their classes are Zoom and Microsoft Teams with 47.5% and 38.5%, respectively. On the other hand, 41.6% of the students prefer to work with Google Meet to carry out work and tasks, because they consider that it is easy to use, has no time limit, and because the login passwords can be saved. room. Another of the videoconferencing rooms that is highly accepted by students is Discord, as they pointed out that the audio and video quality is very good, it is fast and easy, and allows the use of chat, publish images and videos, and has an app desktop and mobile app; besides that it is stable and versatile.
Tables 2 and 3 show the advantages and disadvantages, indicated by the students, of the different videoconferencing rooms that they use in their distance classes.

In relation to the advantages that students consider that Zoom offers, there is its good audio and video quality, and the screen sharing functionality, as well as the ease of interacting with the teacher. Some of the advantages that were pointed out by the students over Microsoft Teams is its integration with Office tools, it has no time limit because the license was purchased by the IPN, and it does not remove them from the session if the internet connection is lost. It also allows you to record the class and save it for up to a month.

Table 2: Advantages of video conferencing

| Advantage | Zoom | Google Meet | Microsoft Teams | Cisco Webex |
|---|---|---|---|---|
| **Easy to use** | ☺ | ☺ | ☺ | |
| **Support tolos** | ☺ | | ☺ | |
| **Room options** | ☺ | | | |
| **Popular** | ☺ | | | |
| **Practice** | ☺ | | | |
| **Good audio and video quality** | ☺ | | | |
| **Good quality for screen sharing** | ☺ | | | |
| **Without time limit** | | ☺ | | |
| **Ease of creating a video conference** | ☺ | ☺ | | |
| **Fast** | | ☺ | | |
| **Ease of functions** | ☺ | ☺ | | |
| **Easy to enter** | | ☺ | | |
| **Use of browser** | | ☺ | | |
| **Comfortable** | | | ☺ | |
| **Integration with office tools** | | | ☺ | |

| | | | | |
|---|---|---|---|---|
| **Ease of recording** | | | ☺ | |
| **Task organization** | | | ☺ | |
| **Doesn't take you out of class if the internet goes out** | | | ☺ | |

With regard to Zoom, among the disadvantages considered by the students, the time limit, the monthly payment and the difficulty to record stand out. Also, they pointed out that, relative to Microsoft Teams, it is resource intensive and has a confusing interface. The main disadvantage that students found in using Google Meet is the difficulty of presenting the screen.

Table 3: Disadvantages of video conferencing

| Disadvantages | Zoom | Google Meet | Microsoft Teams | Cisco Webex |
|---|---|---|---|---|
| **Time limit** | ☺ | | | |
| **Monthly payment** | ☺ | | ☺ | |
| **It locks** | ☺ | ☺ | ☺ | |
| **Difficulty recording** | ☺ | | | |
| **Confusing interface** | | ☺ | ☺ | ☺ |
| **Few functions** | | ☺ | | |
| **Problems presenting screen** | | ☺ | | |
| **Bad video quality** | | ☺ | | |
| **Has problems** | | | ☺ | |
| **Resource consumption** | | | ☺ | |
| **Difficulty creating romos** | | | ☺ | |
| **Little popularity** | | | | ☺ |

The students in the sample did not reflect being convinced with the teaching of the classes online, due to the way their teachers are using videoconferencing platforms, since the scores obtained were 2.59 and 2.7, respectively as shows in table 4, on a scale of 1 to 5, with 1 strongly disagreeing and 5 strongly agreeing. Despite this, the students considered that the use of platforms help their academic performance, scoring this aspect at 3.73, which may be due to the fact that it is preferable to take a virtual guided class, rather than having only to study through of videos and texts. Although the students consider the use of videoconferences as a stressful and boredom factor, because they spend several hours a day in front of a monitor. These aspects scored at 3.78 and 3.84, respectively.

Table 4: Standar deviation of questions

| Question | Average | Deviation |
|---|---|---|
| **5. Do you like videoconferencing classes?** | 2.59 | 1.37 |
| **7. Do you consider that the use of platforms helps your academic performance?** | 3.73 | 1.05 |
| **8. The way in which videoconferencing platforms are being used in classes are of interest to you?** | 2.7 | 1.36 |
| **9. The way in which videoconferencing platforms are being used in classes is boring you?** | 3.78 | 0.85 |
| **10. The way in which videoconferencing platforms are being used in classes is causing you stress?** | 3.84 | 1.05 |

To determine the effect of interest, boredom, and stress, in online classes or by videoconference, question 8 was correlated with questions 5, 7 and 9 using Pearson's coefficient. I manifest that the greater interest in online classes, also generated an increase in the taste of the classes, having obtained a better academic performance and a decrease in boredom. In the same way, question 9 was correlated with question 10, to determine the impact of the correct use of the platform's functionalities by teachers, on student boredom, having discovered that students, of those Teachers who lack the skills to properly operate platforms tend to be more bored.

Based on the analysis carried out, and the review of the literature, a strategy was developed for the use of videoconferencing platforms, which consists of the following suggestions:

1. Explore the platform that will be used by the teacher before giving the class, to know the functionalities it offers, such as: blackboard, reactions, creation of rooms to assign teamwork, screen sharing, chat, recording of the meetings, sending files through chat, among others.
2. Familiarize yourself with the platform and its functionalities, rehearsing before using it to teach your classes.

**ZOOM**

To explain the tools offered by a videoconferencing platform, the Zoom platform [10] was selected. Here's how to use the whiteboard, chat, send files, record the video conference, and use the reactions.

- **Reactions**

To enter the reactions, click on Reactions, which will show the 6 different reactions, as shown in Figure 2. When you click on any of the reactions, it will be displayed centered in the upper part of the screen. screen, as shown in Figure 3.


Figure 2: Reactions

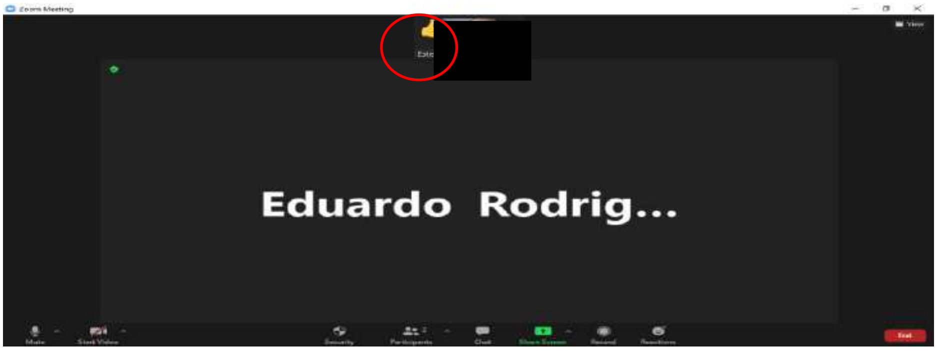


Figure 3: Reactions

- **Board**

To use the board, you must enter as follows: Click on the Share Screen button or (Alt + S), as shown in Figure 4.


Figure 4: Share Screen

On the next screen, select Whiteboard, as shown in Figure 5.

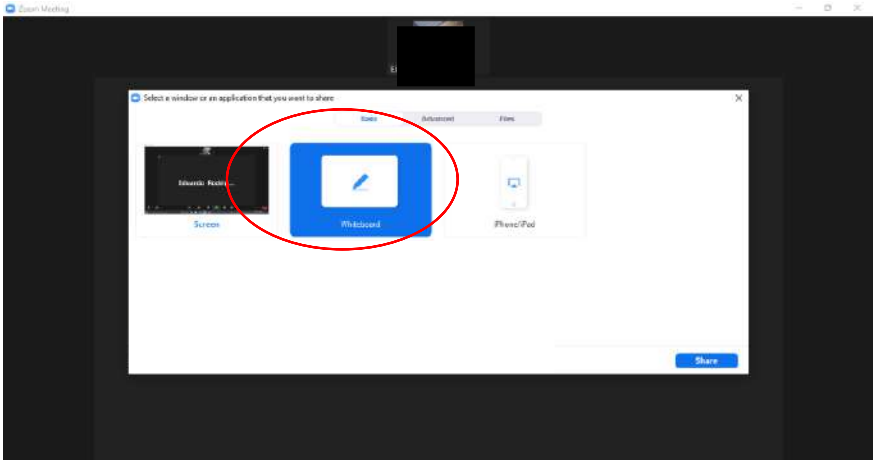

Figure 5: Whiteboard Selection

And the screen will appear with a blank document that Zoom provides. On this screen you can use the text, sticker, pencil, marker, eraser tools, and you can also save the screen to a file, as shown in Figure 6.

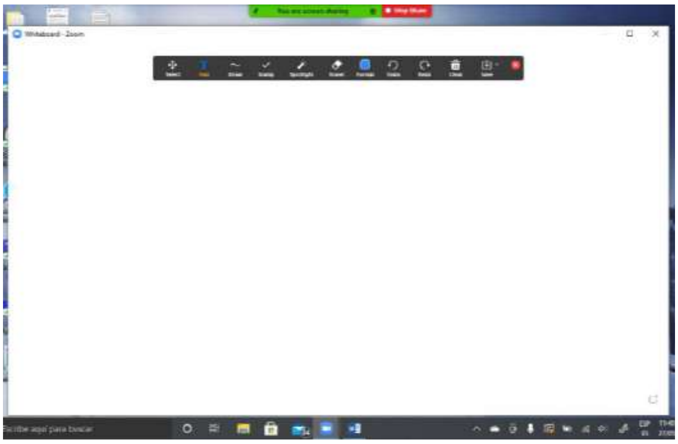
Figure 6 Whiteboard Document

- **Chat and file sending**

To use chat, you must click on Chat, as shown in Figure 7.

Figure 7: Chat

Then, a dialog box will appear that allows you to send and receive messages, and send files. To send a file you must click on File, as shown in Figure 8.

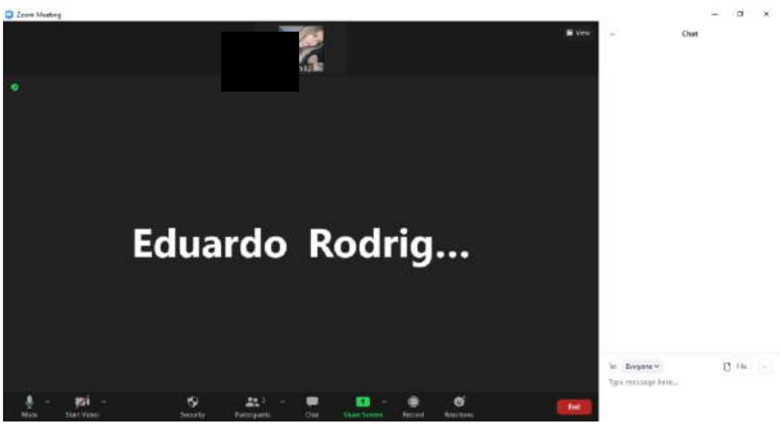

Figure 8: Sending files

This will bring up a dialog box with the options to which the file can be uploaded, that is, Dropbox, Microsoft OneDrive, Google Drive, Box, Microsoft SharePoint, and from the computer, as shown in Figure 9.

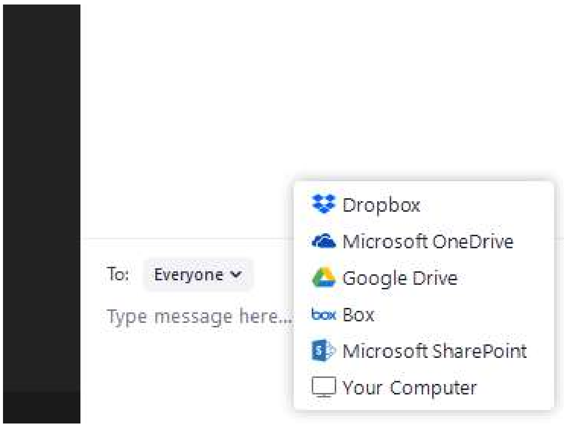


Figure 9: Screen sharing options

Finally, through the dialog box to search and select a file, we mark the file we want to send and click on accept, as shown in Figure 10.

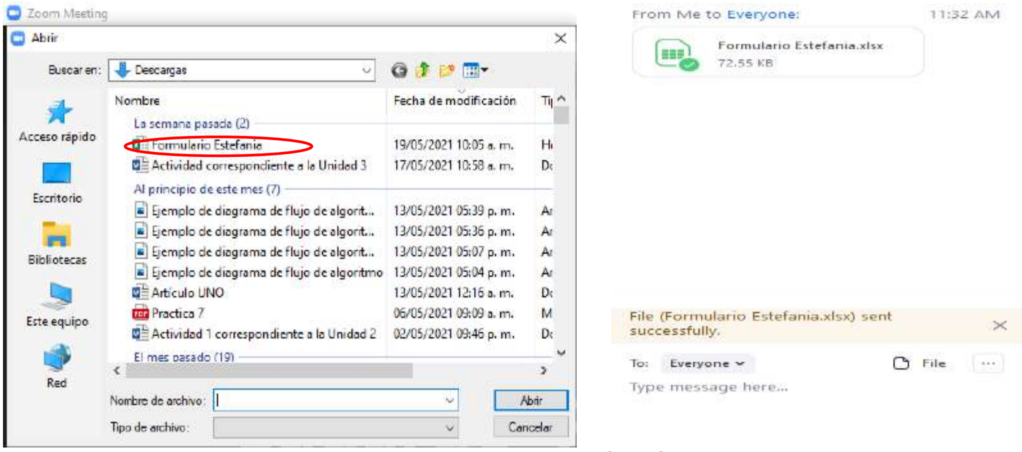


Figure 10: File selection

**Share screen**

To share screen, click on Share Screen as shown in Figure 11.

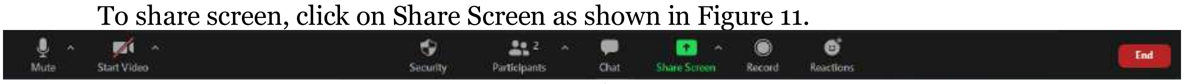


Figure 11: Share screen

And the screen that you want to share is selected, as shown in Figure 12.

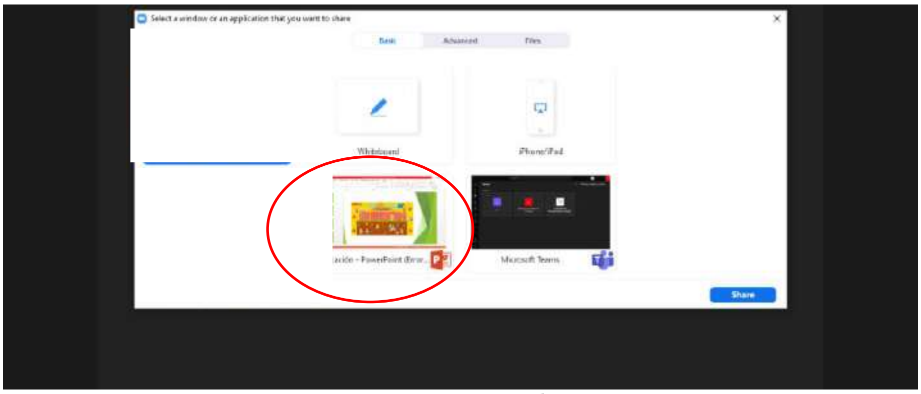


Figure 12: Screen selection

- **Record video conference**

  In order to record the videoconference, click on Record, as shown in Figure 13.


Figure 13: Record Screen

When you click on Record, the controls for recording will appear, and here it can be paused and / or stopped, as shown in Figure 14.

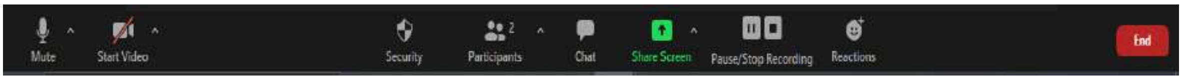


Figure 14: Controls for recording

Once the recording is finished, the following message will appear, indicating that the recording has finished, and the dialog box will open indicating that the recording of the meeting has finished and will be converted to mp4 format at the end of the meeting, as shown in the Figure 15.

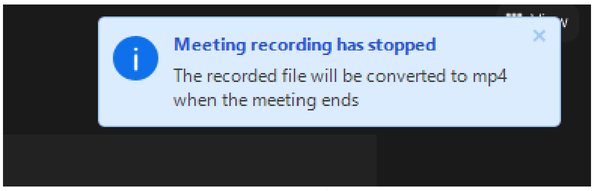


Figure 15: Recording message

**Microsoft Teams**

Given the popularity of Microsoft Teams, a short usage guide is also provided.

- **Reactions**

  To make use of the reactions, it is only necessary to pass the mouse over the bar where there is a happy face button with a little hand, and the 5 reactions that Microsoft Teams has will appear, as shown in Figure 16.

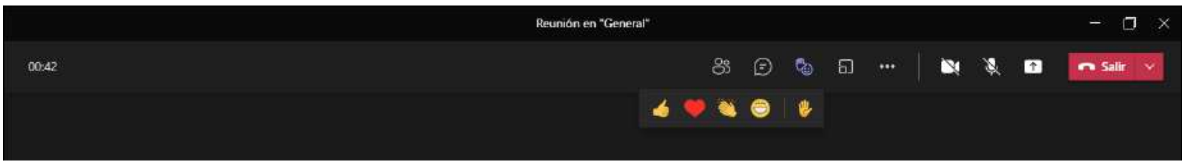


Figure 16: Reactions

- **Chat and share files**

  To open the chat, you must click on the button that has the shape of a dialog cloud (Show conversation), as shown in Figure 17.

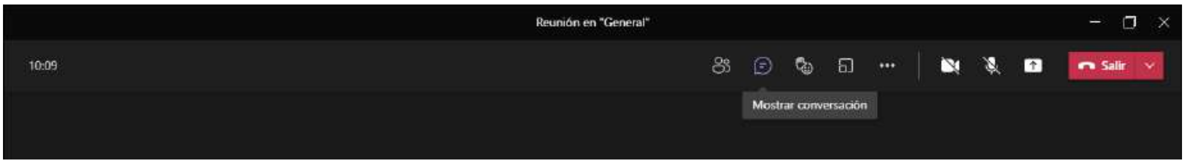


Figure 17: Chat and share files

When you click on the Show conversation button, the screen shown in Figure 18 will appear, in which you can send messages, select the font, draw pictures, mark the message as important or urgent, and send files. emojis, sticker, etc.

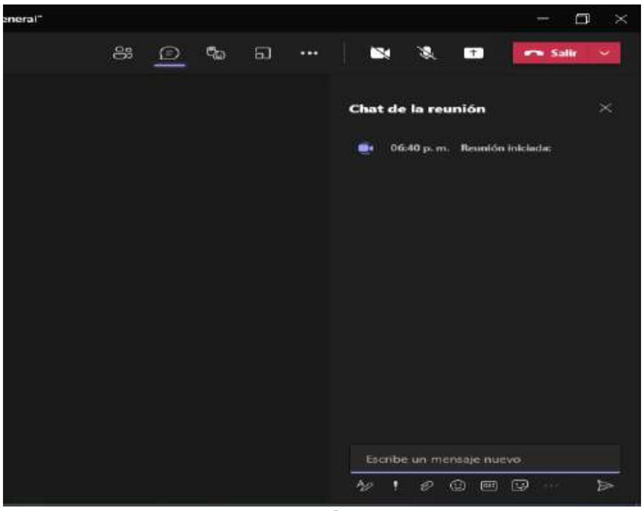


Figure 18: Chat screen

To share a file, click on the button of a clip here, and select where the file is saved, as shown in Figure 19.

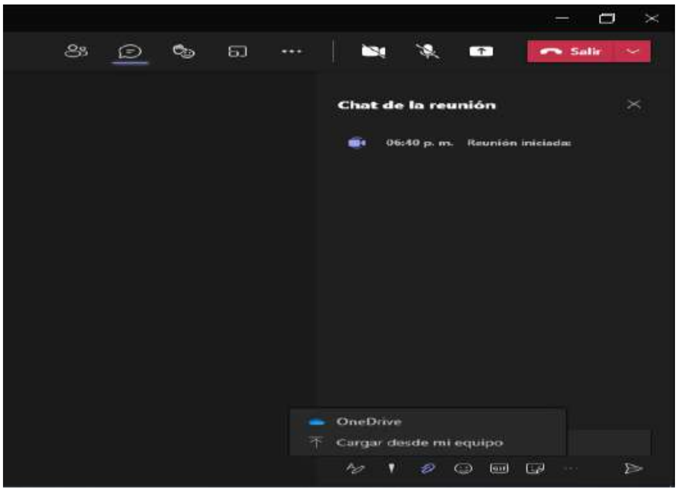


Figure 19: File selection

- **Whiteboard**
  To use the whiteboard, click on the share screen button, as shown in Figure 20.


Figure 20: Whiteboard

Next, the Microsoft Whiteboard is selected, as shown in Figure 21.

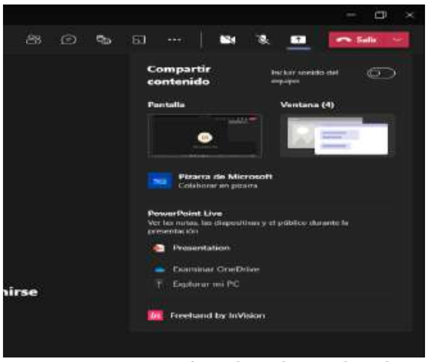


Figure 21: Microsoft Whiteboard Selection

Once the board is selected, a message appears as to how you want the board to look. Here there are two options, the first is only to present the board, and only the one who is presenting can edit. The second option is whiteboard collaboration, in this everyone who is in the meeting can modify the content of the whiteboard, as shown in Figure 22.

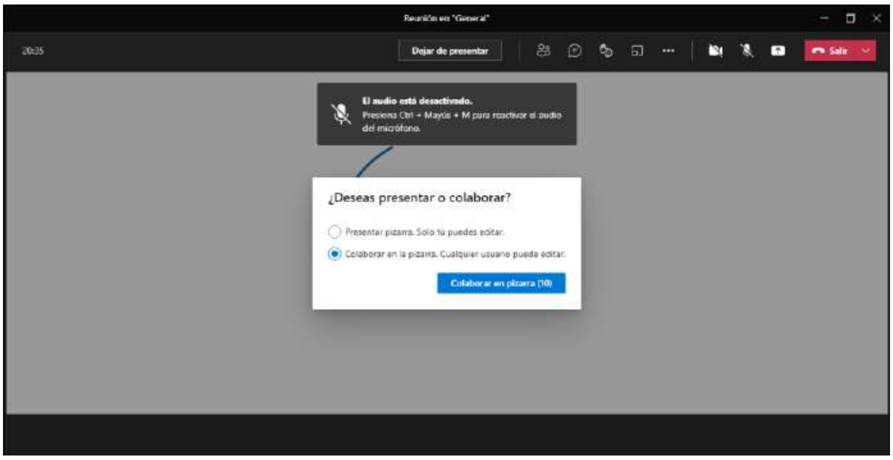


Figure 22: Selection of whiteboard

Once the desired option is selected, the blackboard appears as shown in Figure 23, where you can see the tools to add text, select figures, add shapes or lines, also show the colored pencils, the highlighter and the rubber to delete.

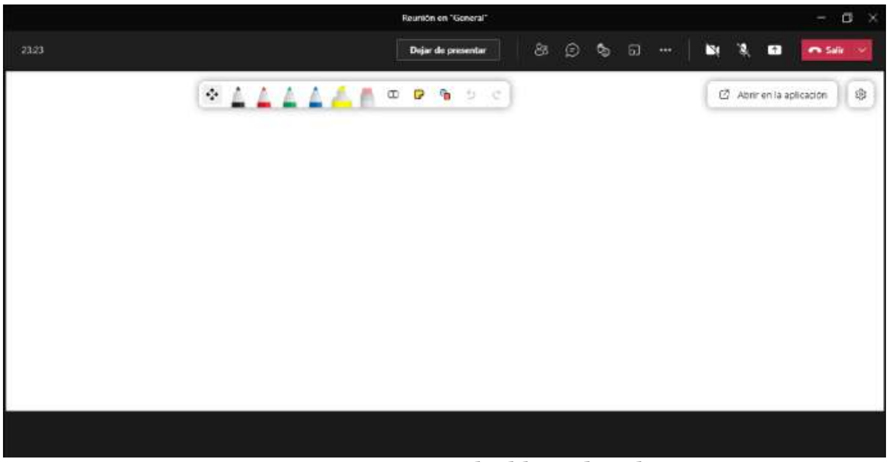


Figure 23: Blackboard tools

Also, the board has a configuration window that is displayed when clicking on the gear icon and that allows you to export images, or change the selected mode of the board, as shown in Figure 24.

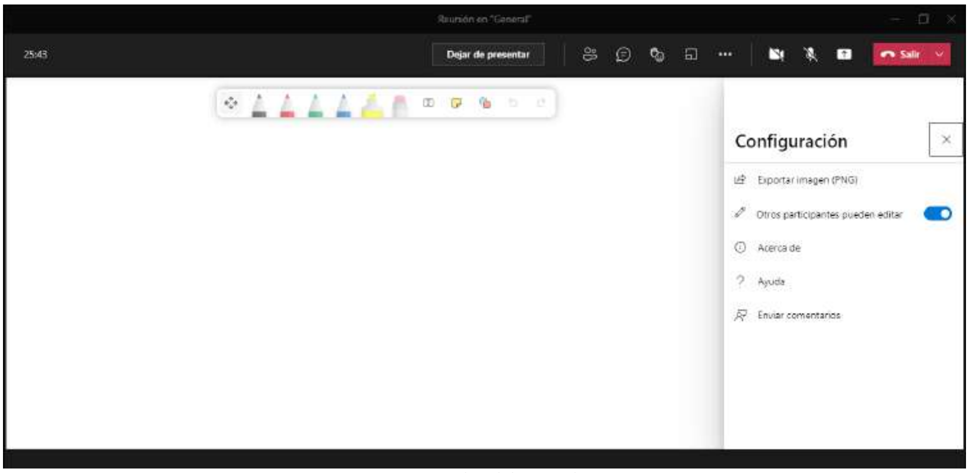


Figure 24: Blackboard set up

- **Share screen**
  To share the screen, click on the share content button, as shown in Figure 25.

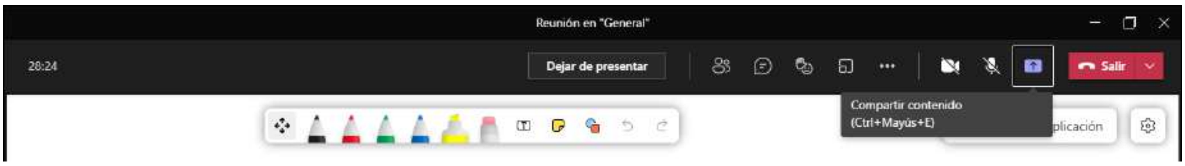


Figure 25: Share screen

Afterwards, you select the window you want to share, as shown in Figure 26.

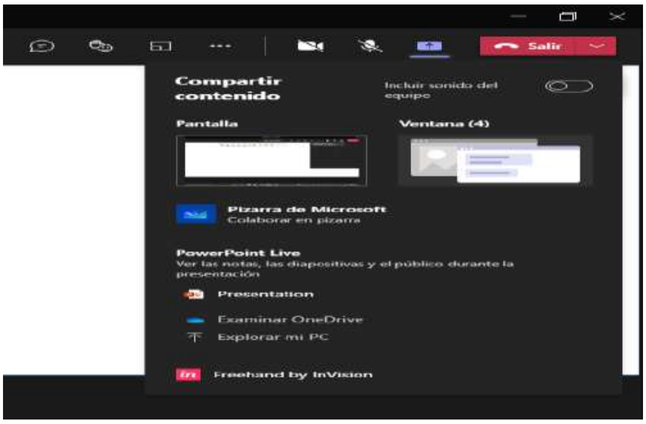


Figure 26: Screen selections

- **Sub-rooms**

To create a sub-room within a Teams meeting, click on Rooms for subgroup sessions, as shown in Figure 27.

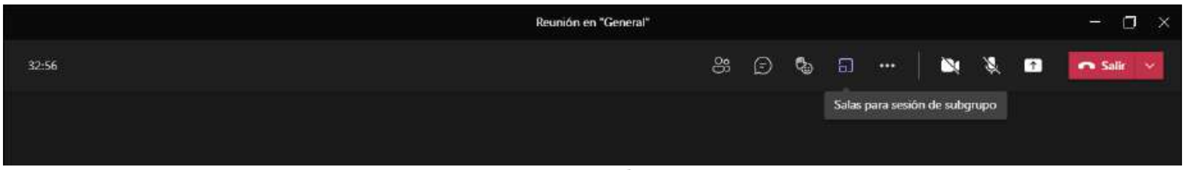


Figure 27: Sub-rooms

This will bring up a window where you can select the number of sub-rooms to create. In addition, you can select the number of sub-rooms to create, and whether it will be done automatically, or by selecting the members of each room, as shown in Figure 28.

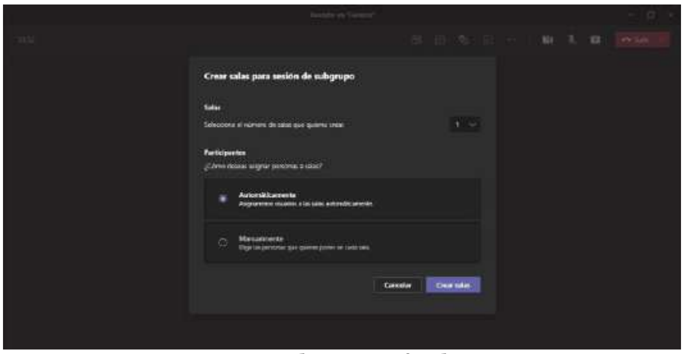


Figure 28: Selection of sub-rooms

## 4. Conclusions

It was identified that students have high acceptance of the use of videoconference rooms for their online classes, compared to other strategies used in their distance education, such as sending material by email: notes, videos, presentations, problems, books, etc., although they prefer the face-to-face educational model.

It was also found that taking all their classes through video conference room causes them stress, boredom and lack of motivation, perhaps because they do not take full advantage of all the functionalities of the video conference rooms, and because it is very heavy to spend all the hours of a day of classes in front of a monitor.

The advance of technology allowed that during this difficult time of confinement due to the pandemic, distance education was functional and allowed to have other alternatives to evaluate, and continue with the academic training of students, and helping to cope with the inclement experienced.

## Acknowledgement

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# Chapter 2

## The importance of measuring user experience on educational platforms used for distance education while the confinement period

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**Abstract**

This article shows the measurement of the usability and user experience of two platforms most used by higher-level students of an Academic Unit of the Instituto Poltécnico Nacional, Mexico City, which are Google Classroom and Microsoft Teams, for this The Systems Usability Scale questionnaire applied to a sample of 79 students was used.

The result obtained for both platforms was 72/100, which means that they are considered as good for distance work that teachers carry out to give their courses. In addition, with the same questionnaire, 4 of the 5 quality attributes that make up usability were evaluated, and they are: easy to learn, easy to remember, low error rate and satisfaction. Regarding the attribute of efficiency, a second questionnaire with five questions was used. The results of the five attributes were considered acceptable to good.

**Keywords** Learning Management Systems, User experience, Usability.

## 1. Introduction

The prevailing conditions today, due to the confinement by the pandemic caused by the COVID-19 disease, has led to mobility restrictions, accelerating a process that for some years had a continuous growth, which refers to the use of technology in all areas, economic, social, health, educational, to name a few. The new needs and others that already existed, have led students to seek alternatives in their learning process and teachers to develop the skills required to make use of technology as part of the teaching process.

Online courses and learning environments where students can access all kinds of content, have been on the rise. However, it is necessary that the contents be of quality, have a good design and meet the objectives set in the courses.

To achieve this, in recent years some multidisciplinary projects have been developed, these involve a variety of professionals interested in making the experience of learning through technology a nice and helpful one.

The result of the interaction of three factors that are: the internal state of the user, the characteristics of the system design and the context, where the interaction occurs, is called user experience (UX) [6]. To achieve a positive UX, those in charge of the design and content of learning environments need convenient feedback, this is where UX measurement plays a preponderant role to obtain the desired information and thus improve their designs.

In the interviews carried out in a study, directed to a group of researchers related to UX design, on the structures and measurements that could be made to this user experience, the interviewees were skeptical and ambivalent, arguing that the results of the measurements would be affected in different contexts [1].

The UX describes the subjective feelings of users regarding the products they use. Different users can have different impressions regarding the UX of the same product. This is the reason that

makes necessary to measure the UX in a large group of users to have greater confidence on the results [2].
And to carry out these measurements, Lewis mentions in [4] that the questionnaire of the System Usability Scale (SUS), has become a valuable tool for professionals and researchers, since it allows evaluating usability and user experience. For his part, Sauro showed [5] that SUS is a valid and reliable usability questionnaire.

This article shows a study carried out on a sample of students from an Academic Unit (UA) of the Instituto Politécnico Nacional (IPN), who used educational management platforms in their distance classes. The SUS questionnaire was applied to measure Usability and User Experience (UX) in the platforms used and thus obtain the necessary information that results in the improvement of distance learning.

The purpose of the research reported here is to evaluate the UX and the usability of the users of any of the educational platforms that they are currently using as support in the teaching-learning processes of an Academic Unit of the IPN, in order to serve of base to improve the contents and the designs of these.

### 1.1 Art Estate

A study presented in [8], used SUS to evaluate the acceptance that 162 university students had when using the online platform Codesay.com in learning a programming subject, the sample was divided into two groups of 81 participants, the first had used the platform for two months and the second for two weeks only, achieving scores of 72.1 and 70 respectively, so both entered the evaluation criterion of *Good* or favorable, with a high correlation in the categories established for usability measurement, which are: easy to learn, efficient, easy to remember, low error rate and satisfaction. The study showed the simplicity of using the questionnaire and the validity of its results.

Another study [9] carried out at the University of Turkey, evaluated the usability of the LMS Moodle in students enrolled in a computer course, appreciating a positive acceptance of the platform by the students, since it allowed them to follow their course online asynchronously and the opportunity to communicate with their instructors directly, also download class materials and upload their assignments, among other facilities, however, the importance of constantly monitoring and maintaining the LMS is highlighted to prevent problems of usability that could be presented to the student.

In Kocaelis University, like the paper reported in [9], the usability of LMS Moodle was evaluated [10] under the categories of being easy to learn, efficiency, easy to remember, errors and system satisfaction. The results showed that the students that used it were not very satisfied with it, mainly because aesthetics reasons, although they did like the error prevention, efficiency, and the fact that it is easy to remember. Concluding that the evaluation on the usability of the LMS on learning environments is essential y its quality can affect learning.

## 2. Theoretical-conceptual aspects

The concepts that are fundamental to highlight due to their importance for conducting the research are presented below:

- Usability. It refers to *the speed and easiness with which the person can do their own assignments while using a product* [7].
- User experience (UX). The UX is the result of the inner state of the user, the characteristics of the system design and the context of the situation [6].
- Measurement instruments. To measure the usability or the users experience, there are several questionaries that can be used. Some of them are:
  - Questionnaire of the System Usability Scale (SUS). This questionnaire consists of ten questions that are evaluated on a five-point scale ranging from *Strongly disagree* to *Strongly agree*.
  - Questionnaire for User Interface Satisfaction (QUIS). This one consists of 27 questions, which are evaluated on a scale of ten points with adjectives that go from *Terrible* to *Wonderful*, or from *Hard* to *Easy*, and so on.
  - Computer System Usability Questionnaire (CSUQ). This one consists of 19 questions which are evaluated on a 7-point scale that goes from *Totally disagree* to *Totally agree*.

Even when the mentioned questionnaires were contemplated on the evaluation of this study, SUS was the chosen one thanks to its simplicity and trustfulness [13].

- 

- Learning Management System (LMS). An LMS provides favorable nonphysical learning environments with the needed tools of organization and management, to speed up the communication between teachers and students. According to [15] the tools which a LMS must have are:

1) Management and distribution of contents, so that they are accessible to students and developers,
2) Users management, so that we can track their activities,
3) Communication, there being a way of communicating between students and teachers and,
4) Evaluation and tracking, it must make the evaluation of students easier. This way an LMS breaks all the limitations of physical spaces of schools improving the efficiency in education.

- Google Classroom. It is an online tool to manage classes on the educational field, where virtual reunions can be planned, information shared, contents, video, or audio, to all the class or on a selective way. It helps the teacher to organize the information within different folders. Any device can access the platform and its classes.
- Microsoft Teams. It is a digital tool that teachers and students use, with which collaborative classrooms can be made, programming reunions between the members of an academic unit or even several ones, in which their members can converse and see each other on real time, contents, files, documents, videos and audios can be shared, and you can also personalize the learning with assignments, which allows the teachers to create personalized learning environments for their students.

# 3. Methodology

The scope of this research is descriptive and correlational according to what Sampieri said in [14], that's why we used with descriptive statistics for the treatment of the information, especially two statisticians were used: the average which allowed to characterize the used sample, and the standard deviation, to check the variability of the data in relation to the median of the two variables aborded in the research, which are the user experience and usability.

The study was carried out during the month of March 2021, in Mexico City, with distance classes being taught due to confinement due to the pandemic. The sample was random and consisted of 79 higher-level students, belonging to an academic unit of the IPN, whose ages ranged between 18 and 27 years.

The methodologic instruments employed was the Questionnaire of the System Usability Scale (SUS). The SUS is a standardized questionnaire of ten questions with five possible answers, the range of measurement of the answers goes from totally disagree to totally agree and the values go from 1 to 5 respectively. The obtained values are homogenized[1] using the following formulas:

$V_i-1$, if the reagent is odd (1)
$5-V_i$, if the reagent is even (2)
Where: $V_i$ represents the initial value, indexed by $i$.

The evaluation of the questionnaire allows us to classify the usability of the technological educational tool, using the following operations: The transformed values of the obtained answers, are firstly added, then multiplied by the 2.5 factor. The obtained results that are greater than 68, but less than 80.3, are considered above the average or are classified with the *good* adjective, which implies that the evaluated tool fulfills with required quality attributes. If the result is greater than 80.3, it is considered *excellent* [12][8]. As seen in table 1.

Table 1. Evaluation range for SUS

| SUS range evaluation | SUS evaluation adjective |
|---|---|
| **>80.3** | Excellent |
| **68 – 80.3** | Good |
| **68** | Sufficient |
| **51 – 68** | Poor |
| **<51** | Very poor |

The SUS questionnaire measures the usability attributes, and according to Nielsen [11], the usability is defined by 5 quality components:

1 The values initially obtained from the odd questions are found in an *inverse code* with respect to the values initially obtained by the even questions, which is why they are required to be homogenized.

1) Learning. It refers to how easy is it for the users to realize the basic tasks since the first time they use the system.
2) Efficiency. It means what the users have learned to use the system, and the speed with which they do their tasks.
3) Easy to remember: How easy is it for the user to remember the functionality of the system after a certain period of disuse.
4) Error rate. It is the number of errors that the users commit while using the system, focusing on how serious they are, and how easy it is to recover from them.
5) Satisfaction. Implies how nice is for the user to use the system.

For the realization of this research the SUS questionnaire was applied to the students of the sample, but 5 additional questions were also included, these proportionated us with extra information about the preferences of the participants. The participants solved the questionnaire online using Google Forms. For the data analysis Excel was used.

As this is a correlational research, the Pearsons coefficient of correlation was applied according to (3), the reason behind this is that it measures the lineal correlation between two sets of information.

$$r_{XY} = \frac{\sum_{i=1}^{n}(x_i - \bar{x})(y_i - \bar{y})}{\sqrt{\sum_{i=1}^{n}(x_i - \bar{x})^2}\sqrt{\sum_{i=1}^{n}(y_i - \bar{y})^2}} \quad (3)$$

Where:
n is the size of the sample. $x_i$, $y_i$ are individual values indexed by i.

In figure 1 we can see the steps that were followed on the process to achieve the initial purpose, this in the shape of a flow diagram.

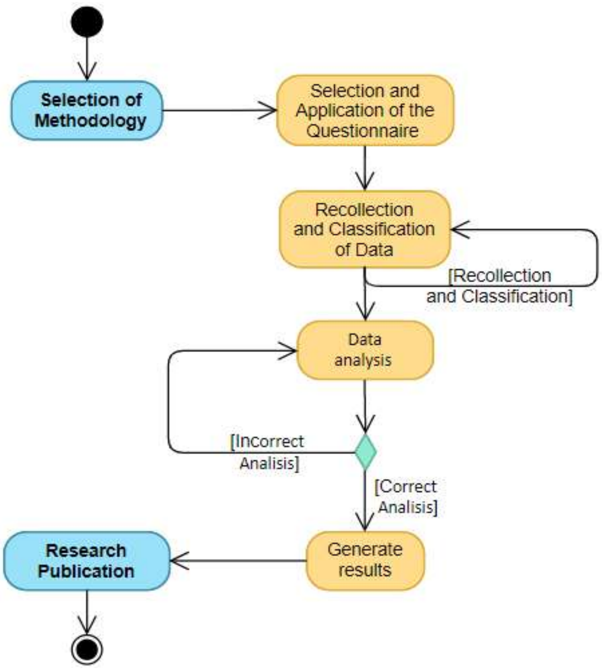


Figure 1. Steps

# 4. Results and analysis

After applying the questionnaire, we downloaded the generated file by the Google Forms Platform with .csv extension and we converted into a .xls file to start with the data management. For the SUS questionnaire evaluation, firstly, the formulas 1 and 2 were used to homogenize the data of the initially obtained values by the reagents of each question, following that, the results of each participant were added, to then multiply them by 2.5. The calculation continued by adding the scores of the participants and averaging them. Lastly, the result was compared with the classification of the ranges of evaluation in the usability scale of the SUS questionnaire.

The students of the sample were given the option to evaluate the platform used for the education management that they are currently employing in their online classes, in which Classroom (30%) and Microsoft Teams (28.7%) stood out. The results of the SUS questionnaire showed a score of 72/100 of approval in the usability that the participants had while working with these platforms, that is why they entered in the range of *Good*. With said result, 4 out of 5 quality components of the usability were evaluated, the components are: Easy to learn, easy to remember, low rate of mistakes and satisfaction. This information is showed on table 2.

Table 2. System Usability Scale questionnaire (SUS)

| System Usability Scale questionnaire (SUS) | | |
|---|---|---|
| **Id** | **Questions** | **Attribute** |
| **R1** | I believe I will use this system or platform frequently. | Satisfaction |
| **R2** | I found the system unnecessarily complex. | Memory |
| **R3** | I consider the system was easy to use. | Memory |
| **R4** | I might need technical support to use the system. | Errors |
| **R5** | I found various functions on the systems were well integrated. | Learning |
| **R6** | I consider the system had lots of inconsistencies. | Errors |
| **R7** | I believe most people could learn how to use the system very quickly. | Learning |
| **R8** | I found the system very annoying to use. | Satisfaction |
| **R9** | I felt very confident while using the system. | Satisfaction |
| **R10** | I need to learn a lot of things before I could use the system correctly. | Learning |

The items that represent the attribute of *Satisfaction* are R1, R8 and R9. From table 2 we can see that students consider using frequently the educational platform that they have used until now for their online classes (Teams and Classroom), thanks to, inter alia, that it is safe, and they feel comfortable with it. The obtained score is of 3.6 for the frequent use of the platform, on a scale from 1 to 5, where 1 is *heavily disagree* and 5 is *totally agree*. The safe feeling that they get from the platform also has a value of 3.6 and the joy that they feel is of 3.2, on the same scale from 1 to 5. The average score surpasses the value of 3 and variability of the data regarding the median does not go beyond 1, that is why the satisfaction level of the Teams or Classroom platform is Good.

Regarding the *Learning* attribute, the reagents that evaluated it are R5, R7 and R10. The students of the sample consider that the learning curve of the use of the platforms Teams and Classroom, it is low thanks to the well-integrated functions, and the speed of their use score a 3.8 on a scale from 1 to 5. Concluding that Teams, as well as Classroom are platforms which learning are basically intuitive.

The *Memory* attribute was evaluated with the R2 and R3 reagents, the students agreed that the used platform was easy to use with a 4.0 score and they disagreed that the platform was unnecessarily complex with a 2.2 score on the same scale from 1 to 5, that is why both results are considered good for both platforms, Teams and Classroom.

Finally, the reagents R4 and R6 evaluate the number of errors that can appear while using the system. The obtained values in the questionnaire were 1.7 and 2.1 on a scale from 1 to 5, so we can assume that the students heavily disagreed with needing technical support to use the system and disagreed with the systems having inconsistencies.

Table 3. Statistic values of SUS

| Id | Deviation | Variance | Average per question | Range in the evaluation |
|---|---|---|---|---|
| **R1** | 0.942 | 0.888 | 3.65 | Agree |
| **R2** | 0.957 | 0.916 | 2.28 | Disagree |
| **R3** | 0.892 | 0.796 | 4.03 | Agree |
| **R4** | 0.882 | 0.778 | 1.73 | Heavily disagree |
| **R5** | 0.837 | 0.701 | 3.78 | Agree |
| **R6** | 0.933 | 0.871 | 2.16 | Disagree |
| **R7** | 1.030 | 1.062 | 3.77 | Agree |
| **R8** | 1.006 | 1.012 | 1.88 | Heavily disagree |
| **R9** | 0.962 | 0.926 | 3.6 | Agree |
| **R10** | 0.899 | 0.809 | 1.97 | Disagree |

To evaluate the fifth component (efficiency), the second questionnaire was used.

The second questionnaire show that most of the students were agree in affirm that the educational platforms they have used allowed them to improve their online productivity (82.5%). Nonetheless, it must be said that even if most students agreed with improving, they also said that a presential modality would be better. A more in-depth analysis can be seen in the table 4 and 5.

Table 4. Complementary questionnaire to SUS

| Complementary Questionnaire to SUS | | |
|---|---|---|
| **Clave** | **Questions** | **Attribute** |
| **S1** | Out of the following platforms and educational tools, which ones have you used on you current subjects? 1. Microsoft Teams, 2. Classroom, 3. Google Meet, 4. Webex CISCO, 5. EDMODO, 6. Moodle and, 7. Zoom | Frequency of use |
| **S2** | Which one do you consider to be the most useful? | Efficiency |
| **S3** | Describe why do you consider it that way. | Memory, efficiency satisfaction and learning |
| **S4** | Has the use of the platforms mentioned in question 1 allowed you to improve your online productivity? | Efficiency |
| **S5** | Do you consider that your online learning has become as good as your presential one? | Efficiency |

Table 5. Statistics values of the complementary questionnaire

| SUS complementary questionnaire | |
|---|---|
| **Clave** | **Analysis** |
| **S1** | Most participants said Microsoft Teams or Classroom. |
| **S2** | 33 votes were in favor of Microsoft Teams and 24 of Classroom. |
| **S3** | The answers given of the most used platforms were:<br>Microsoft Teams: 8 students said it is practical, easy to use, 6 said that it has better tools, 10 that it allows to manage the homework, 5 that it allows to record the classes and 2 that it was an integral solution.<br>Classroom: 11 students said it is practical, easy to use, 2 that it has better tools, 8 that it allows to manage the homework and 2 that it sends notifications. |
| **S4** | 82.5% of the participants said "Yes". |
| **S5** | 86.3% of the participants said "No". |

A direct relationship between the satisfaction (obtained thanks to reagent 1) that the users felt while using the platform and the learning attributes and memory was found, which implies, that the more the user likes the platform, the learning of its functionalities will be easier, faster, and more lasting (according to reagents R3, R5, R7 and R9).

Consistency was also found in the results while evaluating the *Error* attributes, obtained from reagents R4 and R6, the users agreed that the platform did not show a big number of inconsistencies, and that support was not necessary to use It. (Table 6).

Table 6. Correlation between the SUS questions

| | R1 | R2 | R3 | R4 | R5 | R6 | R7 | R8 | R9 | R10 |
|---|---|---|---|---|---|---|---|---|---|---|
| R1 | 1 | | | | | | | | | |
| R2 | -0.042 | 1 | | | | | | | | |
| R3 | 0.497 | 0.086 | 1 | | | | | | | |
| R4 | 0.172 | 0.30 | 0.421 | 1 | | | | | | |
| R5 | 0.610 | 0.049 | 0.637 | 0.316 | 1 | | | | | |
| R6 | 0.250 | 0.329 | 0.159 | 0.513 | 0.246 | 1 | | | | |
| R7 | 0.452 | 0.126 | 0.573 | 0.302 | 0.589 | 0.329 | 1 | | | |
| R8 | 0.215 | 0.283 | 0.319 | 0.422 | 0.329 | 0.396 | 0.305 | 1 | | |
| R9 | 0.415 | 0.217 | 0.474 | 0.318 | 0.474 | 0.264 | 0.456 | 0.269 | 1 | |
| R10 | -0.034 | 0.375 | 0.235 | 0.438 | 0.191 | 0.336 | 0.156 | 0.374 | 0.041 | 1 |

# 5. Conclusions

Even when the acceptability of the usability and the users experience when working with the platforms was graded as good, it remains clear that it is important to realize a continuous evaluation of these to know their quality and improve them, also considering the fact that despite the students feeling that they are useful to learn, they still prefer presential education.

Other of that, it can be ensured by the preference of the participants, that the Microsoft Teams and Classroom platforms are of better quality than the rest of those presented and that they can continue to be used by teachers and students for the didactic purposes established from a start, with very good results.

Future research may try to establish the particular conditions under which students could be convinced that distance education can be comparable to face-to-face education, for the benefit of the next generations of students and so that education can be taught in anytime, anywhere.

The results coincide with a recent survey published by the INEGI [3] about the perception of online classes on Mexico, 58.3% said that you don't learn o that you learn less that on person, 27.1% said that there is a lack of tracking in their learning and 23.9% thinks that teachers and parents alike lack a technical training to transmit knowledge using the internet.

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# Chapter 3

## Assessment in mathematics using computer devices and digital platforms during the pandemic by COVID-19

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**Abstract**
This article shows the information on the benefit of the use of digital platforms in the assessment of mathematics in a random selection of students from a higher level academic unit. The scope of the research was descriptive-correlational. A questionnaire applied to a sample of 79 students was used as a methodological instrument. The results obtained shows the need of a better way to accomplish the learning process before assessment, as the on-line classrooms during lockdown caused for COVID-19 expose the failures in the face-to-face educational system in digital environment. Teachers and students lack the skills to share and obtain knowledge causing a great dropout from schools and universities in México due to distrust in the quality of learning methods through pandemic lockdown. Gamification is proposed as a learning tool that will promote the learning in students in a way familiar to them; games and videogames.

**Keyworks** Evaluation, Online education, higher level.

## 1. Introduction

The pandemic caused by the coronavirus COVID 19 [1] force a worldwide lockdown, this is the first event of this nature to be presented in XXI century, in an era where the mobile, web apps and multimedia were beginning to have a boom as auxiliary tools in the educational field and the number of mobile lines in the world has been increased [2].

Suddenly, the global education system faces significant challenges [3] and in Mexico all the education were limited to virtual classrooms without any further design, capacitation and evidence of success [4], teachers had to contrive a way to use the technology to teach and conduct assessments, however in many cases these tools are not well used not even to the maximum, because certain population of teachers still using the same face-to-face system in a virtual environment through computer displays as the only difference or even writing on a whiteboard as a teaching method.

On the other hand, there are teachers who, due the lack of informatics knowledge, skills, vigilance or personal problems derived by the COVID emergency get limited to just order activities, send PDF files, YouTube media or other resources to the student, leaving the progresses and learning to themselves without further feedback beyond the work delivery and the final assessment, in some cases the lack of practice in e-learning tools might create a perception that they cannot provide students with the full, coherent knowledge [5].

In the student population they often lack prior online learning experience [3]; this could lead to anxiety, jaded, lack of motivation and decrements in academic performance [3]. Those who learn in classes where it is limited to the use of digital files, multimedia and task or project delivery without feedback from the teacher tend to postpone or the importance is relieved with respect to those that are constant through videoconferencing or support platforms such as Google Classroom.

### 1.1 Research Problem

The way to evaluate mathematics at a distance during the pandemic represents a challenge faced by teachers, because the use of written exams has predominated from the face-to-face education model.

### 1.2 Purpose

Taking these factors into account, the purpose of this article is to make an analysis of the evaluation process of students in their mathematics courses during the pandemic to identify the advantages of the use of digital platforms as support in full time online learning assessment in mathematics in university students. With the information obtained, a proposal was elaborated to allows a better evaluating of knowledge and skills in mathematics using e-learning.

## 2. State of the art

The education in universities has been for a long time centered in academic teaching, perhaps too theoretical [6], and the learning method tend to be confused with the process of course accreditation [7], this is because the assessment is used to provide a grade as a knowledge measurement, making students just care about passing the course but not learning [7].
This represents a problem at the university level, where the greatest cause of school dropout is not course approval [8], especially in mathematics due to lack of prior knowledge that generates distrust in the student, coupled with minor vocational guidance and little participation of the academic counselor, all this from upper high school [9].

Based on these assessments, The National Institute of Statistic and Geography *INGEI* (for the acronym in Spanish), defines *the university level* in México as studies of technical, professional or commerce career with antecedents of high school; degrees as well as postgraduate courses which include the specialty, the master's degree and the doctorate [10]. From March 2 to March 27 of 2020 the INEGI lead the population and housing census [11]and the population from 3 to 29 years old made up of 54.3 million people, only 33.5 million were registered in schools [12]. Of which the university population in 2019 before pandemic was 2,790,982, but in December of 2020, the number of students drops to 2,407,335.00 [4]. The 26.6% of population who dropout from school, believes that the on-line classes are not functional, the 17.7% lacked internet, computer or any device to allow internet connection, 28.8% lose contact with teachers or was not able to do or complete homework, and the 6.7% had to leave school to find a job and support family during pandemic in 2020 [12]. The students who did not dropout from school, the 58.3% says that you do not learn or learn less than face to face, 27.1% have less feedback and tracking by the teachers, 23.9% are not satisfied with the skills and technical capacity from the teachers to share knowledge, 18.8% manifests an excess of academic load and school activities.

The digital transformation that came suddenly, and what was planned for a few years, had to be implemented in just a few weeks [4]. In México the on-line classes were forced since March 23 of 2020 [13], in some states started since March 17 [14]. The main digital platforms used by university teachers and students in México for on-line classes showed a significant growth from February 29 to March 18 [4], as can be seeing in Figure 1.

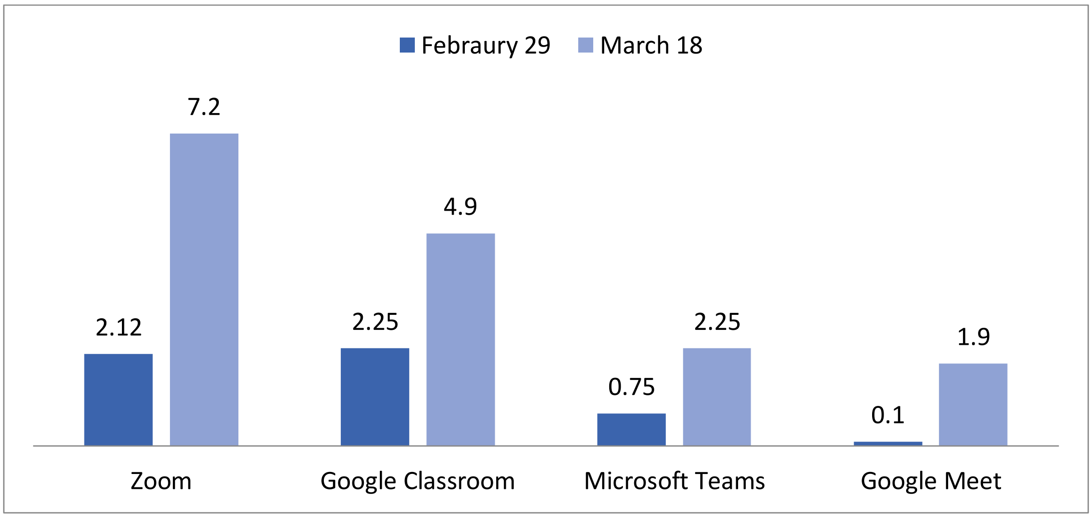



Figure 1: Graphic that shows the growth in digital platforms in million users.

Unfortunately the situation forced numerous users to face difficult situations, unfavorable or frustrating due to the lack of adequate skills, knowledge, computer equipment, or stable connections to internet [15]. On the students side just the 67.7% owned internet and any computer device including tablets, cellphone, laptops and Desktop computers, the 28.5% had to share it to another members in the house, 2.7% had to borrow it, 0.5% had to loan it and 0.6% didn't specify [12].
The computer devices used for on-line classes and internet connectivity by the university students during pandemic was the follow [10], as it shows in Figure 2.

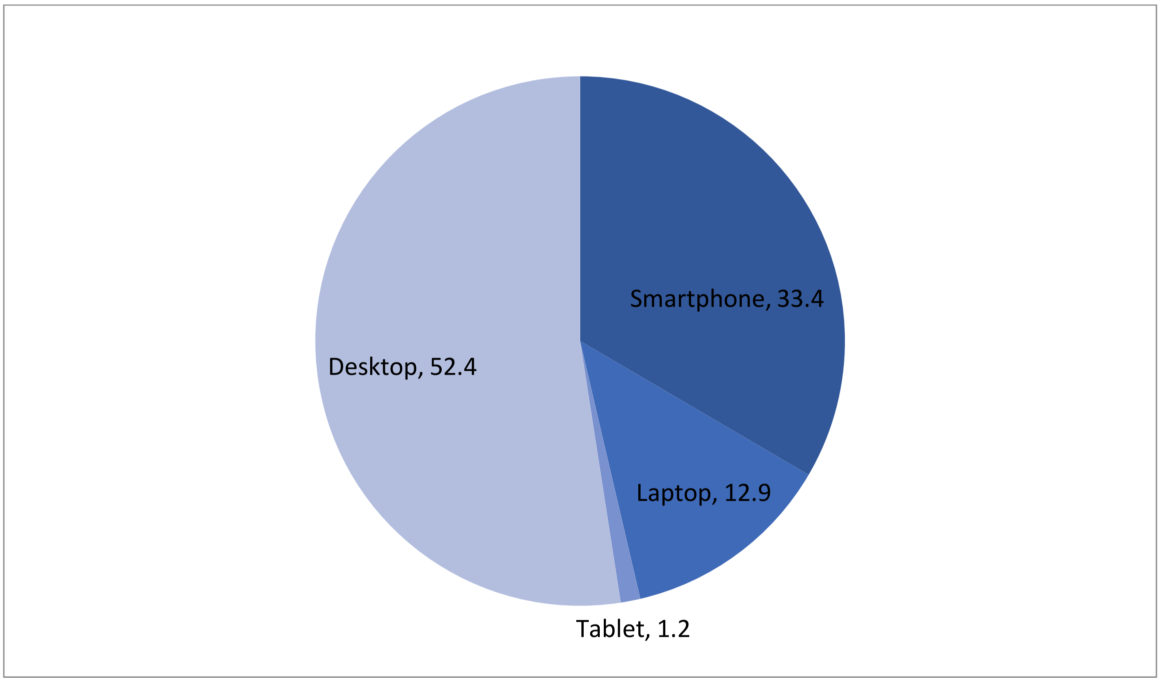



Figure 2: Computer devices used by university students during COVID-19.

On the teacher's side, there were 193,346 in their population in 2019, and during pandemic in 2020 drops to 192,496 teachers [4]. The on-line classes have their own didactic process, from the way to give a class, the use of multimedia resources, communication dynamics and assessment ways [16], for teachers became a great challenge, especially for those in older ages, a challenge for which they did not feel prepared that frequently frightened them due to their ignorance and lack of training of those platforms and digital services [15], required for their on-line classes.
In addition to this, it is important to include that the migration from a face-to-face system to digital reduces educational performance, in both students and teachers [17] for many causes, among them giving and taking classes in a way they don't dominated, lack of strategies, more work than before and mainly the physical and emotional fatigue [15].

Forced on-line classes might have long-term negative consequences [5], with the decrease of motivational interest and negative experiences [5], therefore provide teachers the elements that allow them to design and implement effective strategies within the IT [18]. Some advantages of IT useful as much as students and teachers that should be taken into account is motivation, interest, interactivity, creativity, communication and cooperation [19], those advantages can be used to adapt the academic plans to the today society, shorts, less academic and more practical [6].

One of the most popular concepts to include these advantages in digital environment learning is *Gamification*, because this gives the opportunity to development the tools and skills encouraging the students to complete the learning objectives in a more interactive and amusing way [20].

Gamification achieves this trough development of soft and hard skills with games; they can be board games, card games, videogames, or dynamic activities [21], the basic principle is learning based on games and simulators with motive design and conducting the users to a purpose in a fast and efficient way [20].

At university level, there are 5 main gamification tools in use for STEM [22] (Science, Technology, Engineering and Mathematics) [23] learning.

Table 1: Gamification Tools

| Existing Gamification Tools | Use |
|---|---|
| **Code.org** | Computer Science |
| **CodeAcademy.com** | Programming Learning |
| **CodinGame.com** | Programming Learning |
| **KhanAcademy.org** | Learning Platform for STEM |
| **Kahoot!** | Classroom Response System |

## 2. Theoretical Aspects

Gamification became an object of interest since early 2010 [24], in simple words, gamification is the use of game design in non-gaming context [22]. The term was first used in 2002 by Nick Pellin to describe a game-like interface [25]. It's a modern digital term for all the skills that can be development with new techniques that incite the student to participate and achieve the stablished objectives [20].

This is due to a natural behavior; animals find the game as a learning tool for training in a simulated environment; with this method they face gradually more complex challenges decomposed in basic actions practiced until perfection [26]. In classrooms the cognitive process can use the evolutionary brain capabilities of that natural survival tool in junction with technology and game to development learning activities to maximize the student capacity in problem solving [26]. The theoretical frameworks in which modern STEM gamification software are based on are the following [22]

- Self Determination Theory (SDT)
- ARCS Motivational Theory
- Mechanics Dynamics Aesthetics Theory (MDAT)
- Bloom's Cognitive Goals Taxonomy
- Dynamics Mechanics Components Toolkit
- Flow Theory
- Lander's Theory of Gamified Learning
- Nicolsin's Meaningful Gamification Framework
- Technology Acceptance Model (TAM)

Despite the theoretical framework or if is development on digital or analog environment, the gamification elements to design and implement a learning application are cited below [22].

- Leaderboards
- Badges
- Points
- Levels
- Progress Bars
- Avatars

Some other factors to take into account are a 5-step model proposed by Huang & Soman [25].

- Understand the target audience and the context
- Define learning objectives
- Structure the experience
- Identify resources
- Apply gamification elements

# 3. Methods and Materials

The scope of the investigation is descriptive and correlational Therefore, some statistics tools were used, such as the mean and the standard deviation to describe the variables involved in the questionnaire as well as the relationship between them.

A random sample of 80 students was studied, who were in any semester of the Bachelor of Engineering in computer systems, in an academic unit of the National Polytechnic Institute, for which several courses require developing some competence in one of the disciplines of mathematics such as critical thinking and problem solving, their ages ranged between 17 and 25 years old.

The methodological instrument used was a questionnaire with 11 questions, of which 4 had Likert-type options, in 2 they could choose more than one option as an answer and 3 were open questions. This questionnaire was created in google forms and was applied online in May 2021.

The purpose of the questionnaire was to know the opinion of the students in relation with the use of technologic tools by the teachers in the evaluation process in the long distance classes.

Microsoft Excel was used for data treatment.

Cronbach's alpha coefficient was used to validate the questionnaire, this coefficient is used to know the reliability of a measurement scale, its values range between 0 and 1, and the closer it is to 1, the more consistent are the items in the questionnaire. It is based on the average of the correlations between the items [27], and its formula is presented in (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:
K: Sample size.
$\sum_{i=1}^{k} S_i^2$: Sum of variances.
$S_t^2$: Variance of sums.

Correlations were established between the *variable Efficiency in the use of technological tools by the teacher* that appears in question 5 of the questionnaire with the variables *Development of mathematical skills*, *Feedback given by the teacher* and *Adequate evaluation in mathematics* that are contained in the questions 6, 7 and 10 respectively. In the same way, the variables of question 6 were related to 7, 6 to 10, and 7 to 10, using Pearson's correlation coefficient, this coefficient measure the strange of linear relation between quantitative values of paired x and y variables in a given sample [28], the equation is presented in (2).

$$\rho(x,y) = \frac{\sigma xy}{\sigma xy} = \frac{cov(x,y)}{\sqrt{Var(x)Var(y)}} \quad (2)$$

Where:
$\sigma xy$: Covariance of X and Y.
$\sigma x$: Is the standard deviation of X.
$\sigma y$: Is the standard deviation of Y.

# 4. Results and Analysis

The questionnaire was validated trough the Cronbach's Alpha giving a value of 0.70, which for studies in social sciences area is considered a good parameter. The results are showed in table 2.

Table 2: Croonbach's Alpha

| Variable | Result |
|---|---|
| **K** | 80 |
| **K-1** | 79 |
| **Sum of variances** | 1.626265823 |
| **Variance of sums** | 5.366455696 |
| **Cronbach's Alpha** | 0.705779431 |

In table 3, can be seeing the questions whose options was Likert type answers and was considered 4 values, the 1 corresponds to *Strongly Disagree*, 2 to *In Disagreement*, 3 to *Agree* and 4 to *Strongly Agree*.

The students that made up the population are agree with the use given by the teachers to the technological tools in assessment was efficient in their mathematics class during the COVID-19 Pandemic, giving a 2.7875 of 4 in the Likert scale, since they consider that a good feedback from the teachers could be achieved, designating 2.725. Despite this when we compare the on line classes with face to face they believe that the mathematics skills developed is smaller, as it had 2.0875 points in this matter. In addition the general perception about the technological tools was good with a point given of 2.875 of approval.

Table 3: Likert questions

| Question | Percent (%) | Mean | Standard Deviation |
|---|---|---|---|
| **5. - Do you consider that the way in which the technological tools were used to evaluate you during the pandemic was efficient?** | 1) Strongly Disagree (7.5%)<br>2) In Disagreement (10%)<br>3) Agree (78.75%)<br>4) Strongly Agree (3.75%) | 2.7875 | 0.630325413 |
| **6. - With distance cla sses, do you consider that you had the same or greater development of math skills in distance classes?** | 1) Strongly Disagree (16.25%)<br>2) In Disagreement (63.75%)<br>3) Agree (15%)<br>4) Strongly Agree (5%) | 2.0875 | 0.715006418 |
| **7. - Did the technology used to evaluate your math courses allow feedback with your teacher?** | 1) Strongly Disagree (10%)<br>2) In Disagreement (11.25%)<br>3) Agree (75%)<br>4) Strongly Agree (3.75%) | 2.725 | 0.693094328 |
| **10. - Do you consider that the use of the technological tool for your assessment was adequate?** | 1) Strongly Disagree (3.75%)<br>2) In Disagreement (7.5%)<br>3) Agree (86.25%)<br>4) Strongly Agree (2.5%) | 2.875 | 0.487177352 |

The way students are assessed during online classes presented a similarity with face-to-face system; a higher weight was assigned to the oral exam, research work, homework, and software development. The written exam continued to be the main evaluation method with a weighting to the total grade from 60% to 100% during the pandemic, but showed an important reduction for part of the teachers.

The written exam between the 61-90% of total grade had a weighting of 74.19% before pandemic but after drops to 59%. The teachers who use written exam with a weighing of 91-100% were 84% but fall to 63.70%, as showed in table 4.

Table 4: Written Exam

| **Written Exam** | **Weighing** | **Use in assessment** | |
|---|---|---|---|
| | | Before Pandemic | During Pandemic |
| | 0-30% | 0.35% | 1.50% |
| | 31-60% | 37.84% | 43.15% |
| | 61-90% | 74.19% | 59% |
| | 91-100% | 84% | 63.70% |

From the oral exam, there was a minor change, before pandemic near the 2% of teachers assigned a weighing between 61 to 90% and during the lockdown fall to 0% as showed in table 5.

Table 5: Oral Exam

| Oral Exam | Weighing | Use in assessment | |
|---|---|---|---|
| | | Before Pandemic | During Pandemic |
| | 0-30% | 20.35% | 20.75% |
| | 31-60% | 4.06% | 5.26% |
| | 61-90% | 1.61% | 0% |
| | 91-100% | 0% | 0% |

In relation to the research work, before pandemic nearly 2% of teachers in mathematics assigned a weighing between 61 to 90% and during the lockdown that value increase to 8%, as showed in table 6.

Table 6: Research Work

| Research Work | Weighing | Use in assessment | |
|---|---|---|---|
| | | Before Pandemic | During Pandemic |
| | 0-30% | 19.65% | 18.86% |
| | 31-60% | 13.51% | 13.68% |
| | 61-90% | 1.61% | 8% |
| | 91-100% | 0% | 0% |

The software development; increase in the weighing between 61 to 90% and decrease 2.23% from 31 to 60% of the total grade as shows in table 7.

Table 7: Software Development

| Software Development | Weighing | Use in assessment | |
|---|---|---|---|
| | | Before Pandemic | During Pandemic |
| | 0-30% | 17.19% | 17.73% |
| | 31-60% | 14.86% | 12.63% |
| | 61-90% | 3.22% | 5% |
| | 91-100% | 0% | 0% |

Homework shows increased values in all the weighing during pandemic over the face-to-face system, as shows in table 8.

Table 8: Homework

| Homework | Weighing | Use in assessment | |
|---|---|---|---|
| | | Before Pandemic | During Pandemic |
| | 0-30% | 22.19% | 19.53% |
| | 31-60% | 13.51% | 15.78% |
| | 61-90% | 6.45% | 13% |
| | 91-100% | 12% | 27.30% |

Problem list increase from 12% to 21.63% in 0 to 30% of the total grade during pandemic, but decrease significantly from 31 to 100% of the total grade as seen in table 9.

Table 9: Problem List

| Problem List | Weighing | Use in assessment | |
|---|---|---|---|
| | | Before Pandemic | During Pandemic |
| | 0-30% | 12% | 21.63% |
| | 31-60% | 20.27% | 9.5% |
| | 61-90% | 16.22% | 15% |
| | 91-100% | 12.92% | 9% |

The technological tools employed for assessment during online classes show in table 9, were used mainly those aimed at conducting videoconferences such as zoom or Microsoft Teams and job management of the type Google Classroom or Edmodo, that are platforms created to facilitate distancing conditions, despite this some teachers found educational uses to those that were not intended for this purpose like Kahoot of Google Forms, alike communication platforms as WhatsApp became a foundation for a good development in online classes.

Table 10: Technological Tools used in online classes

| Category | Platform | Application |
|---|---|---|
| **Job Management** | Classroom<br>Edmodo<br>Teams | Task Assignment<br>Support material sharing<br>Assignment delivery<br>Feedback |
| **Videoconferences** | Zoom<br>Teams<br>Meet | On-line classes<br>Surveillance during write exams<br>Oral exams |
| **Interactive Quizzes** | Kahoot<br>Google Forms | Write Exams<br>Questionnaires<br>Exercises |
| **Communication** | WhatsApp<br>E-Mail | Task Assignment<br>Support material sharing<br>Assignments Delivery<br>Feedback |

# 5. Propose

The written exam must be designed by the teachers, applying their professional knowledge to exemplify the mathematical methodologies in real life situations that will be used by university students in their professional practice; it can't be removed, however should evolve with the actual digital society and find mechanism within gamification to promote knowledge instead of course approval, since many existing written exams can be found in internet, as they are taken or copied from books and we all fool ourselves.

The oral exams should have the format of a conversation for this to obtain and understand the reasoning and skills of student's problem solving, to identify the failures and prior knowledge deficit, bringing support to achieve knowledge objectives over course approval.

In assessment, research work requires increasing weighing in the total grade, since it is in this work where students apply their real knowledge.

In a concrete way, an example is shown where the student is asked to explain step by step the resolution of a problem of the probability and statistics learning unit and then formulate the algorithm that allows him to program in some language to arrive at the construction of software that could be used as gamification tool. With this, mathematics is being interrelated with its area of study in computer systems.

The software described below use the following statement:

Suppose that the probability that a certain person creates a rumor about the transgressions of a certain famous actress is 0.8. What is the probability that:

a) Is the sixth person to hear this rumor be the fourth to believe it?
b) Is the third person who hears this rumor the first to believe it?

Three mathematical tools were used, factorial, combinatorial and negative binomial. The factorial receives an integer and binomial negative receives four values as can be seen in (3)

$$\binom{x-1}{k-1} p^k q^{x-k} \qquad (3)$$

Where:
X – People who hear the rumor
K- People who believes in rumor
P – Probability of believe
Q – Failure probability
And combinatorial formula is presented in (4).

$$\binom{x-1}{k-1} = \frac{(x-1)!}{(k-1)![(x-1)-(k-1)]!} = \frac{n!}{x!(n-x)!} \qquad (4)$$

The software interface ask the user for the values of x, k and p from (3) and then shows the answer, as can be seen in figures 3 and 4.

Figure 3: Software interface

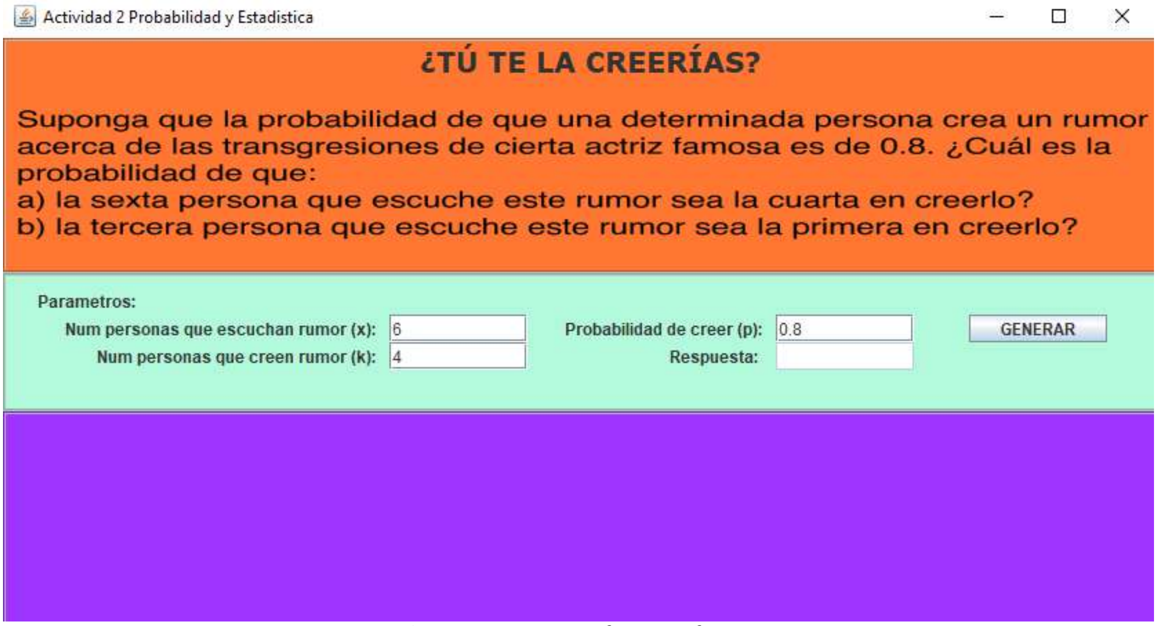
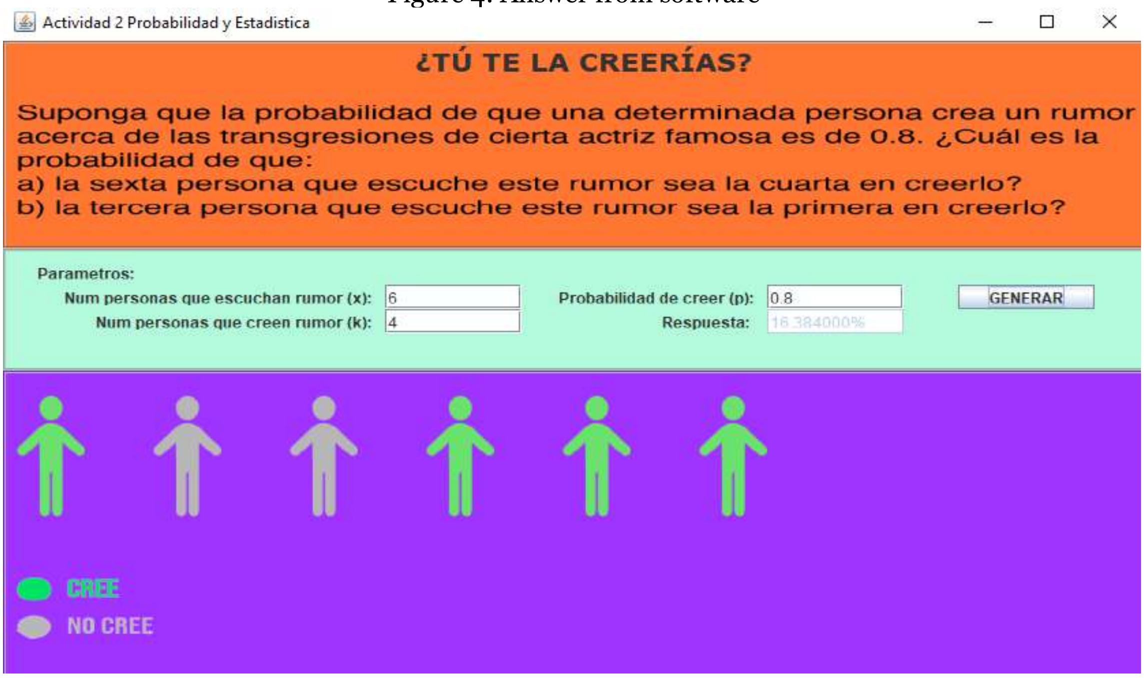



Figure 4: Answer from software




This demonstrates the use of gamification as binomial negative and statistic is presented to the student in game environment making funny and easy to understand.

# 6. Conclusions

On-line learning deserves development of suitable material to present theory, exercises, examples and assorted academic resources that allow students be more explicit with their explanations, that the student can visualize the mathematical problems proposed, and the assessment cannot be based only in written exam, and its weighing must be drop, instead problem list and research projects, what is where students apply their real knowledge must be a priority combine with gamification to encourage students in the learning process.

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# Chapter 4

## Application of Machine Learning methods on a Dataset of COVID-19 cases in Mexico

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**Abstract**

This article addresses the problem and the estimation of infections by COVID-19, as well as the hospital capacity in Mexico, in order to show the need to make better decisions in relation to the measures taken to avoid infections. Similarly, a model is proposed that allows the estimation, for which Machine Learning techniques have been used, as well as the prediction of the behavior of the infection and hospitalization curve, using the polynomial regression algorithm. Additionally, a dataset has been used that was obtained from the epidemiological surveillance system of viral respiratory diseases, which is published by the Ministry of Health. This study was carried out at the end of December 2020 and during the month of January 2021, period of time before the vaccination campaign carried out in Mexico, which is the reason why this variable is not contemplated. The prediction projection that has been made was used with a few days, due to the derivation that the projections obtained with the parameters are reliable for a small number of days. The aforementioned is attributed to the dynamic behavior shown by the spread of the virus.

**Key words:** Machine learning, Polinomyal, COVID-19

## 1. Introduction

Just reviewing the current news is enough to know the situation in Mexico and around world regarding the COVID-19 pandemic. At the beginning of epidemiological week number 50 (more than nine months from the registration of the first case), 1,175,850 confirmed cases of coronavirus are reported in Mexico and 109,717 deaths, according to the latest report from the Ministry of Health [1].

There are many negative impacts that are already occurring and many others that are to come derived from the coronavirus outbreak. One of these impacts affects the economy, which, derived from the political decisions that many governments have implemented (imposition of social distancing policies, blockade restrictions, etc.) have triggered a global economic recession during this year and which will continue featuring in years to come [2]. Likewise, another impact generated has impacted on the mental health of the population, due to the high prevalence of adverse psychiatric symptoms (such as major depressive disorder, post-traumatic stress disorder and suicide) which have occurred since the worldwide apogee of this pandemic. [3].

### 1.1 Problem Statement

Hospital capacity in Mexico has shown to be insufficient to attend and deal with the problem of the pandemic [4]. Despite the measures instituted by the Mexican government, the cases of contagion have been increasing, derived from the unconsciousness of the population and the coming winter. The daily reports show the development of the pandemic situation every day based on the tests that are being carried out, but it is important to make studies on the behavior of the data in order to be able to predict the number of infections and people who require hospitalization, which will allow the government to have information that contributes to take the best decisions about the installed capacity in hospitals that care for patients with COVID-19.

### 1.2 General objective

Machine learning methods help identify patterns in a data set, which is often large in size, in order to make predictions. The sectors in which these algorithms are applied to predict the behavior of the data are becoming larger [5]. These sectors are retail, media, finance, science, industry, security, and government.

Having mentioned the objective of Machine Learning, and added to the problems we have in Mexico about the pandemic, this article proposes to carry out a study to discover findings and the necessary knowledge to face this disease, using Machine Learning techniques, as well as the prediction of the behavior of the infection and hospitalization curve through the use of the polynomial regression algorithm. Polynomial regression is a form of linear regression in which the relationship between the input variables x, and the output variable y, is modeled as a polynomial [6]. The information obtained from this study can be used by the general public or by the Mexican government to carry out actions that contribute to combat and minimize the impact of the COVID-19 pandemic in the country.

## 2. Art State

Work and research studies have been carried out on data sets that contain information on the COVID-19 pandemic in Mexico, through the implementation of Machine Learning methods. In [7], the population growth of cumulative cases and cumulative deaths is defined using three growth models and their respective logistic curve fits in order to predict the inflection point and cutoff value of the COVID-19 outbreak. The three curve fitting models that are used are: Generalized Linear Models (GLM) and two multivariate time series models: Long short-term memory (LSTM) and Vector Autoregression (VAR), which is used to predict the number of daily cases and deaths of COVID-19 in Mexico.

In this study [8], the Naive Bayes algorithms, k-nearest neighbors, decision trees and support vector machine are applied to a dataset of infected patients in Mexico, for the classification of characteristic vectors among the variables that make up the dataset, the support vector machine being the most accurate at the time of classifying.

In [9], models with logistic regression algorithms, decision trees, support vector machine, Naive Bayes and the neutral artificial network are developed for the correlation analysis between the dependent and independent variables and in this way to be able to identify the strength of the relationship that exists between each variable with respect to the other. The result of the evaluation of the performance of the models showed that the decision tree model has the highest precision of 94.99%, while the support vector machine model has the highest sensitivity of 93.34% and the Naive model Bayes has the highest specificity of 94.30%.

## 3. Theoretical framework

Machine learning is a method that uses algorithms to enable computers to learn things without having been previously programmed. The mentioned set of algorithms emulate human intelligence and are based on different disciplines such as artificial intelligence, probability and statistics, computing, among others [10]. The main characteristic of these algorithms is that they learn from the input data processed by the algorithm, and the more data they have, the better the learning [10]. There are many definitions of machine learning, but the most widespread is that of Tom Mitchell in his book [10], "It is said that a computer program learns from experience (E) with respect to some class of tasks (T) and measurement performance (P), if their performance in tasks in T, measured by P, improves with experience E "

The machine learning algorithm processes information and learns from it in three different phases. Each phase uses a different dataset that serves a specific purpose. The first phase, called the *training phase*, uses the training data to train the model from a given input and an expected output. The result of this phase is the learning model. The second *phase of validation and testing* uses the validation data to measure how good the trained learning model is, using measures of error, recall, and precision. The result is a sophisticated learning model. The last is the *application phase*, where the model is subject to new data that is obtained from the real world that will lead to a result [10].

When working with linear models to make predictions, it is found the advantage that they can be interpreted more easily, however, they show limitations in predictive capacity. This is due to the fact that by assuming linearity, it is the simplest way to describe the real relationships between variables [11]. A polynomial regression consists of adding curvature to the model when introducing new predictors, the result of raising either some or all of the original predictors to different powers [11]

Starting from of a linear model:

$$yi = \beta 0 + \beta 1xi + \epsilon i \qquad (1)$$

Polynomial regression seeks to obtain a prediction of a quantitative variable from another quantitative variable, with a relationship modeled as a polynomial function of order or degree n. The result is a polynomial shown in the following equation. ϵi represents the error in the estimation, that is, the difference between the estimated value and the observed value.

$$yi = \beta 0 + \beta 1xi + \beta 2x_i^2 + \beta 2x_i^3 + \ldots + \beta nx_i^n + \epsilon i \qquad (2)$$

Sometimes it is not advisable to use the polynomial model with a degree greater than 3 or 4, since it results in an excess of flexibility or what is commonly known as overfitting. Selection of the optimal polynomial degree can be done using cross validation [11].

The standard error is the standard deviation of the sampling distribution of a statistic. This value indicates the amount of variation between samples from the same population. Large values of this measure indicate that the statistic does not adequately represent the population from which the sample comes [12]. Multiple R-squared represents the percentage of the variation in the response variable that can be explained by the model [12].

## 4. Methodology and Materials

The dataset that was used to carry out this study is the information from the epidemiological surveillance system for viral respiratory diseases that is published by the Ministry of Health through the General Directorate of Epidemiology. The information contained in this system corresponds only to the data obtained from the epidemiological study of a suspected case of viral respiratory disease at the time it is identified in the medical units of the Health Sector. The dataset was obtained from the Mexican government website and is open to the general public [13]. The dataset is made up of 40 variables and 4,642,539 records (data with a cut-off date of January 29, 2021), but for the purposes of this study, Table 1 shows the variables that were used. The programming language used to perform the model and statistical analysis is R, with the help of the R Studio tool.

Table 1: Dataset variables to be used in the study

| **Variable name** | **Description of the variable** | **Format or font** |
|---|---|---|
| Gender | Identify the gender of the patient. | 1 Woman<br>2 Man<br>99 Not specified |
| Patient_type | Identify the care type the patient received in the unit. It is called an outpatient if the patient has returned home or it is called an inpatient if the patient was admitted to the hospital. | 1 Outpatient<br>2 Hospitalized<br>99 Not specified |
| Admission date | Identify the date of admission of the patient to the care unit. | YYYY-MM-DD |
| Death_date | Identify the date the patient died. | |
| Intubated | Identify if the patient required intubation. | 1 Yes<br>2 No<br>97 Not applicable<br>98 Ignored<br>99 Not specified |
| Pneumonia | Identify if the patient was diagnosed with pneumonia. | |
| Smoking | Identify if the patient has a smoking habit. | |
| Diabetes | Identify if the patient has a diagnosis of diabetes. | |

| | | |
|---|---|---|
| Coped | Identify if the patient has a COPD diagnosis. | |
| Asthma | Identify if the patient has a diagnosis of asthma. | |
| Immunosuppression | Identify if the patient is immunosuppressed. | |
| Hypertension | Identify if the patient has a diagnosis of hypertension. | |
| Cardiovascular | Identify if the patient has a diagnosis of cardiovascular disease. | |
| Obesity | Identify if the patient has a diagnosis of obesity. | |
| Chronic Kidney | Identify if the patient has a diagnosis of chronic kidney failure. | |
| ICU | Identify if the patient required admission to an Intensive Care Unit. | |
| Age | Identify the age of the patient. | Numeric in years |
| Classification_final | Identify if the patient is a COVID-19 case. | See Table 2 |

The methodology for the developing of the machine learning and analysis models for this study is shown in Figure 1.

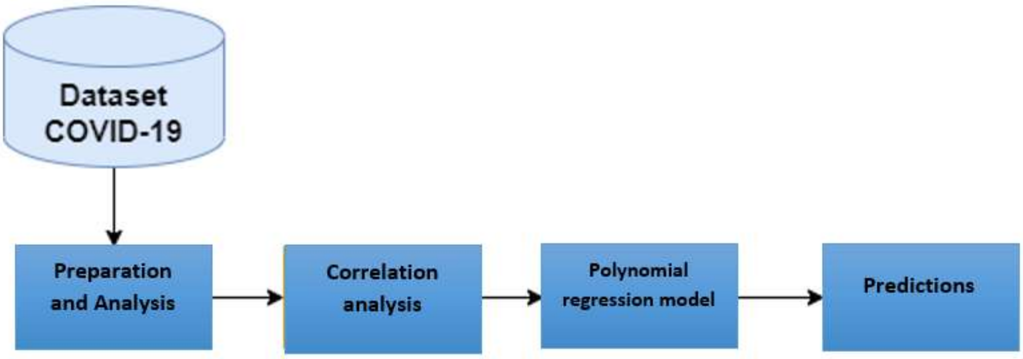


Figure 1: Methodology

As a first step, a work was done on preparing the input dataset to apply data cleaning and selection of records to be used, and additionally, new variables derived from others that were necessary for the study were created. Once the dataset was prepared, an analysis of certain variables was applied in order to know the status of the information. Subsequently, a correlation analysis was made between the clinical variables of the dataset and a new variable called DEATH that identifies whether the patient with COVID-19 died or not. Then, a work was done on the construction of the polynomial regression model to predict positive cases, deaths and hospital occupancy in the next 2 months after the conclusion of the study and the cutoff date of the source dataset.

## 4.1 Preparation and analysis

In order to identify the positive and negative cases in the dataset used in this study, there is a variable called RESULT_LAB that was discarded from its use, because it offers a result only if the

COVID'19 test was performed in a laboratory. To obtain a better use of the data, the variable FINAL_CLASSIFICATION has been used, Table 2 shows the meanings of each possible value in the records. A new variable called RESULT has been created, which, as can be seen in Table 2, keys 1, 2 and 3 of the FINAL_CLASSIFICATION variable have become key 1 with a "Positive" description for the new variable, while keys 4, 5 and 6 has resulted in code 3 with the meaning of "Other", and the code 7 has been derived in the value 2 with the description "Negative". Figure 2 shows the frequency distribution of the cases according to the original variable FINAL_CLASSIFICATION. For the purposes of this study, only records that turned out to be positive COVID-19 tests have been taken. Figure 3 shows the frequency distribution of the GENDER variable, and in Figure 4 the frequency distribution of the AGE variable. As can be seen, of the positive cases of COVID-19 the distribution is almost equal between the two possible characters, while for the age of the patients, most of the cases are in the range of 30 to 40 years.

Table 2: Source variable FINAL_CLASSIFICATION and new variable RESULT

| Variable: **FINAL_CLASSIFICATION** | | Variable: **RESULT** | |
|---|---|---|---|
| **Key code** | **Classification** | **Key code** | **Description** |
| 1 | COVID-19 case confirmed by the Clinical Epidemiological Association | 1 | Positive |
| 2 | COVID-19 case confirmed by the Dictamination Committee | 1 | Positive |
| 3 | SARS-COV-2 case confirmed by laboratory or antigenic test | 1 | Positive |
| 4 | Invalid by laboratory | 3 | Other |
| 5 | Not performed by laboratory and without clinical association | 3 | Other |
| 6 | Suspicious case, pending result | 3 | Other |
| 7 | Negative to SARS-COV-2 | 2 | Negative |

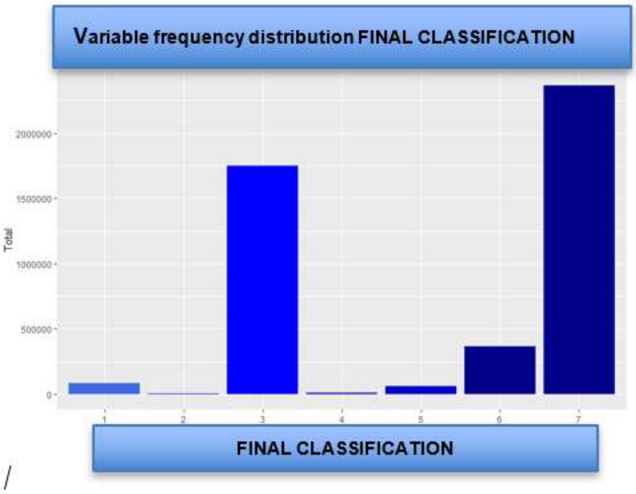


Figure 2: Variable frequency FINAL CLASSIFICATION

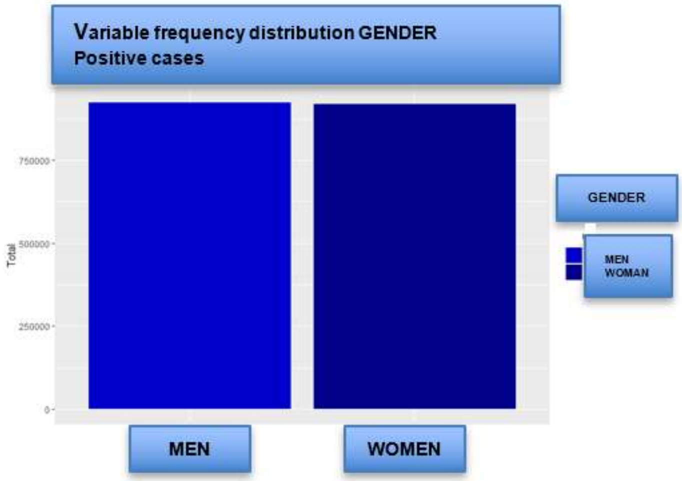


Figure 3: : Variable frequency GENDER

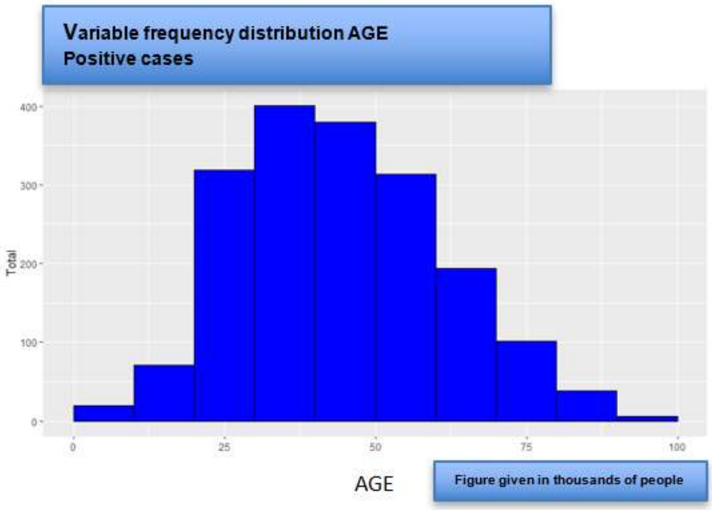


Figure 4: Variable frequency AGE (figure given in thousands of people)

## 4.2 Correlation analysis

For this correlation analysis between the variables, only the records of positive patients were taken and the records whose values were unknown were discarded, that is, those that had 97, 98 and 99 in the value, which mean "Does not apply". "Ignored" and "Unspecified", respectively. The variables used were: AGE, GENDER, ASTHMA, OBESITY, SMOKING, IMMUNOSUPPRESSION, CHRONIC_KIDNEY, PNEUMONIA, DIABETES, COPD, CARDIOVASCULAR and DEAD, a new variable created. The DEAD variable indicates whether the positive case of COVID-19 has died. To assign a value to this variable, the source variable DATE_DEF was used, which indicates the date of death of the patient. If the record has a value of "9999-99-99" it means that it has not died, therefore the value for the new variable is 2, otherwise, if it has a date assigned with the format "YYYY-MM-DD" (Where" YYYY "is the four-digit year, "MM" is the month and "DD" is the day, both two digits) is assigned the value of 1, which means that the patient has passed away. The variables INTUBATED and ICU were also used, but the unknown values were not removed from these, since it is normal for many records to have the value 97 "Not applicable", since not all positive patients have required hospitalization or have had need to enter an intensive care unit. The objective of this correlation analysis of these variables is to know how the aforementioned variables are related in the study data set. The analysis of the correlation coefficient is used to know whether or not there is a relationship between two variables, and if it exists, how strong and what type is that relationship. The numerical value to know this relationship is the *r* value, which is a finite number between -1 and +1. If the value of the coefficient *r* is close to +1, the relationship is positive, and if it is otherwise close to -1, the relationship is negative. If the result is 0 or is very close to that value, there is no relationship [14].

The formula to calculate the value of the correlation coefficient is the following [15]:

$$r = \frac{Cov(X,Y)}{\sqrt{s_x 2 \; s_y 2}}$$

Where Cov (X, Y) is the covariance, or how far each observed pair (X, Y) is from the mean of X and the mean of Y, and s_x 2 and s_y 2 are the sample variances for X and Y.

Table 3 shows the *r* value of the correlation coefficient between all variables, and Figure 6 shows the results of the table graphically.

Table 3: r value of the correlation coefficient between variables

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| GENDER (1) | 1 | | | | | | | | | | | | | | |
| INTUBATED (2) | -0.09 | 1 | | | | | | | | | | | | | |
| PNEUMONIA (3) | -0.08 | 0.68 | 1 | | | | | | | | | | | | |
| AGE (4) | 0.03 | -0.38 | -0.33 | 1 | | | | | | | | | | | |
| DIABETES (5) | -0.01 | 0.26 | 0.22 | -0.34 | 1 | | | | | | | | | | |
| COPD (6) | 0 | 0.1 | 0.09 | -0.14 | 0.08 | 1 | | | | | | | | | |
| ASTHMA (7) | 0.04 | -0.01 | -0.01 | 0.02 | 0.01 | 0.04 | 1 | | | | | | | | |
| IMMUNOSUPPRESSION (8) | 0.01 | 0.06 | 0.05 | -0.04 | 0.05 | 0.05 | 0.02 | 1 | | | | | | | |
| HYPERTENSION (9) | 0 | 0.25 | 0.21 | -0.41 | 0.38 | 0.1 | 0.01 | 0.04 | 1 | | | | | | |
| CARDIOVASCULAR (10) | -0.01 | 0.1 | 0.08 | -0.13 | 0.1 | 0.09 | 0.02 | 0.05 | 0.15 | 1 | | | | | |
| OBESITY (11) | 0.02 | 0.09 | 0.09 | -0.08 | 0.11 | 0.04 | 0.04 | 0.02 | 0.16 | 0.05 | 1 | | | | |
| KIDNEY CHRONIC (12) | -0.02 | 0.14 | 0.11 | -0.09 | 0.15 | 0.05 | 0 | 0.09 | 0.17 | 0.09 | 0.02 | 1 | | | |

| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| SMOKING (13) | -0.09 | 0 | 0.01 | 0.01 | 0 | 0.05 | 0 | 0.01 | 0 | 0.03 | 0.07 | 0.01 | 1 | | |
| ICU (14) | -0.09 | 0.94 | 0.69 | -0.38 | 0.26 | 0.1 | -0.01 | 0.06 | 0.25 | 0.1 | 0.09 | 0.14 | 0 | 1 | |
| DEATH (15) | -0.08 | 0.6 | 0.5 | -0.35 | 0.22 | 0.1 | -0.01 | 0.05 | 0.23 | 0.09 | 0.07 | 0.14 | 0 | 0.54 | 1 |

For the variable DEATH, there is a positive relationship from moderate to strong for the variables INTUBATED, PNEUMONIA and ICU, which means that the probabilities of dying of COVID-19 patients are increased if they have Pneumonia, are intubated or requires admission to an intensive care unit. It is also observed that the probabilities of being intubated or requiring intensive care increase if the patient suffers from Obesity or Hypertension, due to the weak to moderate positive relationship between these variables. Between age and all disease and death variables, the relationship is negative from moderate to strong, which means that at a younger age, the chances of dying from COVID-19 or having these diseases are low.

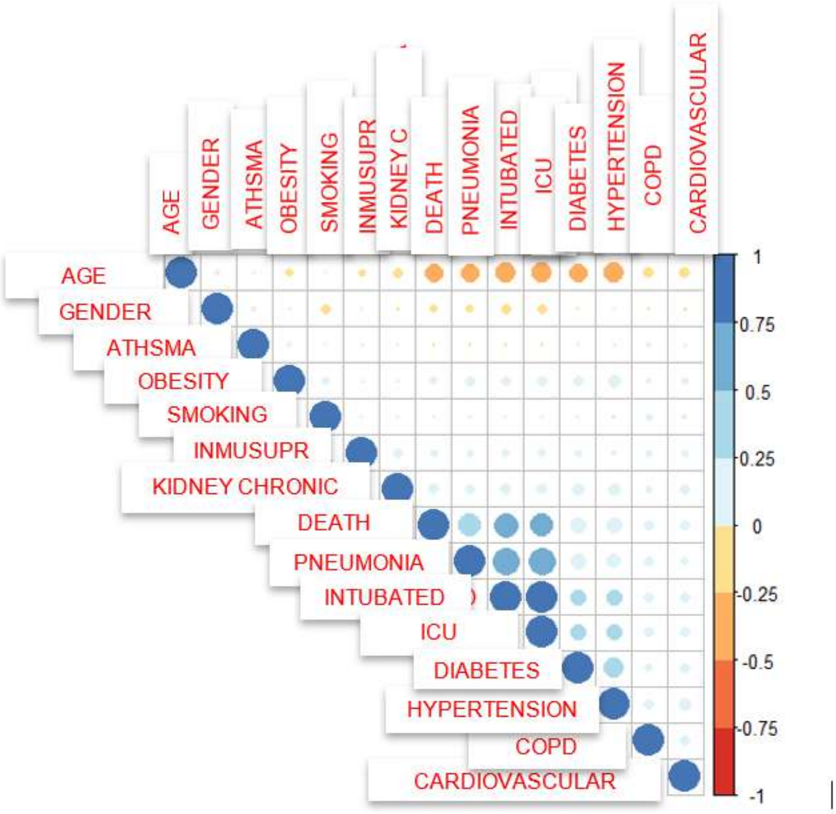


Figure 6: Graphical representation of the correlation coefficient

## 4.3 Polynomial Regression Model and Predictions

In order to create the model, the R programming language was used with the R Studio tool. Within that language, there is a package called ISLR, and in the same way, within this there is the lm () function that allows to fit linear models by least squares, as well as the poly () function that allows to generate a polynomial directly. The use of each one will be explained in the predictions.

### 4.4 Prediction of cases of COVID-19 infections

To make this prediction, a special dataset derived from the dataset explained in point 4 of this preparation and analysis article was prepared. This new dataset has the accumulated number of contagion cases from day 1, when the first contagion case was registered in Mexico, until day 343 of contagion, which was January 29, 2021. Future contagions In Mexico will be predicted until February 15.

First, the polynomial model of degree 3 is calculated.

policontagium_model <- lm (cases ~ poly (day, 3), data = df cases) summary (policontagium model) (3).

The lm () function fits the model to calculate the cases from the variable day with a polynomial of degree 3, and the data set is contained in the data frame df cases. When displaying the summary of the model that is saved in the model_policontagios list, the following is obtained:

```
Call:
lm(formula = casos ~ poly(dia, 3), data = dfcasos)

Residuals:
   Min     1Q Median     3Q    Max
-68082 -37287  -8305  35950  87371

Coefficients:
              Estimate Std. Error t value Pr(>|t|)
(Intercept)     612009       2252 271.696   <2e-16 ***
poly(dia, 3)1  9789896      41718 234.670   <2e-16 ***
poly(dia, 3)2  2091483      41718  50.134   <2e-16 ***
poly(dia, 3)3   -57225      41718  -1.372    0.171
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 41720 on 339 degrees of freedom
Multiple R-squared:  0.9941,	Adjusted R-squared:  0.9941
F-statistic: 1.92e+04 on 3 and 339 DF,  p-value: < 2.2e-16
```

Figure 7: Summary of the infected prediction model

Figure 7 shows that the *p-value* obtained for the **F** statistic is very low, *<2.2e-16*, which means that at least one of the predictors within the model is related to the case response variable. When analyzing the *p-values* of each predictor individually, it can be observed that they are all very small except for $day^3$, so it is concluded that with a polynomial of degree 2 it is more than enough to model the number of contagion cases depending on the day. Analyzing the *Multiple R-squared* value of 0.9941, it is specified that the model is capable of explaining 99% of the variability observed in the cases, a fairly high percentage. The standard residual error is 41720. The graphical representation of the adjusted model would be the following:

$$cases = 612009 + 9789896day + 2091483day^2 + 41720 \quad (4)$$

new_points <- data.frame(day = c(344:360)) predictions <- predict(policontagium model, newdata = new_points, se.fit = TRUE, level = 0.95, interval="confidence")

With the predict() function the prediction of new points is carried out. In this case, it is necessary to start from point 344, since the last one in the input dataset is day 343. The maximum range of the points to predict is 360, since at that point the day will be February 15th. Inside the predict () function, the polynomial model is specified along with the confidence interval.

| | fit | lwr | upr |
|---|---|---|---|
| 1 | 1784988 | 1771601 | 1798376 |
| 2 | 1794770 | 1781226 | 1808314 |
| 3 | 1804577 | 1790876 | 1818279 |
| 4 | 1814411 | 1800550 | 1828272 |
| 5 | 1824270 | 1810248 | 1838291 |
| 6 | 1834154 | 1819971 | 1848338 |
| 7 | 1844065 | 1829718 | 1858412 |
| 8 | 1854001 | 1839490 | 1868512 |
| 9 | 1863963 | 1849286 | 1878640 |
| 10 | 1873951 | 1859107 | 1888795 |
| 11 | 1883964 | 1868952 | 1898977 |
| 12 | 1894004 | 1878821 | 1909186 |
| 13 | 1904069 | 1888715 | 1919422 |
| 14 | 1914159 | 1898634 | 1929685 |
| 15 | 1924276 | 1908577 | 1939975 |
| 16 | 1934418 | 1918544 | 1950292 |
| 17 | 1944586 | 1928536 | 1960636 |

Figure 8: Prediction of the polynomial model of contagions

In figure 8, at point 17 it can be seen that the most adjusted prediction of the model is 1,944,586, which means that this number will be the quantity of infected as of February 15, 2021. The lowest prediction is 1,928,536 cases, and the highest 1,960,636 cases.

## 4.5 Prediction of hospitalizations for COVID-19

To make this prediction, a special dataset derived from the dataset explained in point 4 of this preparation and analysis article was prepared. This new dataset has the number of hospitalizations for each day from the first day on which the first hospitalization was registered, and so on until January 29, which is the 336th day. Unlike the previous prediction, where the number of infections accumulated was counted, in this prediction the number of hospitalizations registered for each day is counted. The number of hospitalizations that will be registered in Mexico will be predicted from February 1 to February 15.

First, the polynomial model of degree 4 is calculated.

polipacient_model <- lm (patients ~ poly (day, 4), data = hospital) summary(polipacient_model) (5)

The lm () function fits the model to calculate patients from the variable day with a polynomial of degree 4, and the data set is contained in the hospital data frame. When displaying the summary of the model that is saved in the model_polipacient list, the following is obtained:

Figure 9 shows that the *p-value* obtained for the **F** statistic is very low, *<2.2e-16*, which means that at least one of the predictors within the model is related to the patient response variable. When analyzing the *p-values* of each predictor individually, it can be observed that they are all very small except for $day^4$, which is why it is concluded that a polynomial of degree 3 is more than enough to model the number of hospitalized patients depending on the day.

```
Call:
lm(formula = pacientes ~ poly(dia, 4), data = hospital)

Residuals:
     Min       1Q   Median       3Q      Max
-2096.15  -156.90   -10.92   165.32   645.11

Coefficients:
              Estimate Std. Error t value Pr(>|t|)
(Intercept)    1038.06      15.66  66.305  < 2e-16 ***
poly(dia, 4)1  6111.77     286.98  21.297  < 2e-16 ***
poly(dia, 4)2 -2138.99     286.98  -7.454 8.01e-13 ***
poly(dia, 4)3  5101.83     286.98  17.778  < 2e-16 ***
poly(dia, 4)4   204.93     286.98   0.714    0.476
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 287 on 331 degrees of freedom
Multiple R-squared:  0.7138,	Adjusted R-squared:  0.7104
F-statistic: 206.4 on 4 and 331 DF,  p-value: < 2.2e-16
```

Figure 9: Summary of the hospitalization prediction model

When analyzing the *Multiple R-squared* value of 0.7138, it is concluded that the model is capable of explaining 71% of the variability observed in the cases, a fairly high percentage. The standard residual error is 287. The graphic representation of the adjusted model would be as follows:

$$patients = 1038.06 + 6111.77day \ - 2138.99day^2 + 5101.83day^3 + \ 287 \qquad (6)$$

new_points <- data.frame (day = c (339: 353))predictions <- predict (polipacient_model, newdata = new_points, se.fit = TRUE, level = 0.95, interval = "confidence")

With the predict () function the prediction of new points is carried out. In this case, it is necessary to start from point 339, which corresponds to the point of February 1. The maximum range of the points to predict is 353, since at that point the day will be February 15. Inside the predict () function, the polynomial model is specified along with the confidence interval.

Figure 10 shows the number of hospitalizations for each day from February 1, first point, until February 15, point number 15. On February 15, 2,556 new hospitalizations will be registered in the most highly adjusted prediction, with the lowest prediction being 2380 new patients and the highest being 2731 new hospitalized patients.

| | fit | lwr | upr |
|---|---|---|---|
| 1 | 2154.930 | 2024.791 | 2285.070 |
| 2 | 2181.111 | 2048.065 | 2314.157 |
| 3 | 2207.664 | 2071.657 | 2343.670 |
| 4 | 2234.590 | 2095.571 | 2373.609 |
| 5 | 2261.893 | 2119.809 | 2403.978 |
| 6 | 2289.575 | 2144.373 | 2434.778 |
| 7 | 2317.638 | 2169.265 | 2466.012 |
| 8 | 2346.085 | 2194.488 | 2497.682 |
| 9 | 2374.917 | 2220.044 | 2529.790 |
| 10 | 2404.138 | 2245.936 | 2562.340 |
| 11 | 2433.749 | 2272.165 | 2595.332 |
| 12 | 2463.752 | 2298.734 | 2628.770 |
| 13 | 2494.151 | 2325.646 | 2662.656 |
| 14 | 2524.947 | 2352.902 | 2696.992 |
| 15 | 2556.143 | 2380.505 | 2731.781 |

Figure 10: Prediction of the polynomial model of hospital patients

# 5. Conclusions

The final intention of this article is to help predict the behavior of COVID-19 infections and the number of hospitalized patients in Mexico, by applying a set of equations modeled and tested within the R programming language, using polynomial regression techniques, which in the end are a set of mathematical tools that help predict and model the behavior of a data set. The values obtained from Multiple R-squared in the models presented, conclude that the polynomial equations correctly model the behavior of the data set of those infected with COVID-19 in Mexico.

The prediction projection that was executed in both models, was carried out with a few days, since as the new prediction points are increased, the result of this is far from the projected values, which is derived from the fact that the projections that are obtained with the parameters are reliable for a small number of days. The aforementioned is attributed to the very dynamic behavior of the spread of the virus.

Until the date of this article preparation, the vaccination process in Mexico had not yet begun, so the prediction was made without taking this variable into account. It is assumed that when considering vaccination, the input data set when a high point in the vaccination process is reached will be totally different from the one used, consequently the polynomial regression models presented in this article would have to be adjusted. In the future it is intended to fit the models presented in this study with a data set that includes a high point of the vaccination phase in Mexico.

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