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Artigo Original

The use of computational tools in the teaching and learning process of Mathematics in Distance Education

O uso de ferramentas computacionais no processo de ensino e aprendizagem de Matemática na EaD

El uso de herramientas computacionales en el proceso de enseñanza y aprendizaje de las Matemáticas en EaD

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Abstract

Education is one of the fundamental means of ensuring the development of a society and, although technologies have been introducing a new concept of education, several concerns regarding the use of computational tools in the teaching-learning process have been intensified. In this context, this article investigated how the use of these tools has affected the process of teaching and learning mathematics in Distance Education (DE). To this end, two descriptive and quantitative researches

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were carried out: the first via Google Forms with the participation of 847 students majoring in Computer and Production Engineering at the Universidade Virtual do Estado de São Paulo (UNIVESP) that sought to identify the students' perception in the educational process mediated by technological tools and the second, through our personal experience reports as facilitators of Calculus 3 and Numerical Methods classes. The results indicated that there was a proportional participation among the students of both majors, predominantly sophomores and juniors, of which 71% said they had had a teacher or facilitator who used some computational tool. The highlights were the Microsoft Excel, Matlab and Scilab tools, whose use was predominant in Calculus and Statistics classes with high approval (59%), stimulus (57%) and adequacy (63%) rates. In turn, according to the facilitators' perception reports, alternative methodologies such as videos, animations and programming codes showed a positive outcome with a greater association between theory and practice. Thus, in view of the teaching-learning process, this study suggests a more stressed use of computational tools in the teaching of mathematics in Distance Education.

Keywords: Distance Education. Computational Tools. UNIVESP. Excel. Matlab.

Resumo

A educação é um dos meios fundamentais de se assegurar o desenvolvimento de uma sociedade, e, embora as tecnologias venham introduzindo um novo conceito de educação, diversas preocupações concernentes ao uso de ferramentas computacionais no processo de ensino e aprendizagem vêm se intensificando. Neste contexto, este trabalho investigou como o uso dessas ferramentas tem afetado o processo de ensino e aprendizagem de matemática na educação a distância (EaD). Para tal, duas pesquisas descritivas e quantitativas foram realizadas: a primeira via Google Forms, com a participação de 847 alunos dos cursos de Engenharia de Computação e Produção da Universidade Virtual do Estado de São Paulo (UNIVESP), que buscava identificar a percepção dos alunos no processo educacional mediado por ferramentas tecnológicas; e a segunda, por meio de nossos relatos de experiências pessoais enquanto facilitadores

das disciplinas de Cálculo 3 e Métodos Numéricos. Os resultados indicaram que houve uma participação proporcional entre os alunos de ambos os cursos, com matrículas preponderantemente nos 2º e 3º anos letivos, dos quais 71% afirmaram ter tido algum professor ou facilitador que utilizou alguma ferramenta computacional. Os destaques ficaram para as ferramentas Microsoft Excel, Matlab e Scilab, cuja utilização foi preponderante nas disciplinas de Cálculo e Estatística, com elevadas taxas de aprovação (59%), estímulo (57%) e adequação (63%). Por sua vez, de acordo com os relatos de percepção dos facilitadores, metodologias alternativas como vídeos, animações e códigos de programação apresentaram um retorno positivo com maior associação entre teoria e prática. Assim, tendo em vista o processo de ensino e aprendizagem, este estudo sugere que o uso de ferramentas computacionais seja mais explorado no ensino de matemática na EaD.

Palavras-chave: Educação a Distância. Ferramentas Computacionais. Ensino de Matemática. UNIVESP. Excel. Matlab.

Resumen

La educación es uno de los medios fundamentales para asegurar el desarrollo de una sociedad, y aunque las tecnologías están introduciendo un nuevo concepto de educación, se han intensificado varias preocupaciones sobre el uso de herramientas computacionales en el proceso de enseñanza y aprendizaje. En este contexto, este trabajo investigó cómo el uso de estas herramientas ha afectado el proceso de enseñanza y aprendizaje de las matemáticas en la educación a distancia (EaD). Para ello, se realizaron dos encuestas descriptivas y cuantitativas: la primera a través de Google Forms, con la participación de 847 alumnos de los cursos de Ingeniería en Computación y Producción de la Universidad Virtual del Estado de São Paulo (UNIVESP), que buscó identificar la percepción de los estudiantes en el proceso educativo mediado por herramientas tecnológicas; y la segunda, a través de nuestros relatos de experiencias personales como facilitadores de las asignaturas de Cálculo 3 y Métodos Numéricos. Los resultados indicaron que hubo una participación proporcional entre los alumnos de ambos cursos, con inscripciones predominantemente en el 2º y 3º año lectivo, de los cuales

el 71% dijo haber tenido un profesor o facilitador que utilizó alguna herramienta computacional. Se destacan las herramientas Microsoft Excel, Matlab y Scilab, cuyo uso fue predominante en las disciplinas de Cálculo y Estadística, con altas tasas de aprobación (59%), estímulo (57%) y adecuación (63%). A su vez, según los informes de percepción de los facilitadores, metodologías alternativas como videos, animaciones y códigos de programación mostraron un retorno positivo con una mayor asociación entre teoría y práctica. Así, considerando el proceso de enseñanza y aprendizaje, este estudio sugiere que se explore más el uso de herramientas computacionales en la enseñanza de las matemáticas en EaD.

Palabras clave: Educación a Distancia. Herramientas Computacionales. Enseñanza de las Matemáticas. UNIVESP. Excel. Matlab.

1. Introduction

Education has a unique importance in human development. It is the basis for the advancement of science and progress as a whole. Data from developed countries corroborate this fact: countries with better human development indices (HDI) have equally high educational indices.

Thus, any nation that has development as its goal has numerous programs to monitor and measure educational indices. Based on these statistics, intervention plans and development of public policies are created.

In this context, a new teaching modality has been gaining more and more public and notoriety: distance education (DE).

Non-face-to-face teaching takes shape in a context of development of information and communication technologies (ICT), despite its beginnings preceding them. And, despite the incorporation of these technologies, DE presents the same problems as face-to-face teaching — high dropout rates, associated with outdated and poor quality teaching, among other factors.

This article seeks to illustrate these problems with some solutions

adopted by the team of facilitators of the Virtual University of the State of São Paulo (UNIVESP) in the practice of teaching Calculus 3 (MCA-503) and Numerical Methods (MMN-001) in classes Computer and Production Engineering.

As a research methodology, we sought to identify, through electronic research, the degree of contact of students with software and support media used in synchronous lives (video calls), as well as whether the use of these technologies contributed to the teaching process and learning.

2. New teaching, old problems

2.1. The student profile

The profile of the DE student has a strong regional connection, as the university has centers throughout the state. This variation in the profile can even be illustrated if we focus on just one city, such as São Paulo: the centers located in the periphery, for example, are not surrounded by the same educational infrastructure as the centers located in the center of the city.

Knowing the student's profile is important so that it is possible to adapt the best teaching methodology when this is at a distance. From this idea, it is concluded that knowledge of the profile of the DE student facilitates and helps the learning process (SCHNITMAN, 2010).

When it comes to teaching in EaD, it is remarkable that the student audience is very specific. Commonly, students are adults around 30 years of age, mostly female and with regular employment (MARTINS *et al*., 2012; AQUINO; OLIVEIRA, 2016). Another characteristic described by Isler and Machado (2013) is that adults in distance education are more motivated to study.

According to the age profile of UNIVESP students, 86% are over 25 years old. Student education is also high, with 35% of students having a completed graduation, 23% with incomplete graduation, and 36% without graduation; 80% of these come from public high school (UNIVESP, 2018).

The main aspects mentioned above are mutually justified due to the profile of the evaluated student. Godoi and Oliveira (2016) evaluated a sample of students and were able to attest how each aspect fits into each profile. According to the authors, adulthood has an interference in studies, linking the issue of older age to distance education. As for gender, the presence of the female audience is due to the degree courses that are offered, given that women seek teaching more than men (MARTINS *et al*., 2012).Finally, Martins *et al*. (2012) also point out that the male enrollment was approximately 30% of those enrolled in this type of education.

The issue of work is also relevant, because according to Godoi and Oliveira (2016), most people seek DE for flexibility and the possibility of conciliation with other responsibilities. It is also possible to highlight the incentive provided to the employer for their employees to take distance courses when this is private.

That said, another aspect that is also taken into consideration refers to the style of teaching, which can be private or public. The present work deals specifically with an analysis focused on UNIVESP, where teaching in EaD is completely free. The educational cut made for this research is aimed at higher education classes in the Computer Engineering and Production courses at UNIVESP.

2.2. Evasion

One of the main difficulties faced by educational institutions that offer distance learning (DL) courses is pointed out by Pedrosa and Nunes (2019), Toczek *et al*. (2008) and Fávero (2006) as being student dropouts. Dropout is characterized as: students who have never introduced themselves or expressed themselves in any way, both for mediators and for fellow students, that is, those who drop out of the course they enrolled in. And the higher courses offered by UNIVESP fit into this scenario.

UNIVESP was created with the objective of expanding access to higher education and is the result of the integration of three public universities in the state of São Paulo (USP, UNESP and UNICAMP), being

the only state university in São Paulo to offer only courses in the distance education modality. Unfortunately, it entails a high dropout rate and a decline in the demand for students, as highlighted in the article entitled "Government bet on DE, UNIVESP has high dropout rates and only graduates 174 students" (PALHARES, 2019).

Thus, the dropout of students represents a constant concern for educational institutions that offer their courses in the DE modality, as well as for those who intend to offer them in the future, since the DE model in Brazil has been gaining prominence and credibility.

According to the *Brazilian Statistical Yearbook for Open and Distance Education* (SANCHEZ, 2017), in the last three years the number of institutions offering distance courses in Brazil has grown by 54.8%. However, the concern about evasion remains. According to the yearbook (SANCHEZ, 2017), by providing opportunities for studying in the home, social or professional environment, and also allowing the student to choose the times they will study, DE usually has more competitive stimuli (family, television and neighborhood noises, among others) and depends, in a much more direct way, on some of the student's aptitudes, such as the ability to organize and concentrate for studies (PEDROSA; NUNES, 2019).

However, distance learning cannot and should not be seen as a competitor to on-site education, but rather as a different way of learning, serving an audience with specific and differentiated needs. "DE is a great ally of the cultural changes that emerge from a digitalized and connected society" (PEDROSA; NUNES, 2019, p. 15).

2.2.1. Reasons for evasion

There are several reasons that lead institutions, whether public or private, to be more concerned with the problem of evasion in distance education. According to Silva Filho et al. (2007), the problems related to DE courses are these: for the public sector, resources are invested without having the proper return; for the private sector, there is an important loss of revenue; for both sectors, such courses are a source of

idleness for teachers, employees, equipment and, in some situations, physical space (PEDROSA; NUNES, 2019).

The DE student faces a complex, difficult and almost always lonely routine, as the classroom and the computer, or the technology used, merge with him. It is possible to affirm, in this sense, that the methodologies used, reconciled with this isolation, as well as with the unexpected, but real, complexity, are the main factors for evasion. The effort to assimilate the content together with the lack of time are the elementary complaints of UNIVESP students on social networks, in addition to technical problems, such as the slowness of the teaching platforms. However, EaD courses are based on technology, and if it is not functional, students will lose interest and/or will be harmed by the system (PALHARES, 2019).

In the article entitled "6 fatores que aumentam a evasão na EaD e como combatê-los" (6 factors that increase dropouts in DE and how to fight them), the following dropout factors are pointed out: the lack of meeting the expectations of students; the lack of institutional support and interaction; the lack of quality of the online course; difficulty with the distance learning platform; financial problems and poor academic performance (6 FATORES…, 2018).

The causes of evasion involve a series of complex variables, which makes it very difficult to explain them. The data show that a significant portion of the dropouts performed other tasks concurrently with the course, and also show that, of the dropouts, a good part of the interviewees had difficulties in interacting with the platforms used in the learning process (PEDROSA; NUNES, 2019).

3. Methodologies used

For the elaboration of the article, two methodologies were used: research with the students about the computational resources used and their perceptions about the teaching and learning process; and the report of our experiences as facilitators in the disciplines of Calculus 3 and Numerical Methods.

3.1. Quiz for Engineering Students

The first quantitative method consisted of preparing a digital questionnaire on Google Forms. The questions addressed the student's course, the year of enrollment, the computational tools used by educators and the perceptions of learning.

To diagnose learning, we chose the Likert scale (LIKERT, 1932) with the following questions:

- Did the teaching didactics with the tool contribute to your learning?
- Did the use of this tool encourage you to seek learning?
- Is the use of this tool adequate and does it facilitate learning?
- Was the application of this tool for teaching adequate?
- Was the use of the tool unprecedented for you?
- Has interest in the discipline increased with the use of this tool?

3.2. Use of computational resources in UNIVESP disciplines

In the next topics, the report of the teaching experience of two UNIVESP facilitators in the Production and Computer Engineering courses, teaching in the disciplines of Calculus 3 and Numerical Methods will be presented.

3.2.1. Experience report in the discipline of Calculus 3 — Fourier Series

The French mathematician and physicist Jean Baptiste Joseph Fourier (1768–1830), among numerous achievements, proved that any periodic signal could be decomposed into an infinite series of summation of trigonometric functions. This topic is usually dealt with in the second year of undergraduate courses in Engineering, after the student has gone

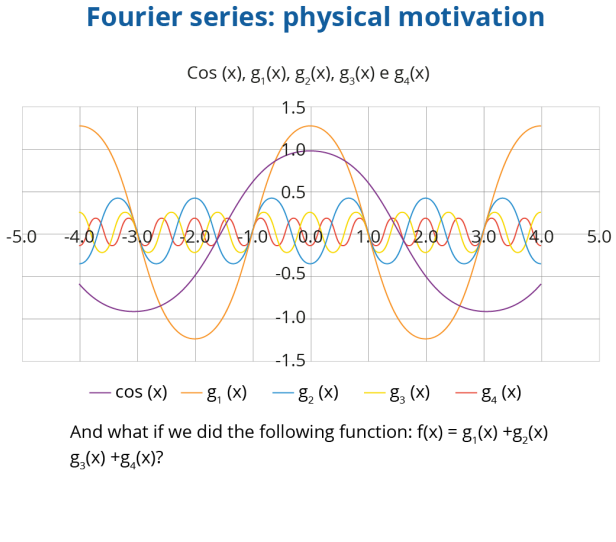
through the disciplines of Calculus 1 and 2. At UNIVESP, this topic is presented to students in Calculus 3 in the 5th bimester of Engineering, together with the themes of differential equations, sequences and series.

In higher education, when teachers give classes on the aforementioned topic, they focus on mathematical proofs of how Fourier arrived at these results. Therefore, the formalism is far-fetched, and requires from the student solid knowledge of concepts previously taught, such as grades, integral, manipulation of functions, among others, which precede the discipline of Calculus 3.

A video made by engineer and communicator Destin Sandlin served as inspiration for an alternative methodology, used to complement teaching (WHAT..., 2018). In his channel, Sandlin illustrates mathematical and physical concepts through animations, and tries to detail the concept down to the most basic levels.

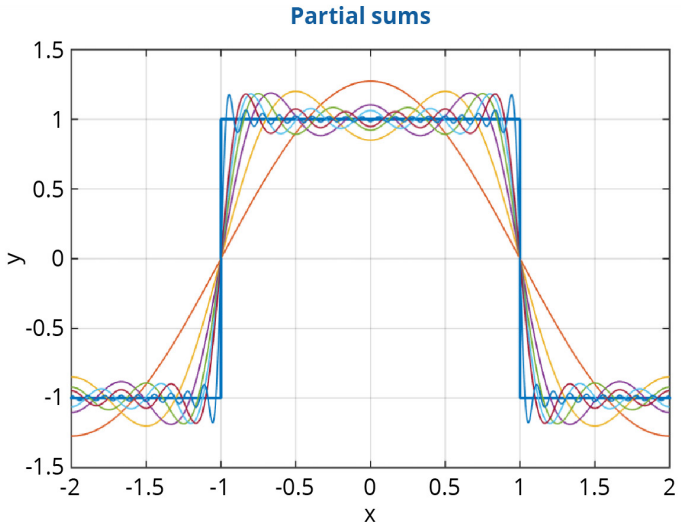
The video was recommended to UNIVESP students by posting on the question boards; later, it was supplemented in the streamings, first with a PowerPoint presentation of a step sign, and then with a spreadsheet. See Figures 1 and 2:

Figure 1 - Presentation used in the streaming



Source: Prepared by the author.

Figure 2 - Presentation used in the streaming

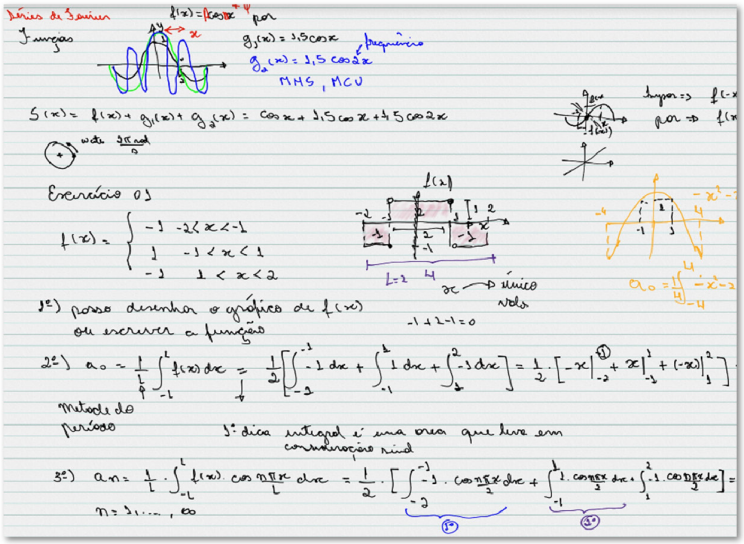


Source: Prepared by the author.

After the results, the calculation methodology with the use of integrals was presented. Thus, the path used was from the result to the calculation, which allowed the students, first, to recall the simplest concepts of trigonometric functions and uniform circular motion.

The presentation of the calculations was made through Google Meeting, with the aid of a digital whiteboard and the MyPaint program. An excerpt from the note sheet is shown in Figure 3 below:

Figure 3 - Development of the streaming using a virtual whiteboard



Source: Prepared by the author.

The synchronous participation was about ten students, varying to more or less over the one hour duration of the streaming. Overall, student feedback was positive, demonstrating that the association of different learning resources (digital spreadsheet, presentation, digital whiteboard) made the teaching and learning process more didactic.

3.2.2. Experience report in the subject of Numerical Methods

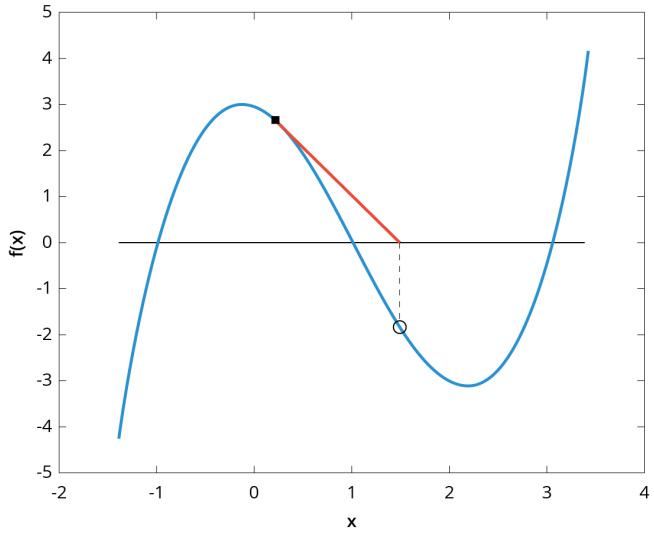
According to the curricular matrix of the Computer Engineering and Production Engineering courses at UNIVESP, the Computer Programming discipline is taught in the 4th bimester of the 1st year of the course; the subject of Numerical Methods is offered in the 6th bimester, in the 2nd year of the course. In view of this, the discipline of Numerical Methods, of a more practical nature, could make use of the knowledge already acquired in the Computer Programming course, in order to assist in the implementation of algorithms used in the resolution of examples of application of the methods presented.

However, according to the experience of one of the authors of this work as a facilitator of Numerical Methods in the 4th quarter of 2019,

the course's classes were limited to the exposition of mathematical algorithms, without the explicit application of the methods using any programming language. There was only the creation of a thematic forum on C and Octave language, briefly mentioned in Class 10 of the course, but without a broader use of these tools throughout the course.

In this sense, the idea was to present in the streamings the application of these methods in solving examples using programs written in Matlab, a tool for numerical calculations with a language compatible with Octave. In addition to implementing the algorithms, it was also sought to provide students with a graphical view of how the methods work, enabling a better understanding of the content of the discipline. Among the examples presented, there are applications of methods to find zeros of real functions (roots of the function), such as the bisection, false position, Newton-Raphson and fixed point methods. Figure 4 illustrates an interaction of the Newton-Raphson method in which you can graphically observe how the derivative at a point is used to obtain the point of the next iteration of the algorithm. It is just a frame of the graphic animation formed by all iterations up to the stopping criterion and obtaining the approximate root of the function.

Figure 4 - Animation frame showing all iterations of the Newton-Raphson method



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It is understood that this approach was effective in teaching Numerical Methods, given that there was positive feedback from students in the lives where the examples were presented, which may have aroused greater interest in the studies. Therefore, with a view to a possible reformulation of the curriculum of the UNIVESP courses along with the updating of the video classes of the courses, it is proposed that computational tools be addressed and included in the teaching of mathematical subjects, aiming at an improvement in the learning process from the students.

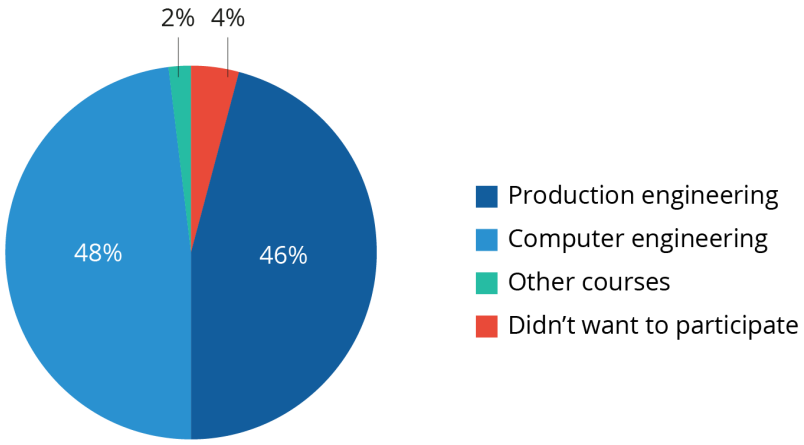
4. Results and discussion

In this section, the results of the research carried out with engineering students at UNIVESP will be presented.

4.1. Profile of students who answered the questionnaire

The survey carried out in the 1st semester of 2020 had the participation of 906 students. Among them, 865 students (95%) agreed to answer the questionnaire and 847 students (93%) were studying Engineering — of which 431 students (48%) were studying Production Engineering and 416 (49%), Computer Engineering, as shown in Figure 5.

Figure 5 - Percentage of students who responded to the questionnaire; among those who did or did not want to participate, those who attended engineering or not and which one, between Production Engineering and Computer Engineering

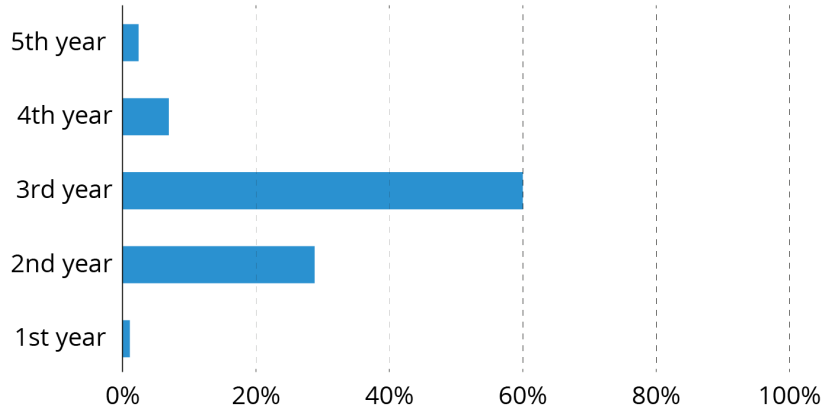


Source: Prepared by the author.

4.2. Profile of engineering students

Among the 847 engineering students who answered the questionnaire, the majority (60%) were in the 3rd year of their respective courses; 29% in the 2nd year; and, on the other hand, the minority (1%) was in the 1st year, as can be seen in Figure 6.

Figure 6 - Percentage of Engineering students and their respective years

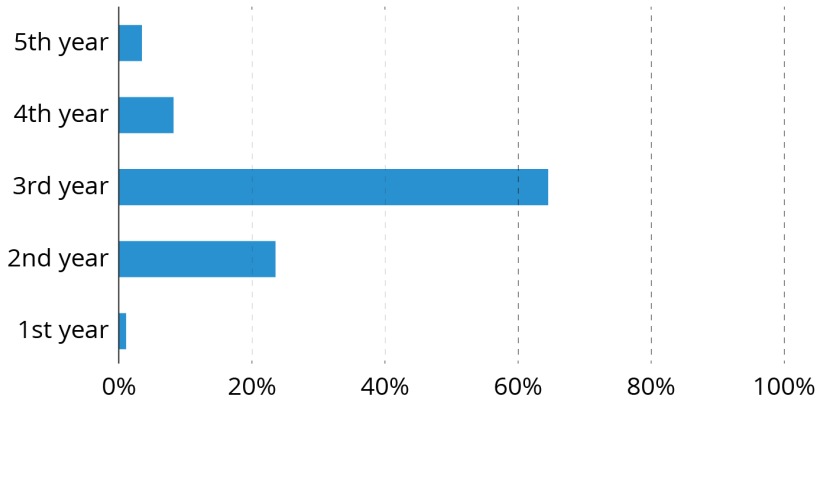


Source: Prepared by the author.

4.3. Profile of students who said they had witnessed the use of computational tools

Still among Engineering students, 600 (71%) said they had a teacher or facilitator who used some computational tool, but the other 247 students said they had not witnessed the use of these tools. When comparing Figures 5 and 6, the profiles were similar, and for engineering students who responded to the questionnaire saying they had witnessed the use of computational tools, just under two-thirds (65%) were attending the 3rd year; followed by the 2nd year, with 23%; and, at the other extreme, only 1% was attending the 1st year, as shown in Figure 7.

Figure 7 - Percentage of Engineering students and their respective years who witnessed the use of computational tools



Source: Prepared by the author.

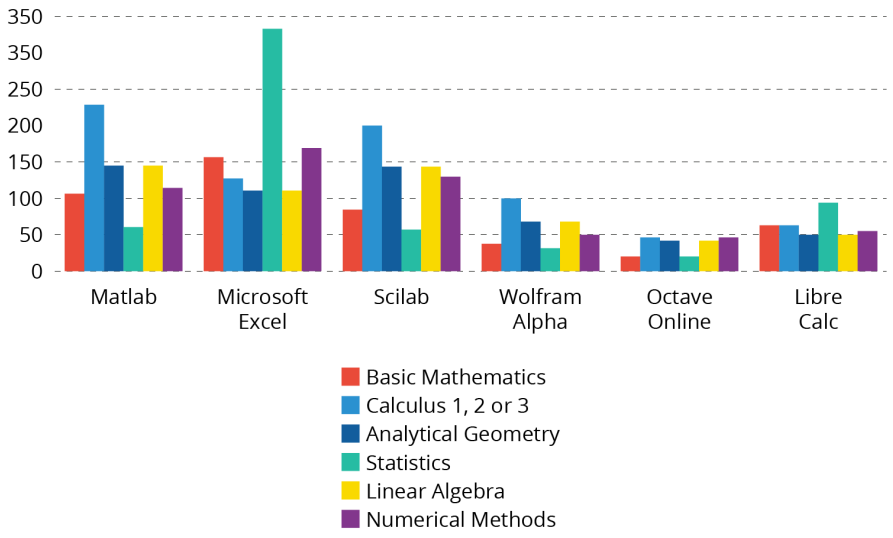
4.4. What subjects and computational tools did the students witness

The computational tools considered in the questionnaire were: Matlab, Microsoft Excel, Scilab, Wolfram Alpha, Octave Online and LibreOffice Calc, and their use occurred in the following subjects: Basic Mathematics, Calculus 1, 2 or 3, Analytical Geometry, Statistics, Linear

Algebra and Numerical Methods.

According to the results obtained, we can see in Figure 8 that Matlab, Scilab and Microsoft Excel were the most cited tools in the questionnaire, with a total of 2551 citations — with greater emphasis on Microsoft Excel, with 1002, and mainly on Statistics, with 331. As less cited tools, the highlight was Octave Online, with 214 citations. The greatest use of tools was in the disciplines of Calculus 1, 2 or 3, with 761 citations; the least use was in Basic Mathematics, with 461 citations.

Figure 8 - Engineering students who witnessed the use of computational tools (Matlab, Microsoft Excel, Scilab, Wolfram Alpha, Octave Online or Libre Calc) and the corresponding discipline (Basic Mathematics, Calculus 1, 2 or 3, Analytical Geometry, Statistics, Linear Algebra, Numerical Methods)

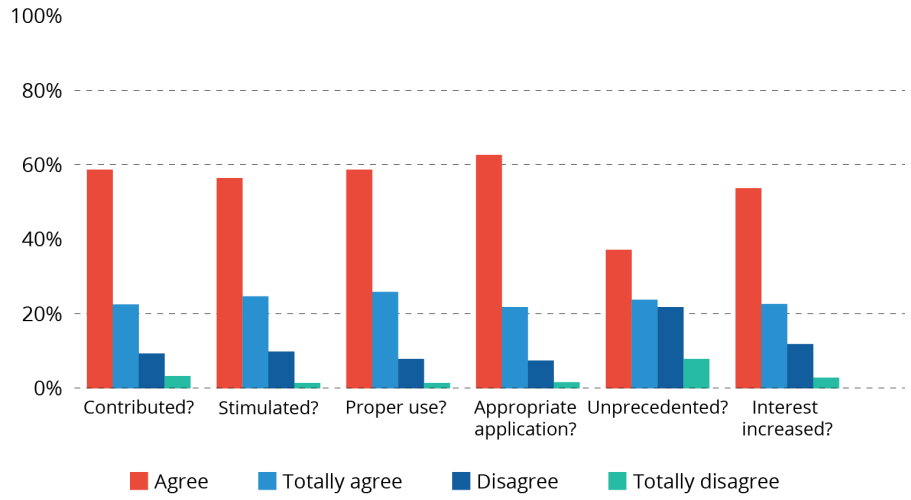


Source: Prepared by the author.

4.5. Student evaluation of the use of computational tools

Regarding the evaluation of 600 students on the use of computational tools, most agree that they contributed (59%), encouraged (57%), had their proper use (59%), were properly applied (63%), were unpublished (37%) and increased interest in the discipline (54%). It is also important to highlight that around 10% of the students totally disagreed with the same items in the questionnaire, as can be seen in Figure 9.

Figure 9 - Assessment of engineering students regarding the use of computational tools in relation to contribution, stimulation, proper use, proper application, novelty and increased interest



Source: Prepared by the author.

5. Conclusion

From the present study, and based on literature considerations related to the teaching and learning process of mathematics in distance education, we can enunciate some considerations based on our main results.

First, it is possible to identify that, although the profile of UNIVESP students is quite diversified, the process of teaching and learning mathematics mediated by the use of technologies is a topic that attracts the attention of a large number of students, given that the research achieved a significant participation rate, with 416 students from the Computer Engineering course and 431 students from the Production Engineering course, which represents a total of 847 students from the Engineering courses at UNIVESP.

The interview reveals a preponderance of the use of these technologies throughout the 3rd year of the course, although the Computer Programming discipline is already offered throughout the 1st year. Such data may indicate a low association between the application of

theoretical knowledge to educational practices in the initial and final years of the course, or even a delay in the use of such technologies in solving everyday problems. This gap has only been minimized thanks to the attempts of some teachers and facilitators to relate the solution of numerical problems to the use of computational tools in disciplines such as Calculus 3, Statistics and Numerical Methods.

Furthermore, although about 59% of students believe that the use of these tools contributes and is adequate for the teaching and learning process, some reports from facilitators indicate that there is little investment in this area by the institution. Some discussion forums are briefly mentioned and even the video classes of the Virtual Learning Environment (AVA) do not present the application of the mathematical algorithm in some computational language.

On the other hand, reports from facilitators who tried to implement such alternative methodologies, either in thematic forums or in their lives, indicate that there was positive feedback from students, whose interest increased, as well as the search for such study methodologies. This report is confirmed by the survey carried out with the students themselves, in which 54% of the interviewees stated that their interest in the subject increased after the application of some computational tool. For a relatively high fraction (about 37%), the use of the computational tool was even unprecedented.

In view of these statements and a possible reformulation of the curriculum of the UNIVESP courses, this work proposes an eventual update of the video classes of the courses with an emphasis on the use of such methodologies, since facilitators and students agree that the use of the tools has not only improved the association between theory and practice, but also contributed to the teaching and learning process, arousing students' interest and search for knowledge.

Therefore, among the factors that increase evasion in distance education, it is understood that the lack of meeting the expectations of students, the lack of quality of the online course and poor academic performance could be mitigated with the use of computational tools in disciplines UNIVESP, which could reduce student dropout at this university.

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