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The Academic Success of Computer Science Students in the COVID-19 period

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Abstract
Comparative study of students' evaluation in technological degrees, between COVID-19 and thehomologous period before COVID-19. The study covers a wide range of students, all from the computerscience areas. It is intended to verify whether the transition to the 100% online class model impacted studentsuccess and, if so, what type of impact.

Index Terms—Covid-19, Education in Covid-19, Academic Results in Online Classes, Online Classes Advantages.

I. INTRODUCTION

IN the early 2020s, the world was surprised by the emergence and rapid advancement of Covid-19. The impact on educational programs was enormous. With social distance being one of the few ways to mitigate the Pandemic's advance, remote distance learning became an imposition. In this context, it is crucial to evaluate these initiatives to quickly make the necessary changes so that the objectives of the educational programs can be at least minimally met.

The present paper was conducted at the Institute of Advanced Technologies (ISTEC) in Lisbon and used as a universe of analysis of the students of the licentiate degrees in Informatics and multimedia engineering. Therefore students, by themselves, are already inclined to information technologies and the use of all the tools in the context of the computer sciences.

A literature review was employed on materials already published in the educational area and related to the Pandemic of the new coronavirus, and an exploratory, descriptive approach was adopted. We realize that technology can be a great asset to mitigate the impact of the Pandemic in the educational area. However, all the possible strategies must be thought and reflected upon from different perspectives, considering, as much as possible, all the existing pros and cons so that the potential solution does not imply damages to the learning of the students who the public policies may not contemplate due to the distortions in the social realities experienced by the population. Knowing the comparative results in the students' evaluation allows us to conclude if the information technologies are allies in moments of abrupt transition from the residential teaching model to the 100% online distance learning model.

II. Literature Review

N. Yahaya (1) describes the period of COVID as a time when universities faced crucial decisions about how to continue teaching while keeping their faculty and staff safe in terms of public health. Furthermore, according to this author, many institutions altogether discontinued face to face classes, including laboratory classes. Instead, they urged all faculty members to switch to 100% online classes to prevent the spread of COVID-19. Even stating the critical paradigm, "Moving instruction online can enable the flexibility of teaching and learning anywhere and anytime" (1).

E. Mikuskova (2) states that most teachers adapted quickly to the new paradigm, even seeing future possibilities of using specific digital tools. However, the system proved tiring for most teachers, even

implying more working hours, which demotivated some teachers.
R. Shukla (3), the author, categorically states that it is evident that online education can be a method during the Pandemic period. But, still, it cannot be a long-term replacement for face-to-face teaching. He also states that face-to-face education is more effective than online education. But, on the other hand, the author says that regardless of this opinion, his institution prepared all the required infrastructures for distance learning, and they worked well and correctly.
Z. Aksu (4), refers that one of the main problems of the rapid shift to online learning derived from the Pandemic problem was computer equipment failures, Internet access failures, and recurring bandwidth issues, which negatively affected the distance learning process.
M. Seker (5) mentions that many platforms have gone open access in most countries and have prioritized and increased investment in technologies aimed at online education.
M. Tabassum (6) states that teachers pursued their activities with normality during COVID-19 confinement and sometimes supplemented studies through this type of teaching. The main problem was issues with Internet access.
J. Park (7), education in the engineering fields, both short and long term, always depends on providing positive teaching experiences, specifically in distance learning, which is now essential with the Pandemic. Also, according to the author, engineering teachers need to understand the students since new experiences are created for the students so that performance is not affected at the assessment level.
R. Ramola (8), this author, states that the Pandemic has completely changed the traditional structure of the educational system globally. All digital platforms during the Pandemic were used in one way or another for education, especially for students in higher education. According to the author, it was a challenge for all members of the universities, both teachers and students. Since everyone abruptly had to switch to 100% online education. Even with the efforts of the universities, there were many complaints from the students. According to the author's study, nearly 30% of the students complained mainly that they did not have access to the Internet and the suitable devices to do this access and to study digitally. Also, in R. Ramola's opinion, the dynamics and pedagogy of online education are different from those used in a presential classroom and require very efficient planning. Good quality technology and support are necessary to attract students to distance learning. Universities must develop the infrastructure to support this type of education. The quality of online teaching will come as part of everyday life, and the authorities and the members of the universities have an important role in this process.
K. Sarovar (9), the digital world of education has changed completely at all levels of education. Remote learning was facilitated by many Apps developed for this purpose and made available online, such as Google Classroom, Zoom, Microsoft Teams, BlackBoard, etc. Education using these technologies allowed a fully online teaching regime, where techniques such as meetings, conferences, workshops, quizzes, notes, short-term courses, and regular online classrooms were used. According to this author, most students were satisfied with these methods. Moreover, according to this author, the learning process seemed flexible, but they had some difficulties for other people who were less familiar with these technologies. On the other hand, some students did not have the appropriate material for this type of teaching, such as laptops, computers, and even quality Internet connections. A key aspect mentioned by this author is that he states that the student's satisfaction in online teaching depended more on the quality of the content provided than on the type of technology used. In general, both teachers and students were satisfied. The online teaching system is a good resource for situations where presential classes are not possible and a permanent complement to traditional teaching.
T. Chang (10), in dental education, there was a quick shift to online teaching. The process was successful, and there were many online meetings and sessions. Mainly technologies such as Zoom, Google Meet, Skype, Microsoft Teams, Panopto, Canvas, etc., were used. Microsoft Teams was found to be the most used tool. The laboratory simulation courses were on hold. But the online courses were significant.
According to this author, S. Weine (11), educators worldwide had to adapt to a new model. He points out that there had to be a strong partnership among peers to achieve this profound paradigm shift. In addition, new models had to be used to address the constraints created by the Pandemic.
S. Parvin (12), online classes, for medical education, during the COVID-19 Pandemic, was a good experience, but with limitations. Nevertheless, the online system cannot replace the classroom system,

especially in medical sciences, with a strong foundation of practical and laboratory classes and highly technical classroom work. However, some benefits were found in the online classroom system, yet there were also constraints to learning.

G. Kolcu (13), the COVID-19 Pandemic has created opportunities and significant challenges in all areas. This new paradigm has created the opportunity to reevaluate many perspectives on education paradigms, such as the concept of the student at the center of education, the self-learning system, the sharing of educational resources, and lifelong learning. According to the author, this process will make it possible to demonstrate that the blended learning system is very beneficial and will probably be widely used in the future.

Muller (14), in the emergence of online teaching imposed by the Pandemic, interaction between educators was key to the success of the process. However, some limitations of interaction created a problem in the motivation of some students. Educators also had some difficulty knowing exactly what students were doing during the 100% online class period. Nevertheless, the teachers stated that there were new teaching opportunities and new positive experiences with online teaching, mainly because it was more flexible.

According to this author, M. Rapalo (15), during the COVID-19 Pandemic, most educational institutions switched to the online system, and simultaneously many of them also switched to the online assessment system. According to the author, this may have created less qualified professionals, who would experience training gaps when entering the labor market. These hypothetical consequences would affect both the new graduates and society itself. Furthermore, if the social distance and the education itself were to continue for a very long time, this would have serious mental problems and, consequently, impact, according to this author.

W. Chiparra (16), this author estimates that 91.3% of the world's population saw their educational institutions physically closed during this pandemic period, a disruptive situation in terms of teachers and students having to get used to and implement online teaching mechanisms. Few were prepared for this type of education. Since practically everyone has access to the Web, it made it easier to implement this system.

In the author's opinion, R. Queiroz (17), the abrupt transition to online education forced institutions to launch a package of totally new methods and technologies for teachers and students, where the lack of experience with these technologies prevailed, which caused immense difficulties for everyone. In many cases, adapted programs had to be created to "save" the educational programs. [18]

Ya Wan [19], refers to this phase as a "new normal," and according to him, our education system has to change to this "new normal." Indeed, we were not prepared, but there has been a systematic change. And this is a unique opportunity to adopt many methods definitively. Even if there were many imperfections (according to the author), everything was done according to what was possible.

With the national emergency, J. Osores [20], all universities had the opportunity to improve the conditions and technologies to support remote teaching through electronic means (according to this author). The responsibility for the success of this system was delegated to the professors, who in turn improved their digital skills considerably, and created new adaptations of didactic exploitation. The academic authorities specified the parameters of this action. Therefore, we can say this was a unique opportunity for teachers to innovate their teaching strategies, with consequences that will undoubtedly go beyond COVID-19.

Singh [21], for two semesters, the students had to do the entire assessment via the Internet, and it was not possible to evaluate the comparison of results.

S. Adarsh [22], teachers and institutions adapted to the new educational paradigm (according to this author). Digital solutions were found that helped students without a doubt.

K. Hoernke [23], about students in the medical sciences virtual reality, was used very successfully for learning, namely HoloLens. The students were able to interact remotely, and the system worked very well.

P. Rodriguez [24], the disruption of the initial conditions that each institution had to face in the face of a new communication system, namely the migration to the online teaching system, was problematic. For this reason, it was crucial to implement training mechanisms to facilitate the whole process by creating new tools for teachers.

III. Methodology Employed

The methodology used in the study is based on the modern procedures of exploratory and confirmatory data, this data is the collection of all students from to courses, in a total 300 in analysis.

As part of the exploratory data analysis, the descriptive measures of characterization were used: sample mean, and standard deviation, whose R language inputs are as in the appendix.
The data were taken from the evaluation guidelines of the Degree in Computer Science in a total of 300 analyzed students. The institute has a total of 1470 students, this is the total universe of students.

IV. The Context

During the year 2020 and part of 2021, mainly Europe and Portugal were under the devastating effect in social terms of the Pandemic COVD-19. This had repercussions in all social life, including the education system in all its degrees.
In Portugal, as of March 2020, the entire education system switched to online distance learning; this extended until 2021.
Universities have made an extreme effort to adapt.
The Institute of Advanced Technologies of Lisbon (ISTEC) is a polytechnic higher education institution highly focused on teaching Information Technology, Computer Science, and Computing. This fact was an advantage in this period because both the institution and the students were familiar with the technological tools that supported the paradigm shift from classroom teaching to online learning.
The institution under study created processes to adapt to online teaching, gearing already existing technologies to this new paradigm. In addition, a detailed plan was made of how technologies and pedagogy should be used simultaneously to put curriculum development into practice.
That plan was as follows:

A - Platforms for class curriculum development
CTESP: Google Classroom
Undergraduate: Google Classroom
Post-graduation: Moodle
Master: Moodle
Synchronous communication:
Google Meet, Cisco WebEx

B - Asynchronous Classes
Workload: the asynchronous weekly workload should be equivalent to 3 hours per week (and does not necessarily have to occur during class time on time, hence its name). This workload includes (1) material made available by the teacher (time for reading and viewing it), (2) consultation/research work (encouraged by the teacher), (3) discussion among peers (and with the teacher) in a discussion forum, (4) asynchronous attendance (e.g., chat, e-mail) to the student and (5) completion of assignments/activities (which may or may not be used for continuous assessment, in case they are assessed, the student must be expressly informed and must accept, for more information see point 4 - "Continuous Assessment").
Completing "compulsory" assignments (even if the student agrees to perform continuous assessment) should be proportional. The teacher should not require weekly assessed work with tight deadlines. The completion of assignments/activities may be optional.
Teachers should place (weekly), in their classes in asynchronous format, the documentation related to their course unit and to the specific context of the study cycle, namely hyperlinks, PDF documents, videos (including originals), among other formats (see Point 9 "Content Typology").
Important note: You do not have to submit every week all types of files, i.e., one week there may be videos, another week hyperlinks, and PDFs, etc., etc. What must exist is a weekly availability of contents in which the formats may be varied, depending on the context of the course unit and the concepts to be discussed.
Regarding original videos (mandatory). These should be of short duration (up to a maximum of 10 minutes) and focused on exemplification, explanation of the concepts to be addressed. It is preferable to split into several videos, reducing the number of conceptions per video rather than making long videos. External resources may be added (in addition to the original content, not replacing it) as long as their origin is adequately referenced. Some examples of Open Educational Resources can be found in the following repositories (videos from Youtube and Vimeo can also be used):
Merlot – https://merlot.org/
OERCommons.org - https://oercommons.org/
Jorum - https://store.jisc.ac.uk/home

University of Leicester OER -http://www2.le.ac.uk/projects/oer

C - Synchronous Classes
Synchronous classes should use the tools in the following list, but the teacher may use others if he wishes and has licenses for them (e.g., Zoom).
CTESP: Google Meet
Degrees: Google Meet
Post-graduation: Cisco Webex
Master's Degree: Cisco Webex

Regardless of the tool used, the lesson must be recorded and available to students within 24 hours.
Workload: the weekly synchronous workload should be equivalent to 1 hour a week, in the case of CTESP, Undergraduate, and Master's degrees. In the Post-graduate courses, between 2 and 3 hours. The synchronous session should be scheduled, one week in advance, for one hour within the UC schedule (e.g., a unit taking place on Mondays from 8 am to 12 noon should have its synchronous session within that time slot).
Note: for cTeSP and degree courses, the weekly load may exceptionally be extended to a maximum of two hours depending on the course and teacher (in these cases, the asynchronous time is reduced in the same proportion, e.g., two synchronous hours + two asynchronous hours). It is suggested that there be a break (e.g., fifteen minutes) in the middle of a two hour synchronous session.

Guiding principles:
According to Chen & Wu (2015), we can distinguish four main types of video, Class capture, Voice over presentation, Canvas videos, and Picture in Picture.
Classroom Capture - Filming the teacher's image similar to a presential classroom context.
Voice-over presentation - Screen capture (e.g., PDF presentation) with teacher narration.
Canvas Videos - One Frame Screen Capture (e.g., Whiteboard - https://awwapp.com/) or digital tablet, where the teacher writes/draws, and the student sees the result.
Picture in Picture - Simultaneous presentation of the teacher's image footage with screen capture/slide show.
Given the theoretical and practical dimension of ISTEC courses, "demonstration" is significant, so the teacher should opt for less expository and more demonstrative content, sharing the screen and demonstrating the concepts (whenever possible) and/or clarifying doubts. You can also create short asynchronous demonstrative videos and use the synchronous sessions for discussion/debate/clarification of doubts.

D - Continuous Evaluation
Continuous assessment is of enormous importance in any context (presential, distance, or mixed), guaranteeing the teaching-learning process and making the student more autonomous and active throughout the course. Additionally, it places the student at the center of his learning. Therefore, the teacher should privilege elements of continuous assessment that are appropriate to the context of the curricular unit.
Notwithstanding the teacher's duty to propose this assessment element, it is up to the student to decide whether to carry them out. For example, the student may choose to perform only a summative assessment, and, in this situation, the summative assessment will be the only element of assessment (100% weighting).
This evaluation should follow a set of guiding principles, namely:
It should be clear and objective - The request should be formulated clearly and unambiguously. In addition, the student should know what is intended to be accomplished in each assignment (including information, whether it is an individual or group assignment).
It should be transparent - The student should be informed of this (these) element (s) at the beginning of the curricular unit (not in the middle or at the end), knowing the weighting that it (they) will have in the final assessment and the deadlines that must be respected. Furthermore, this information should be communicated and made available in writing (for example, a PDF with the work proposal) on the platform used in the curricular unit (Moodle or Classroom according to the course - see Point 1 "Platforms for curricular development and classes").
Should provide feedback - This feedback should be timely (preferably within 72 hours) and mandatory (if requested). It can be done individually or in groups but must be substantial and meaningful in its content and can be done using different means, i.e., written, audio, or video.

It should be responsibly dated - In the description of the assignment, there should be a deadline for completion that should be responsible, on the one hand allowing the student to complete it correctly and on the other hand considering time for feedback (from the teacher). For example, hardly weekly assignments will be sustainable for the student to complete them, question the teacher if they have questions, have a timely response from the teacher, and again time for the student to complete after feedback is received.
It should be supportable and sustainable - The work should be requested considering the technical means (e.g., equipment, specific software) available to the student and the teacher's availability to follow up.
This evaluation will be a 40% weighting in the final evaluation.
E - Summative evaluation
The individual summative evaluation is mandatory under the "ISTEC's Higher Education Course Regulations." (http://www.istec.pt/wp-content/uploads/2016/03/SGQ-REG-01-Regulamento-de-FuncionamentodoscursossuperioresR5_0316.pdf).
As described in the previous point (see Point 4 - "Continuous Assessment"), it is up to the student to choose the mode they want to be assessed (Continuous Evaluation + Summative Evaluation or Summative Evaluation), without any prejudice to the student for the choice made.
If there has been continuous evaluation, the summative evaluation will weigh 60% of the final evaluation.

F - Use of Forums
In the case of courses whose base platform is Moodle, they must use the Moodle Forums and the Moodle chat system.
Teachers who use the Google Classroom platform and tools such as Stream and Meet must also use Google Chat as tutorials.
Teachers who are required to use Google Classroom by the nature of their course need to create a forum for their class using the "QUESTION" tool, where there will be no evaluation and where students can answer freely.
In courses that make use of Moodle, the Forums that integrate this platform should be created.

G - Teacher's training
Teachers will have initial training on the procedures and technologies they should use in synchronous and asynchronous classes.
Teachers who have attended training courses paid for by ISTEC in distance education should practice what they have learned in these courses.

H - Multimedia content production support team
Teachers will have a team of multimedia designers for teaching or helping to produce content for classes, as long as they are Teaching Videos, Video Tutorials, or aggregation of image capture, with or without sound.
The tools that will be used for these purposes will be TechSmith's tools: Camtasia and Snagit.

Teachers should use two free tools for content production par excellence: Open Broadcaster Software, for video recording and capturing (https://obsproject.com/); and the "Cropping" tool that comes with Windows 10, for image capture.

The plan's implementation worked very well. Considering this fact, we decided to do a complete study to compare the school achievement before the Pandemic and during the Pandemic, using homologous period.
Namely, we compared all the school results of Computer Science and Computer Engineering undergraduate degrees in the second semester of 2019 (Pre-Pandemic) with the second semester of 2020 (in full Pandemic and 100% online education system).
We wanted to know if the paradigm shift, i.e., the transition from presential classes to the online class system, had any deviating effects on student achievement outcomes.
We compared all the curricular units of the degrees in Computer Science and Multimedia Engineering. We considered the results of all the students, so the universe under analysis was the totality of the students of these two degrees.

V. The Comparative Study

Table I : Universe Under Analysis – 2019 – 2nd Semester

CURRICULAR UNITS		2019 - 2nd Semester		
		Nº Students	Average	Standard Deviation
1st Year	AED	29	15.448	3.728
	ED	112	10.295	3.551
	MAT II	82	10.768	1.920
	P II	53	10.094	3.794
	RC II	69	11.667	3.480
	TI II	106	13.877	3.804
2nd Year	AR II	113	11.372	4.283
	CF	114	9.877	3.356
	P IV	117	11.436	4.509
	SGBD	63	13.016	3.774
	SM II	92	13.402	3.092
	TI IV	49	15.776	2.220
3rd Year	HCT	74	10.987	4.009
	MSC	111	10.766	1.940
	P V	93	14.871	3.146
	SI	125	11.784	3.461
	PG	55	13.927	2.673

Table II : Universe under analysis – 2020 – 2nd Semester

CURRICULAR UNITS		2020 - 2nd Semester		
		Nº Students	Average	Standard Deviation
1st Year	AED	24	15.500	3.065
	ED	49	10.857	2.880
	MAT II	71	11.423	2.796
	P II	37	10.595	4.450
	RC II	34	11.794	5.062
	TI II	67	12.851	4.211
2nd Year	AR II	80	12.463	5.134
	CF	75	9.200	3.484
	P IV	97	12.144	5.234
	SGBD	55	11.306	4.656
	SM II	72	14.306	2.787
	TI IV	49	14.449	2.836
3rd Year	HCT	64	13.703	3.444
	MSC	83	11.892	1.546
	P V	65	14.339	3.369
	SI	91	12.725	3.317
	PG	52	15.654	2.300

Interpretation: in 64.7% of curricular units, student achievement measured by the average results is higher in distance classes than presential classes.

Charts Acronyms:

AED: Algorithms and Data Structures

ED: Descriptive Statistics
MAT II: Math II
P II: Programming II
RC II: Networks and Communications II
IT II: Information Technologies II
AR II: Network Administration II
CF: Financial Calculus
P IV: Programming IV
DBMS: Database Management System
SM II: Multimedia Systems II
TI IV: Internet Technologies II
HCT: History of Science and Techniques
MSC: Methods of Computational Simulation
P V: Programming V
S I: Computer Security
PG: Global Project.

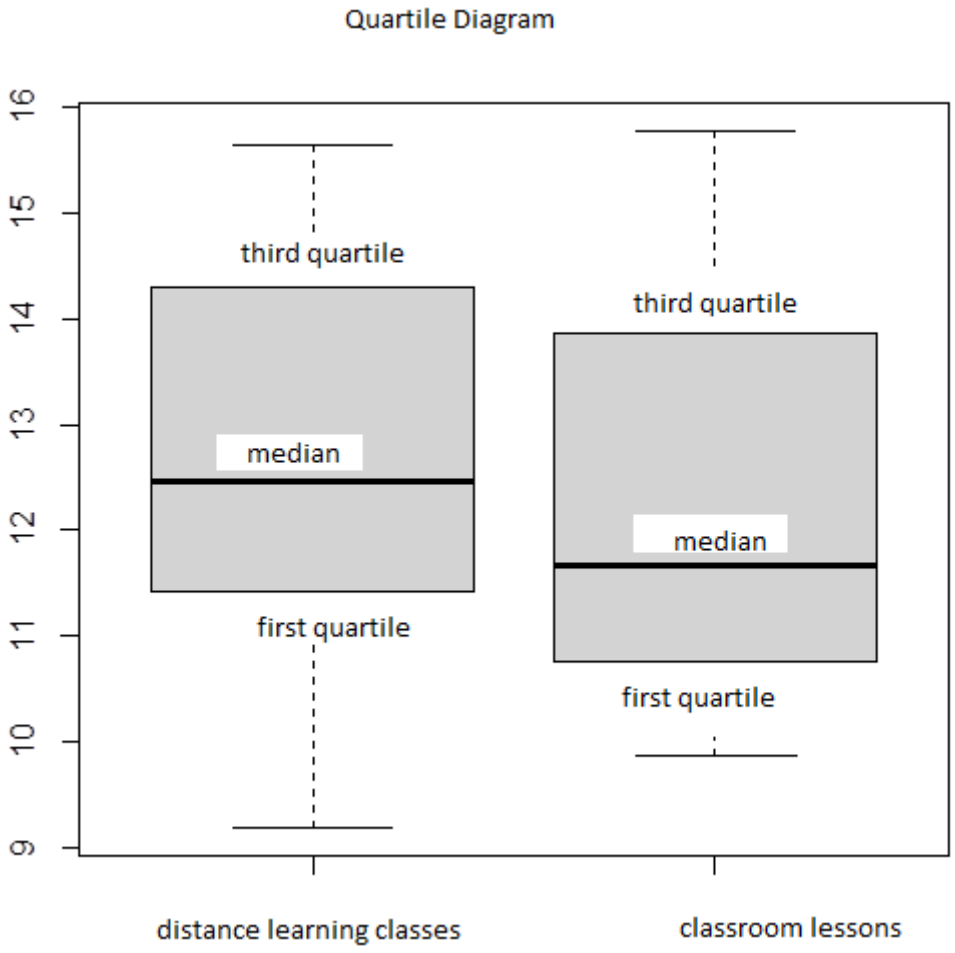

Fig. 1. Results 1

In the context of exploratory analysis, a quartile diagram is a form of comparison of two or more data sets. Interpretation: The median and 1st and 3rd quartile scores of the distance education classes are higher than those of the presential courses. It is important to remember that, in terms of statistical properties, the median (2nd quartile) "is a measure of resistant location"(demonstration in "Exploratory data analysis"- Prof. Bento Murteira).

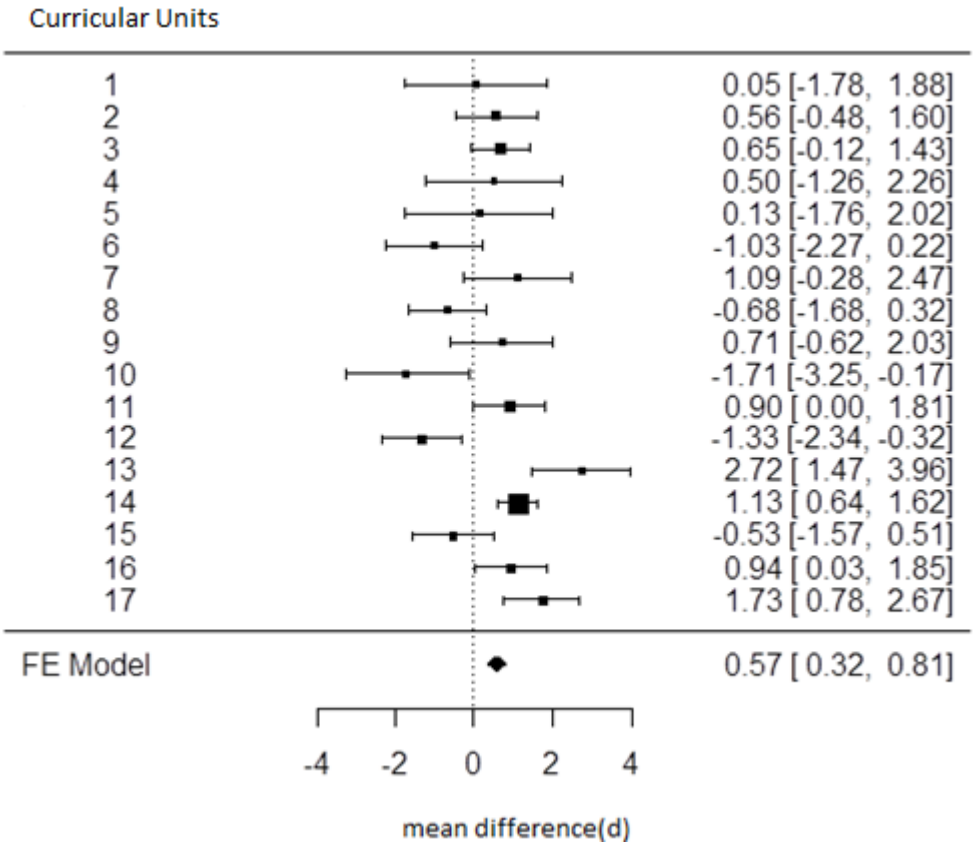

Fig. 2. Results 2

The random errors of this model are assumed to be normal normally distributed and the estimate of the effect measure, which in this case is the difference in means, is approximately 0.57, has the desirable statistical properties of the maximum likelihood estimators.

Interpretation: Hence P-value is close to zero (<0.0001), it is very likely that the difference in means is positive, which means that there is statistical evidence of the superiority of the results obtained in distance learning compared to those in presential education.

V. Discussion

The statistical conclusions that result from the application of quantitative methods based on the language of numbers are as follows:

At the exploratory level of data and by the descriptive measures used, it is found that the results obtained by students in distance learning were higher than those verified in the presential education system.
At the inductive inference level, in terms of the confirmatory data analysis, there is also statistical evidence that the difference between the averages of the results obtained by the students is favorable in the distance learning system.

The inductive statistics that formed the basis of confirmatory data analysis, as a repository of instruments and techniques that guide the realization of inferences, is part of the so-called Classical Statistics.
In order to characterize the classical inference, we can only outline the confrontation with its great rival, Bayesian Statistics. The inferential work of this statistic is mainly faced with a priori information (intuition or sensitivity of the researcher), while the classical inference process uses exclusively the information obtained by sampling.
Within the scope of classical inference, it is assumed that the differences in the means are independent with normal distribution. In fact, by the normality tests (Shapiro-Wilk and Jarque-Bera), there is evidence of the normality of the differences in the means.

V. Conclusion

In exploratory and confirmatory terms of the data, there is statistical evidence of the superiority of the results obtained in distance learning concerning those of presential learning. This means that the transition to distance learning, specifically in the area of computer sciences, did not affect the learning and assessment results of all students considering the same period of the previous year. The vocation and preparation of students for the use of tools related to all areas of computing possibly contribute to this academic success.

The foundation of these conclusions is based on the procedures of classical inference versus Bayesian inference, through the p-value that measures the evidence against the hypothesis that is admitted as true.
From this perspective, it is more likely that the data actually observed by student outcomes are consistent with the fact that distance learning shows significant advantages over face-to-face teaching.

APPENDIX

As part of the exploratory data analysis, the descriptive measures of characterization were used: sample mean, and standard deviation, whose R language inputs are as followsmean(X)

```
sd(X).
```

Graphically, the box plot and histogram were used, whose R language inputs are as follows: boxplot(X)
As part of the confirmatory data analysis, tests for normality of the difference of means were used: Shapiro-Wilk normality test, jarque-bera normality test, whose R language inputs are as follows:

```
shapiroTest(X)
jarqueberaTest(X)
```

Student's t-tests for the difference in means were also used; the input from the R language is as follows:

```
t.test(X)
```

Combining the exploratory analysis with the confirmatory analysis, a metadata analysis was developed, whose R language inputs are as follows:

```
library(metaphor)
RMA.uni(X)
forest(rma.uni(X ))
```


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