

Original article


## Teaching-learning process of Calculus I based on programming with the assistant Mathematica





**Proceso de enseñanza-aprendizaje de Cálculo I sustentado en la programación con el asistente Mathematica**

**O processo de ensino e aprendizagem de Cálculo I é apoiado pela programação com o assistente Mathematica**

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### ABSTRACT

Training highly qualified engineers is one of the challenges facing the Cuban Ministry of Higher Education today. In Cuba, the last decade of this century has seen engineering advancements that have improved every aspect of human life, which necessitates increasing the knowledge of future engineers to improve the country's socioeconomic conditions and thus remain at the forefront of technology and scientific development. However, the desired results and levels of preparation have not yet been achieved. This study aims to consider a teaching and learning approach for Calculus I, based on programming with Mathematica, for the Computer Engineering program at the Hermanos Saíz Montes de Oca University of Pinar del Río, as a support for developing mathematical problem-solving skills and professional expertise. The research used scientific methods: theoretical, empirical,

and statistical, through the review of journal articles, research, and theoretical-methodological references associated with the teaching-learning process of Calculus I. The main results of the exploratory study are presented, and it is concluded, with a quasi-experiment, that the proposed conception has practical validity and a professionalized path with a systemic, contextualized, problem-solving, and interdisciplinary character for the resolution of professional problems.

**Keywords:** didactic conception; educational technologies; evaluation of the educational process.

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## RESUMEN

La formación de ingenieros con un alto nivel de preparación es uno de los retos que tiene hoy el Ministerio de Educación Superior cubano. En Cuba, en la última década del presente siglo, se han generado avances procedentes de la ingeniería que han mejorado cada aspecto de la vida humana, lo que implica incrementar el conocimiento de los futuros ingenieros, para así poder mejorar las condiciones socioeconómicas del país y de esta forma estar a la vanguardia en tecnología y desarrollo científico. Sin embargo, aún no se logran los resultados deseados y niveles de preparación a los cuales se aspiran. El estudio tiene el objetivo de considerar una concepción del proceso de enseñanza-aprendizaje del Cálculo I, sustentada en la programación con Mathematica, para la carrera de Ingeniería Informática, en la Universidad de Pinar del Río Hermanos Saíz Montes de Oca, como soporte en el desarrollo de habilidades de resolución de problemas matemáticos y de la profesión. En la investigación se utilizaron métodos científicos: teóricos, empíricos y estadísticos mediante la revisión de artículos de revistas, de investigaciones y de referentes teórico-metodológicos asociados al proceso de enseñanza-aprendizaje del Cálculo I. Se exponen los principales resultados del estudio exploratorio realizado y se concluye con un cuasiexperimento, que la concepción propuesta tiene validez práctica, y una vía profesionalizada con un carácter sistémico, contextualizado, problémico e interdisciplinar para la resolución de problemas profesionales.

**Palabras clave:** concepción didáctica; tecnologías educativas; evaluación de proceso educativo.

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## RESUMO

A formação de engenheiros altamente qualificados é um dos desafios enfrentados atualmente pelo Ministério da Educação Superior de Cuba. Na última década deste século, Cuba testemunhou avanços

na engenharia que aprimoraram todos os aspectos da vida humana, o que torna necessário ampliar o conhecimento dos futuros engenheiros para melhorar as condições socioeconômicas do país e, assim, mantê-lo na vanguarda do desenvolvimento tecnológico e científico. Contudo, os resultados e níveis de preparação desejados ainda não foram alcançados. Este estudo visa analisar uma abordagem de ensino e aprendizagem para Cálculo I, baseada na programação com Mathematica, para o curso de Engenharia da Computação da Universidade Hermanos Saíz Montes de Oca, em Pinar del Río, como suporte para o desenvolvimento de habilidades de resolução de problemas matemáticos e expertise profissional. A pesquisa utilizou métodos científicos: teórico, empírico e estatístico, por meio da revisão de artigos de periódicos, pesquisas e referências teórico-metodológicas associadas ao processo de ensino-aprendizagem de Cálculo I. Os principais resultados do estudo exploratório são apresentados e conclui-se, com um quase-experimento, que a concepção proposta possui validade prática e um caminho profissionalizado com caráter sistêmico, contextualizado, voltado para a resolução de problemas e interdisciplinar.

**Palavras-chave:** concepção didática; tecnologias educativas; avaliação do processo educativo.

## INTRODUCTION

Training highly qualified computer engineers is one of the challenges facing the Cuban Ministry of Higher Education today. In Cuba, the last decade of this century has seen significant advances in computer engineering (platforms such as Viajeros, Versat Sarasola, and Sigenu, among others) that have improved every aspect of human life, making it essential to enhance the knowledge of future engineers.

According to Estopiñan and Telot (2017), computer engineers carry out their professional activities in a field of science considered one of the most dynamic today. In this area, what is a groundbreaking innovation today will be obsolete tomorrow; whether planned or not, this becomes a problem that hinders the continuous development of society, demanding imagination, creativity, and skills.

When analyzing the Professional Model of the computer engineer, the need to relate the teaching-learning process (PEA in Spanish) of Calculus I, with other disciplines of the career (Discrete Mathematics, Programming I, among others), with tasks specific to the exercise of the profession and with the performance of quality interdisciplinary activities directed to the professional profile, so

that the academic, the work, the research and the extension are integrated in the process (MES, 2017).

For this professional, programming is a process closely linked to mathematics, especially logic, overall theory and work with mathematical functions and models; therefore, this science is the ultimate means by which this professional achieves description, modeling and solution of technical situations, of unexpected complexities that it faces (Iglesias *et al.*, 2017).

In this sense, a conception of the teaching-learning process of Calculus I in the Computer Engineering career, of the University of Pinar del Río, must focus on its integral character, starting from determining its components, its relationships and its systemic organization, which facilitate its analysis and understanding from its organization and projection to its development and evaluation, while also allowing to expose a variant to relate the mathematical content with programming.

An important aspect is the level of interaction and communication between participants in the process, the relationship between activity and communication as socialization processes, ideal for fostering the exchange of ideas between students and teachers. From this dynamic is born the system of ideas for problem-solving based on the object of the profession and which, from the teaching learning process of Calculus I, supported by programming with the software Mathematica manifests its maximum expression (Cala *et al.*, 2020).

In this regard, Caraballo *et al.* (2019) highlight the role played by the group as active subjects in the construction and appropriation of their own learning in a cooperative manner, acquiring attitudes, interests and values that facilitate the precise mechanisms to govern themselves, leading them to take responsibility for their learning.

Similarly, and according to Mena and Mena (2020), the context is seen as the system of influences and relationships of subjects, objects and scenarios in which the basic and professional training of the computer engineer is developed; thus, some subjects transform others and are, in turn, the object of transformations as a result of these interactions.

Therefore, the teaching-learning process conception of Calculus I in the Computer Engineering career, of the University of Pinar del Río, conceives the group as a dynamic agent of interdisciplinarity (vertical and horizontal), between Calculus I, programming with Mathematica and the integration of

the actors of the process (teacher and student), committing them to individual and collective progress.

From this perspective, conceiving the interdisciplinarity between Calculus I and programming with Mathematica allows reaching higher levels of learning in the solution of mathematical and professional problems, allowing considering the development and learning that the student acquires in the process, in close dialectical unity; learning must constitute the basis of the Zone of Potential Development of the students, generating an authentic co-learning, thus becoming a socializing and culturally established process (Pedroso *et al.*, 2021).

Consistent with the above, the objective of this study is to consider a conception of the teaching-learning process of Calculus I, integral, systemic, contextualized, supported by programming with the Mathematica assistant, while facilitating interdisciplinarity, as a product of the relationship that occurs between the mathematical contents that will be the object of assimilation and appropriation by the student in the resolution of mathematical and professional problems.

## **MATERIALS AND METHODS**

The research employs a mixed-methods approach, integrating both qualitative and quantitative methods in the data collection and analysis process. The methods used are based on dialectical-materialist theory, specifically applied to theoretical, empirical, and statistical mathematical methods. These include: systematization, used in the study of articles, theses, regulatory documents for the computer engineering program, and research, which facilitated the organization of information and the study of different approaches to the Calculus I Learning Process; historical-logical analysis, which enabled the study of the dynamics, trajectory, and logic of the Calculus I Learning Process within the Computer Engineering program, based on the impact of this subject on the training of future professionals and the determination of its antecedents and theoretical frameworks; and modeling, used to achieve a sufficiently clear simplification and representation of the development of the Calculus I Learning Process, allowing for the restructuring of the didactic components that comprise the proposed conception. Documentary analysis was used to review the curriculum of the Computer Engineering program, emphasizing the profession's objective, the direction of the Calculus I learning process, and the structuring of its content. Methodological work plans from the department, program, and disciplines, as well as lesson plans, were also reviewed to assess the structure of mathematical activities and the grades obtained. A survey was administered to professors of Mathematics and

Programming to determine their opinions on the development of the Calculus I learning process for Computer Engineering students at the University of Pinar del Río. The experimental method, in its pre-experimental variant, was used to validate the proposed didactic approach through the practical implementation of the methodology. Finally, statistical methods were employed in frequency analysis for presenting results in tables and graphs, and in working with indices to reduce the information to a concrete value.

For the final analysis and validation of the pre-experiment results, a variant of fuzzy logic was used, with which it was possible to verify the level achieved in terms of the understanding-assimilation of fundamental concepts and procedures of Calculus I and their application in the solution of mathematical and professional problems.

The research has its background in the school year 2022-2023. In this case, 60 first-year students were selected from both the Day Course (40) and the Encounter Course (20). Twenty professors were also included in the sample; five of them were course administrators, and fifteen were Computer Engineering graduates who taught in the program. Initially, a review of the program's regulatory documents was conducted, followed by scientific observation of 16 Calculus I classes. This was complemented by non-probability sampling of the course syllabus, and subsequently, a survey was administered to the students.

The didactic approach is based on leveraging the capabilities of the Mathematica software, a computational tool that allows for any type of algebraic or numerical calculation, the generation of graphs, and in-depth analysis of mathematical models. This tool helps introduce students to different representations of mathematical concepts, such as functions, graphing, limit calculations, differentiation, and integration of a single variable. Furthermore, Mathematica's programming language is based on term rewriting (also known as symbolic computation) and supports both functional and procedural programming (although functional programming is generally more efficient).

To verify the origin of the results obtained with the application of the previous instruments, a research survey was used with the professors who manage the discipline of Calculus I and the graduates of the professional career of Computer Engineering.

A quasi-experiment was conducted for two independent samples; each group was randomly selected. Group I consisted of 20 students (control group) and Group II consisted of 20 students (experimental

group). The quasi-experiment was structured as PPI  $\Rightarrow$  STIMULUS  $\Rightarrow$  PPF (PPI: initial pedagogical test, PPF: final pedagogical test).

To carry it out, the following actions were taken into consideration:

The independent variable (IV) was defined as the didactic conception, specified in the subject Calculus I and the dependent variable (VD) the PEA of Calculus I supported by programming with the Mathematica assistant.

Hypothetical scenario: if the didactic conception for the PEA of Calculus I, based on programming with Mathematica, is implemented in the Computer Engineering career, significant results are obtained in terms of a contextualized, interdisciplinary and professionalized learning of Calculus I, which translates into a comprehensive and competent training.

The ways in which the variables will be operated and controlled are specified, the necessary measurement instruments for the dependent variable are developed, the way of carrying out the quasi-experiment is determined: functions, actions, participants, time spent and, finally, the procedures for collection, organization and statistical analysis of the relevant information are designed.

In order to avoid the influence of elements unrelated to the content of the proposed conception, the following were controlled in the results: objective conditions of the University of Pinar del Río for the development of laboratory activities; centers of origin of the students, fundamentally for the case of the encounter course; technical conditions (PC, Laptop, smartphone, etc.) for the development of independent activities.

## RESULTS

A general analysis of the students' results reveals that, in the initial pedagogical test (PTI in Spanish), the most affected indicators are those related to the level of knowledge and skill in working with the Mathematica assistant, where 75% of students are classified as having low performance. Similarly, the indicators related to organization, originality, and logic in developing algorithms for solving problems with Mathematica, and the potential to generate solutions with the assistant for assigned tasks, shows that 86.6% and 78.3% of students, respectively, are classified as having low performance. Meanwhile, the indicator with the best results was related to flexibility in assimilating

new approaches and proposed solutions to the assigned task, where 91.6% of students obtained results evaluated between medium and high.

After implementing the concept, the quasi-experiment concludes with the application of the final pedagogical test (PPF in Spanish) to 40 first-year students of the Computer Engineering program. In this case, 20 students were selected to form the control group and 20 for the experimental group. The input variables were defined as Calculus I and Calculus I supported by programming with Mathematica. The output variable was the evaluation of the learning of the first-year Computer Engineering students at the University of Pinar del Río.

Evaluating student learning based on traditional measurements is often somewhat subjective, as the grade that teachers establish within a predetermined model can vary depending on the style and sensitivity of each of them, so the grade assigned to a student could be an approximation.

In this sense, to evaluate the learning of first-year students of the Computer Engineering program at the University of Pinar del Río, a variant of Fuzzy Logic was used, based on the center of gravity method, which converts a membership function associated with the fuzzy set into a numerical value, precisely from the calculation of its center of gravity.

In this sense, a student's learning is considered to be high (H) if their center of gravity is greater than or equal to 4.5, medium (M) when  $3.5 < C_g < 4.5$  and low (L) if  $C_g \leq 3.5$  ( $C_g$ : understood as the central value of those that are in the vicinity of the confidence interval).

The following tables show the results of the Teaching learning Process assessment of the control group (without the use of the assistant) and the experimental group (PEA of Calculus I supported by programming with Mathematica).

**Table 1.** Results of the PEA control group without the use of the assistant

Est	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
MA	4,6	3,9	3,6	4,6	3,5	3,8	3,6	3,6	4,6	3,6	3,5	3,5	4,6	3,6	4,1	4,0	3,7	3,5	3,7	3,6
Cg	4,8	4,3	3,5	4,8	3,3	4,5	3,0	3,5	4,8	3,3	3,3	3,3	4,8	3,3	4,7	4,3	3,3	3,0	3,5	3,3
EA	A	M	B	A	B	A	B	B	A	B	B	B	A	B	A	M	B	B	B	B

**Table 2.** Results of the PEA of the experimental group supported by programming with Mathematics

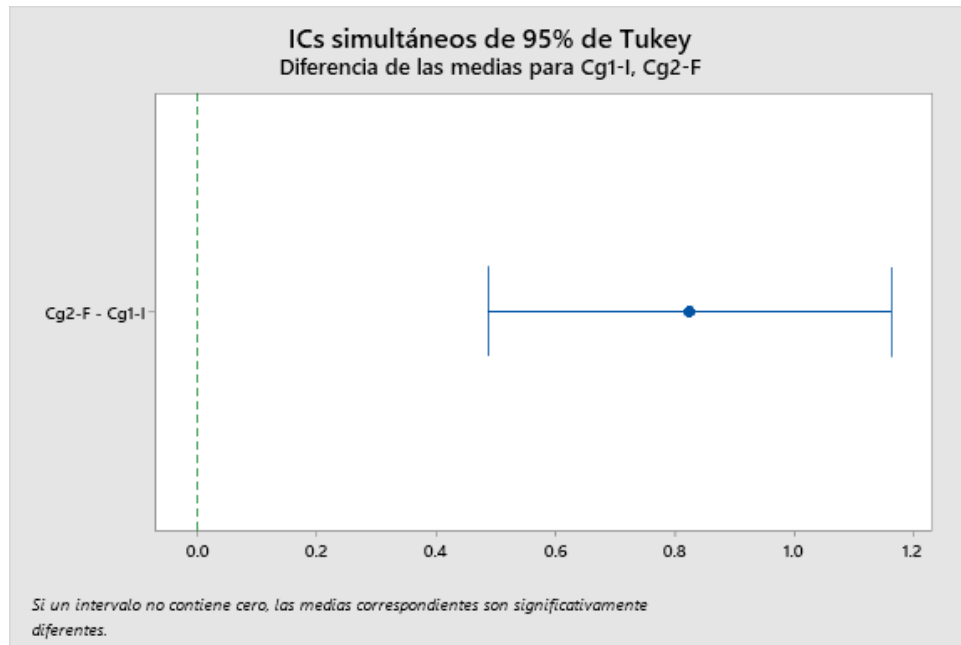
Est	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
MA	4,7	4,3	4,7	4,6	4,6	4,3	4,0	4,0	4,6	4,6	4,0	4,1	4,6	4,2	4,3	4,0	4,7	4,5	4,0	4,2
Cg	4,8	4,3	4,8	4,8	4,5	4,5	4,5	4,5	4,8	4,3	4,3	4,8	4,8	4,5	4,7	4,7	4,4	4,5	4,5	4,8
EA	A	M	A	A	A	A	A	A	A	M	M	A	A	A	A	A	M	A	A	A

The above serves to determine if there are significant differences between the mean results of the factor levels, which in this case would be: factor, type of exam to be performed, continuously; level 1 (center of gravity  $C_g$  -I) and level 2 (center of gravity  $C_g$  -F) corresponding to the control group (CG) and experimental group (EG). In relation to this, the one-way analysis of variance (ANOVA) tool is applied, which allows us to confirm the existence of these differences in the means, under the null hypothesis that all means are equal ( $H_0: m_1 = m_2$ ), in contrast to the alternative hypothesis, not all means are equal) ( $H_1: m_1 \neq m_2$ ), for a significance level of  $\alpha=0.05$ . The final result is shown in the ANOVA table, with a *p*-value less than the significance level.

**Table 3.** One-way analysis of variance

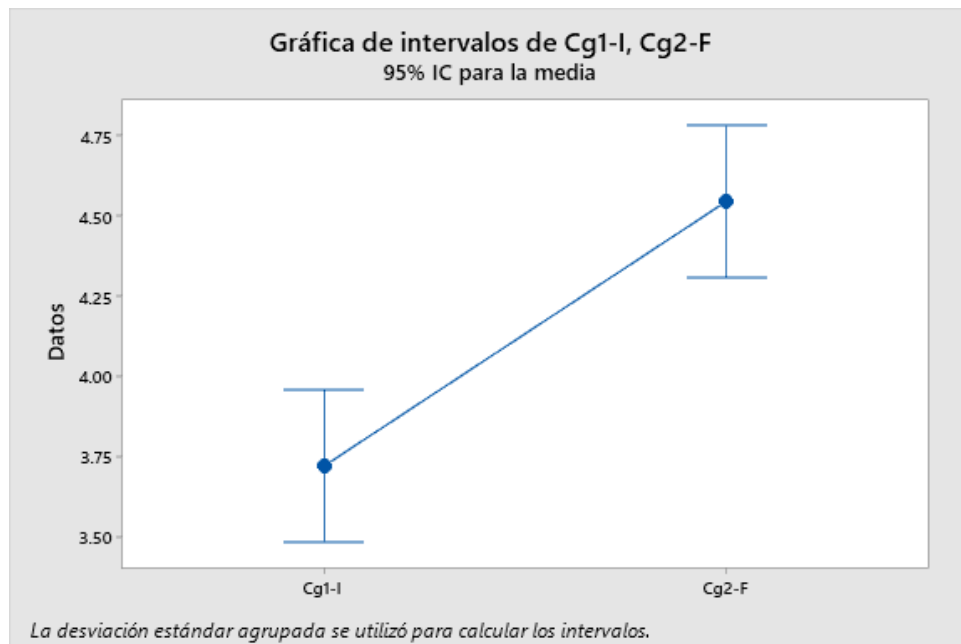
Fountain	GL	SC Adjust.	MC Adjust.	F value	P value
Factor	1	6,806	6.8063	24.72	0.000
Mistake	38	10,462	0.2753		
Total	39	17,268			

Once differences between the means have been established, Tukey's *post hoc tests* allow us to determine which means differ. Figure 1 graphically confirms the existence of these differences by excluding the null value from the confidence interval, for a 95% confidence level.



**Figure 1.** Simultaneous confidence intervals

By graphically representing the confidence intervals for each level, the above analysis with the applied tools can be verified, so it can be stated that the results obtained in  $C_g$ -F in terms of learning assessment are statistically superior to  $C_g$ -I, as shown in figure 2.



**Figure 2.** Confidence intervals for the mean

As shown in the figure, the conception of a PEA of Calculus I, supported by programming with the assistant Mathematica, in the course of Computer Engineering, brings with it a significant increase in results in terms of assimilation, understanding and application of concepts, definitions and procedures of Calculus I, to the solution of mathematical problems and of the profession, expression of a contextualized, interdisciplinary and professionalized process, laying the foundations for the professionalization of the process, which is equivalent to organizing it according to the object of the profession, while allowing concepts and procedures of Calculus I to be linked with programming, so that a problem-solving approach is achieved, the work scenario that the student will face once graduated.

Similarly, the results presented are an essential part of the set of actions carried out by the professors of the Mathematics department who develop their teaching work in the Computer Engineering career, to favorably influence the teaching-learning process of Calculus I, and which, supported by programming with the Mathematica assistant, constitute a fundamental basis in the initial training of the computer engineer, while contributing significantly to the development of mathematical problem-solving skills and the profession.

## DISCUSSION

Next, and as an essential part of the discussion of the results obtained, firstly, interdisciplinarity is conceptually valued as an element that energizes the didactic conception of the PEA of Calculus I, supported by programming with the Mathematics assistant, from the perspective of the use of mathematical assistants in the PEA of Calculus I (Pico *et al.*, 2017) and, secondly, the aspects that characterize the didactic conception of the PEA of Calculus I in the professional career of Computer Engineering.

Interdisciplinarity, according to Mena and Mena (2020), is seen as the significant process of curriculum enrichment and the learning of its participants, achieved by recognizing and developing the existing links between the different disciplines within a curriculum. It has been the subject of study by numerous researchers, both nationally and internationally. Currently, many studies highlight the use of mathematical assistants (Pico *et al.*, 2017; Pedroso *et al.*, 2021) as an essential tool for an interdisciplinary teaching and learning process, making it the central focus of the didactic approach developed.

In this context, the role of mathematical assistants is essential in the ongoing comprehensive training of the Computer Engineering student, which cannot be seen as an isolated and independent fact from each subject that makes up the curriculum, but as a process where additional knowledge is not proposed, but seeks to establish connections and relationships of knowledge and problem-solving skills, in an integrated and dynamic way, based on the object of the profession.

Therefore, and taking into account the role played by the mathematical assistant and interdisciplinarity in the comprehensive training of the computer engineer, a didactic conception of the PEA of Calculus I is presented below, based on programming with the Mathematica assistant, in order to achieve the integrality of the process. The use of computational environments such as Mathematica has proven to be an effective resource for supporting the teaching of calculus in the early years of university. Contreras de la Fuente *et al.* (2019) point out that incorporating this software into calculus practice allows for the identification of recurring errors in students and facilitates immediate feedback, which contributes to deeper and more meaningful learning.

The dynamic visualization offered by Mathematics facilitates the understanding of abstract concepts such as the Riemann integral or functions of a complex variable. Pérez (2015) highlights that interactive graphical representations allow students to independently explore the fundamentals of calculus, which increases their motivation and reduces anxiety about the subject.

Aleman Martínez and Checa Martínez (2012) emphasize that a practical calculus course supported by Mathematica not only improves the accuracy of procedures but also fosters critical thinking by allowing students to focus on interpreting results rather than on the mechanics of calculation. This approach contributes to a more comprehensive education in mathematics.

PEA of Calculus I, in the Computer Engineering career, is defined as a theoretical construction based on a system of principles and basic ideas, related to each other, which ground the PEA of Calculus I in the theoretical order, in order to favor the interdisciplinarity of the mathematical content with programming, based on a mathematical processor assistant and on the contextualization, updating and professionalization of this process.

Its content highlights the basic ideas as an expression of the PEA of Calculus I, which give rise to essential contributions regarding the use of the Mathematica assistant, as exponents of interdisciplinarity of the contents of Calculus I and programming, in the resolution of mathematical

and professional problems, the role of the teacher, the student and the group and the reconsideration of the didactic components of the process, in the computer engineering career

Therefore, from this perspective, the PEA of Calculus I supported by programming with Mathematics is understood as the system of actions carried out by the teacher, with an integral and professionalized approach to the components, aimed at the appropriation by the students of the content of the Calculus I subject, for the resolution of problems of the profession, supported by programming in a contextualized and interdisciplinary way, according to the object of the profession.

The didactic conception of the PEA of Calculus I supported by programming with Mathematica is based on a system of principles that energize, govern and regulate the process:

*Principle of linking science, teaching, and profession.* This principle is based on relating the Calculus I learning process to the scientific advancements and results that impact professional training. Adopting this principle inevitably leads the computer engineering student to consider the Calculus I learning process, based on programming with Mathematica, as the fundamental context for professional development. This context, characterized by the very essence of the profession, becomes a cornerstone for developing problem-solving skills and a passion for the profession.

In this regard, the integrated work of the teaching staff should foster conditions to meet the research and professional needs of the students and conceive a system of teaching tasks aimed at progressive involvement.

*Principle of the indissoluble link between theory, practice and professionalization.* It involves linking concepts, definitions and procedures of Calculus I to the solution of problems sustained in programming with Mathematica, thereby contributing to the professional development of the computer engineer in training and allowing teachers and students to have a holistic view of the professional profile. This principle recognizes in the PEA of Calculus I the unity in the didactic conception of the components of the process and the object of the profession, through the development of learning tasks supported by programming with Mathematica.

*Principle of technological interactivity.* It is manifested in the PEA of Calculus I, based on programming with the Mathematica assistant, which favors the design of personal and social learning environments, allowing the adaptability of the Mathematica assistant to the cognitive needs and learning pace of the student, multidirectional communication between the different actors in the

process and the management of the assistant.

This dialectical relationship, which takes place between the actors of the Calculus I PEA, involves the passage through several stages of interaction, which materialize the systemic realization of the didactic components of the process and the relationships that are established between students, group, teacher and the resolution of problematic situations in the social context.

*Interaction between student and Mathematica assistant.* This is clearly fundamental for other types of interactions to occur; in it, the student must demonstrate mastery of the fundamental skills for working with Mathematica as an essential tool in linking mathematical content with programming.

*Student-content interaction.* In the process of acquiring knowledge, skills, and values, there must be a dynamic of relationships that allows the student to interact with the content through Mathematics in an exchange environment.

*Student-teacher interaction.* In the Calculus I learning process in the Computer Engineering degree, it has special significance, where working with the students' Zone of Proximal Development in solving mathematical and professional problems, supported by programming with Mathematica, is essential, since the teacher becomes a guide, mediator and orienteers of the student during learning.

*Student interaction.* Student interaction occurs through pre-established communication channels, as well as through collaborative teamwork when solving a specific problem or year-long project. This interaction allows students to share questions, opinions, and exchange solutions. This principle fosters the development of values such as solidarity, autonomy, self-management, and responsibility.

### **Basic ideas of the didactic conception of the PEA of Calculus I, in the Computer Engineering degree**

The ideas presented below aim to characterize the didactic conception for the teaching learning process of Calculus I in the Computer Engineering career, based on programming with Mathematica, as a didactic and interdisciplinary process in which all the components of the process converge, which is energized not only in the university context, but in the social environment in which the student develops, from the interaction given between the academic, work and research components.

The ideas articulate the Calculus I teaching plan by leveraging the interdisciplinary nature of the subject and the curriculum. Therefore, the proposed didactic approach is based on the following fundamental ideas:

1. The PEA of Calculus I, supported by programming with Mathematics, conceives this as the professionalized path of a systemic, contextualized, problematic and interdisciplinary nature.
2. In the PEA of Calculus I, interdisciplinarity with programming with Mathematica contributes to the development of problem-solving skills.
3. The PEA of Calculus I in the Computer Engineering degree is realized in diagnosing, modeling, algorithmizing and programming as a professional teaching task.

Becoming a competent computer professional requires a Calculus I PEA that is based on the integration not only of its didactic components, but also with the professional development context in which it develops in a systemic way, where the resolution of problems based on programming with Mathematica becomes a cornerstone of a contextualized, interdisciplinary and professionalized learning of the subject in training (Mena and Mena, 2020).

In this sense, the interdisciplinary that exists between the PEA of Calculus I, with subjects of the curriculum (Discrete Mathematics and Programming), will allow the computer engineer in training, to develop skills to achieve an integral training, to assume and solve mathematical and professional problems with Mathematics and whose solution is through the practical link of the mathematical content and programming.

From this perspective, the following characteristics are identified in the PEA of Calculus I in the Computer Engineering degree:

**Systemic character:** it is based on the systematization and relationship that occurs between the mathematical content and the programming with Mathematica, the components of the process and the didactic units that make up the program of the subject Calculus I; likewise, in the context of professional development in which the student develops, highlighting the genetic and evolutionary nature in terms of the determination and appropriation of the necessary culture from the invariants of the content, for the assimilation, understanding, modeling and application of fundamental concepts and properties in the transformation of the social reality on which the student has an impact.

**Problematic nature:** It constitutes the basis for the interdisciplinarity of mathematical content and programming with Mathematica and is manifested from the posing of situations associated with the current socio-economic context, as a dynamic element that supports and guides professional activity, allowing the assimilation of knowledge and methods of practical intellectual activity; in addition, it motivates cognitive interest and enhances the student's ability to construct their own knowledge with imagination and creativity, developing the scientific spirit from cognitive independence and the assimilation of the knowledge system, so that they can effectively face the solution of cognitive or social problems, supported by programming with Mathematica (Cala *et al.*, 2020).

**Contextualized character:** It is based on the principle of the indissoluble link between theory and practice, the relationship between the studied content and the student's future profession. It arises from the way the student manages knowledge, with the aim of understanding social reality and, in some way, transforming it through problem-solving. This demonstrates the correspondence established between problem-solving skills, programming with Mathematica, the content, and the context in the professional's training; a correspondence that demands alternative thinking from the student, which is realized in the development of integrative tasks.

**Interdisciplinary character:** it is manifested in the conception of the PEA of Calculus I, based on programming with Mathematica, which makes it possible to understand problem-solving from a didactic, technological and axiological perspective, where the student, with the advice of the professor, visualizes, graphs and develops small programs, aimed at stimulating independence, creativity and motivation for the profession, in which, in an environment of cooperation and exchange of knowledge, models and algorithms are managed with the purpose of solving the problem posed (Caraballo *et al.*, 2019).

The interdisciplinary nature of the content of Calculus I with programming with Mathematica, in the Computer Engineering degree, lays the foundation for the professionalization of the process, which is equivalent to organizing it according to the object of the profession, where it allows relating concepts and procedures of Calculus I with programming, so that an approach is achieved from the resolution of problems with the assistant, to the work scenario that the student, once graduated, will face.

The PEA (in Spanish) of Calculus I, taking into account the elements that characterize it and the interdisciplinary relationship that takes place with the programming with Mathematica, depending

on its training, takes into account the systemic relationships between its didactic components, made up of the problem or learning need, object, objective, content (knowledge, skills and values), methods, means, forms and evaluation, as well as the teacher-student-group relationship.

The components of the Calculus I learning process include: the teacher, the student, and the group, whose relationship determines the dynamics of the process and brings the student closer to or further away from the object of the profession, to the extent that the interdisciplinarity between Calculus I and programming with Mathematica becomes an educational and motivational reference for their training.

In the relationship that takes place between teacher, student and group, the latter plays a determining role in the development of the PEA of Calculus I, supported by programming with Mathematica, as an ideal context for the development of exchange and cooperation activities between the members and in the solution of professional problems, where the main role in the process is exercised by the student himself, under the advice of the teacher.

In this sense, in the relationship established between the protagonists of the process, teaching focuses on the learner, and their learning will be contextualized, interdisciplinary, and professionalized, as the student appropriates the content in a personalized, conscious, and motivated way, in collaboration with the teacher and the group, which allows them not only to develop skills for problem-solving with Mathematica, but also the integral development of their personality, personal growth, and interaction with other subjects in an environment of cooperation and exchange.

This interaction, driven by the interdisciplinarity between Calculus I and programming with Mathematica, leads to the development of tasks with a professional character, from a cognitive and contextualized tutoring of the teacher, as an expert capable of guiding the student to the resolution of problems from a real approach, while making visible the teaching and learning strategies that allow for competent professional training.

The above leads the teacher to find new ways of teaching, thinking, and transferring the object of science (Calculus I) associated with the object of the profession (developing processes related to solutions and computer systems in organizations), which allow the student to be constantly in a process of questioning what they know, what they need it for, and to take control of their own learning.

The PEA of Calculus I in the Computer Engineering career recognizes in the interdisciplinarity between Calculus I and programming with Mathematica, the need to professionalize the components of the process as a way of a competent professional training of the graduate, as an option of his personal and professional growth and the satisfaction of his cognitive and volitional needs, from the solution of problems linked to the profession.

The Calculus I Learning Outcome (PEA), based on programming with Mathematica, recognizes the problem as the need to solve mathematical problems specific to the profession, supported by programming with the assistant. The object, as a didactic component where the problem manifests itself, is given by the system of concepts, definitions, and relationships of differential and integral calculus of real functions of one variable. Meanwhile, the objective, as a guiding component that expresses the aspiration to be achieved throughout the entire process, is aimed at solving mathematical and professional problems based on programming with Mathematica, as an example of interdisciplinary and professional training, in accordance with the object of the profession.

The systemic, dynamic, and contextualized nature of the problem-object-objective triad allows for the definition of the content to be developed. Content, as a didactic component, articulates the system of knowledge, skills, and values.

The knowledge system in the Calculus I Learning Process, based on programming with Mathematica, will not only focus on aspects related to differential and integral calculus of a real variable, but will also emphasize aspects related to programming elements with Mathematica. The content of calculus will be integrated with programming in the development of teaching tasks, aimed at developing the fundamental skill of the process: solving mathematical and professional problems. These tasks will be based on programming with Mathematica, which fosters values such as responsibility, creativity, scientific rigor, diligence, professionalism, and solidarity in students.

Without a doubt, in a Calculus I PEA, based on programming with the Mathematica assistant, the method to be used constitutes, like the rest of the components, an essential element that configures the space of interaction between student, teacher and group, vital to guarantee an interdisciplinary and professionalized training process.

In this sense, and taking into account the role of Calculus I in the interdisciplinarity with other disciplines of the computer engineer curriculum, the method to be used is that of project, understood as the set of activities articulated among themselves, oriented and under the tutoring of the teacher,

in order to generate products or services capable of solving problems of the profession and satisfying learning needs, considering the resources and the time allocated (Cobo & Valdivia, 2017).

The successful implementation of a project in the PEA of Calculus I requires that the academic year collective, where the integrating main subject (Engineering and Software Management), is systematically integrated into the process plays an essential role in the coordination and planning of situations present in the sector of production and services, on which the student must research. In this process, the following stages can be identified (Cobo & Valdivia, 2017).

- **Project organization and planning.** In this stage, relevant situations related to the course content are identified that require project-based development. The instructor, for their part, should foster motivation and interest in the task, highlighting its importance for social development and professional training. An important aspect is the organization and distribution of responsibility among team members. While autonomy is recommended, the teacher should intervene when necessary. Teacher support in generating ideas is also feasible to ensure the project's quality.
- **Research on the topic.** Its purpose is to understand the project topic and delve deeper into its foundations. It is recommended to provide systematic feedback to each team through guides, tutorials, etc., in order to appropriately orient their research toward the project they are developing.
- **Defining the objectives and work plan.** A project aims to generate a product, so students are expected to construct their learning throughout the process and connect it to the course content. The professor will establish the objectives, taking into account the main topics covered in the course, available resources, and time. Finally, the professor will develop a guide of the activities necessary to achieve the project objectives.
- **Implementation.** Depending on the project's characteristics, students will require varying degrees of guidance throughout the process. The professor should be attentive to any difficulties and learning needs that may arise, in order to guide the student if they need to adjust their plan or request information to ensure the project's ultimate success.
- **Presentation and evaluation of results.** The projects developed are displayed and the results are presented by the students, which requires prior preparation that allows the deployment of fundamental skills, such as oral and written communication.

Conceiving the project method in the PEA of Calculus I requires cultivating a culture of cooperation, socialization and exchange between students-teacher-students, with the aim of transforming a traditional process into one that is more active, participatory and integrated into the social and work environment.

For their part, the resources, as the material support for the method, will increase the effectiveness of the Calculus I teaching process, foster convictions, shape students' personality traits, consolidate creative activity, and strengthen skills that will enable them to develop abilities for working life and professional life. In this sense, the use of the Mathematica software is proposed as a fundamental tool in professional training, which lends a professional character to the process by relating mathematical content with programming in an interdisciplinary manner.

In turn, the form, as a component that expresses the external configuration of the process, is realized from the point of view of the group in conferences, practical laboratory classes with Mathematica, seminars and workshops and from the individual point of view, in independent activity, tutoring and advising on the different tasks assigned to the students, as well as on the oriented projects.

For its part, the evaluation, in accordance with the objectives and as a continuous process that promotes the discussion of alternatives and procedures for the solution of mathematical and professional problems, with the use of the Mathematica assistant, in a collaborative environment and exchange between the actors of the process, will have its greatest weight without ruling out the continuous and systematic evaluation in the elaboration and presentation of an integrative project.

A proper evaluation of the guided project allows students to showcase the results achieved, fosters awareness of the steps or strategy followed, and thus encourages self-evaluation. Furthermore, when these projects are presented at various student scientific forums, the product of collaboration and knowledge exchange between professors and students is evident, reflecting their professional development. Therefore, by opening up to the sociocultural and professional environment, the educational and professional community values and benefits from the students' work.

In this sense, and taking into account the professional skills of the computer engineer, it is necessary to structure the current PEA of Calculus I towards a more conceptual teaching, with more work in the development of problem-solving skills, aimed at carrying out actions that lead to a purpose: to contribute from the resolution of problems supported by programming with Mathematica, to the development and personal growth of the student.

Programming with Mathematica is considered a driving force for developing problem-solving skills. In this sense, the teacher becomes a mediator and facilitator of learning, providing students with pathways, methods, work strategies, and procedures. Likewise, the student is recognized as an active participant and builder of their own learning, not simply a passive recipient of information. To solve the assigned problem, the student must independently seek information, manage procedures, and process data and results.

Similarly, and consistent with what has been discussed, the interdisciplinarity between the PEA of Calculus I and programming with Mathematica establishes a link in professional training not only with the school environment, but also strongly rooted in continuing and work training, where the effectiveness of the method, the form and the means to be used are important, since the student appropriates the content only if he recognizes the importance and relevance of the problem in the application of its solution.

Therefore, in the interdisciplinarity of Calculus I and programming with the Mathematica assistant, the project method contributes to the development of skills that constitute actions within problem solving, such as *diagnosing, modeling, algorithmizing and programming*, while integrating the components of the process in the solution of a problem in a dynamic way, in order to make the most of the knowledge, skills and motivations of the student for learning and problem solving.

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### **Conflict of interest**

Authors declare no conflict of interests.

### **Authors' contribution**

The authors participated in the design and writing of the article, in the search and analysis of the information contained in the consulted bibliography.



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