DIDACTIC STRATEGY FOR TEACHING CALCULUS I IN THE GEOLOGICAL ENGINEERING PROGRAM

ESTRATEGIA DIDÁCTICA PARA LA ENSEÑANZA DEL CÁLCULO I EN LA CARRERA INGENIERÍA GEOLÓGICA

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ABSTRACT

Problem-Based Learning (PBL) has proven to be a promising methodology in the current university context. Applied within a didactic strategy, it seeks to contextualize Calculus I through real geological problems while fostering critical thinking, collaboration, and the development of digital competence. Significant shortcomings were identified in the Geological Engineering program at the University of Moa, Holguín, including theoretical and practical difficulties in representing functions of a real variable, limited student understanding of the problem-based approach, and low motivation toward the subject. This led to the formulation of the scientific problem: How can the teaching-learning process of Calculus I be enhanced? In response, a didactic strategy grounded in Problem-Based Learning was designed to strengthen the representation of functions of a real variable within the program. The study employed a quantitative, descriptive, and exploratory approach. The proposed strategy improves the teaching-learning process by structuring activities around active learning and problem-solving, thereby reinforcing students' conceptual understanding and stimulating greater motivation.

KEYWORDS: problem-based learning; functions of a real variable; teaching-learning process; academic performance

RESUMEN

El Aprendizaje Basado en Problemas (ABP) constituyó una metodología prometedora en el escenario universitario actual y al aplicarlo en una estrategia didáctica buscó contextualizar el Cálculo I en problemas reales de la Geología, y promover el pensamiento crítico, la colaboración y el desarrollo de la competencia digital. Se detectaron grandes insuficiencias en la carrera Ingeniería Geológica en la Universidad de Moa, Holguín, dificultades teóricas y prácticas en la representación de funciones de una variable real, baja comprensión del enfoque problémico por parte de los estudiantes y poca motivación por el estudio de la asignatura, lo que llevó a plantear como problema científico: ¿Cómo favorecer el proceso de enseñanza-aprendizaje de la asignatura Cálculo I? Debido a esto se elaboró una estrategia didáctica sustentada en el Aprendizaje Basado en Problemas, que favorece la representación de funciones de una variable real en la carrera Ingeniería Geológica. Se utilizó un enfoque cuantitativo de carácter descriptivo y exploratorio. Con la propuesta se mejora el proceso de enseñanza-aprendizaje, al estructurar las actividades basado en el aprendizaje activo y la resolución de problemas, fortaleciendo así la comprensión de los conceptos por parte de los estudiantes y estimulando una mayor motivación en ellos.

PALABRAS CLAVE: aprendizaje basado en problemas; funciones de una variable real; proceso de enseñanza-aprendizaje; rendimiento académico

INTRODUCCIÓN

Problem-Based Learning (PBL) is a student-centered pedagogical approach in which learning occurs through the resolution of complex problems (Barrows, 1996).

PBL is grounded in constructivism, where knowledge is actively constructed by the student through interaction with the environment and reflection on experience (Piaget & Inhelder, 2008; Vygotsky, 1978). It is also supported by Ausubel's (1968) theory of meaningful learning, which emphasizes the importance of relating new knowledge to the student's prior knowledge.

PBL is characterized by (Hmelo-Silver, 2004):

- ✓ Presenting students with a complex, ill-defined problem.
- ✓ Fostering collaboration and teamwork.
- ✓ Promoting research and information seeking.
- ✓ Developing critical thinking and problem-solving skills.
- ✓ Contextualizing learning in real-world situations.

In mathematics education, PBL can help students understand the relevance of abstract concepts and develop skills for the mathematical modeling of natural phenomena (Barrera & Shively, 2022, as cited in Pinargote & Chancay, 2022).

In the current context of higher education, where adaptability and complex problem-solving are crucial skills, it is necessary to rethink traditional didactic strategies. Mathematics instruction in engineering programs, in particular, faces the challenge of connecting abstract concepts with practical applications in the professional field. At the University of Moa Dr. Antonio Núñez Jiménez (UMoa), students of Geological Engineering have shown difficulties in Calculus I subject, especially in function representation, understanding the problem-based approach, and a lack of motivation due to the absence of connections with the mathematical modeling of geological phenomena.

Given this problem, the following scientific question is formulated: How can the teaching-learning process of Calculus I be enhanced in the Geological Engineering program at the University of Moa Dr. Antonio Núñez Jiménez? Therefore, the objective is to develop a didactic strategy grounded in Problem-Based Learning that favors the teaching-learning process of Calculus I in the Geological Engineering major.

MATERIALS AND METHODS

Research design

The approach of this research corresponds to a mixed methodology, employing methods, procedures, and techniques of both quantitative and qualitative nature, with a descriptive and exploratory character. Additionally, empirical methods, such as student surveys and documentary review of final grades from academic records were used. The population consists of 116 first-year students enrolled in the Geological Engineering program during the period 2020-2024, while the sample comprises 90 first-year students from the 2021, 2022, and 2023 full-time cohorts, where the aforementioned deficiencies are most evident.

Active teaching-learning methods in the mathematical curriculum of the geological engineer

According to Merina (2009), teaching methods are distinct sequences of professor actions aimed at provoking specific actions and modifications in students to achieve the proposed objectives. In the teaching-learning process, both passive and active methods can be used depending on the requirements. With passive methods, students learn by listening to lectures or reading textbooks. These are characterized by passive student participation, which limits the development of cognitive independence and creative ability.

Conversely, active methods imply that students engage with the material and participate in their own learning (Prince & Felder, 2007). Active teaching-learning methods consist of a series of strategies and techniques that seek effective student learning. Their ability to integrate with technology offers a new educational reality that has transformed in recent years, placing the student at the center of education.

Among the various methods proposed by these methodologies are: the flipped classroom, challenge-based learning, cooperative learning, discovery learning, project-based learning, and Problem-Based Learning (PBL). The latter is based on problem-solving, where the student significantly develops their cognitive structures, fosters cooperative work, develops skills for autonomous learning, and promotes values such as responsibility, cooperation, and love for truth (Velázquez et al., 2021).

Duch, Groh, and Allen (2001) consider that Problem-Based Learning has been established in higher education institutions in recent years, inverting the traditional learning path, where knowledge is first discovered and then applied to solve a problem.

RESULTS

Diagnosis of the current state of active methods in Calculus I subject in the Geological Engineering major

Using a sample of 90 students from the full-time regular course of the Geological Engineering major and six professors from the Mathematics Department who taught Calculus I over the last three years, a diagnosis was applied to analyze the current state of the teaching-learning process of this subject.

Figure 1 shows the results of the survey applied to students, where it is evident that 51% of respondents consider that representing functions in Calculus I subject is necessary for the major, for their academic progress, and has applications in other studies. However, 49% do not consider it relevant to their professional profile.

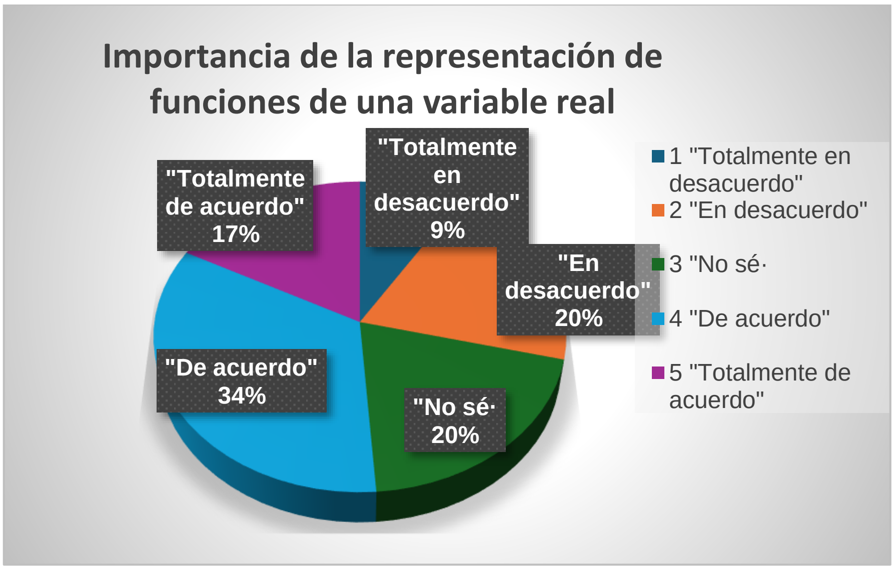

Figure 1: Student perception of the importance of representing functions of a real variable

Furthermore, Figure 2 shows that 54% of students feel satisfied with learning about functions of a real variable, based on their correct representation, determination of their properties, and explanation of processes through specific functions in the geological field. Nevertheless, 46% report no degree of satisfaction with how learning is managed.

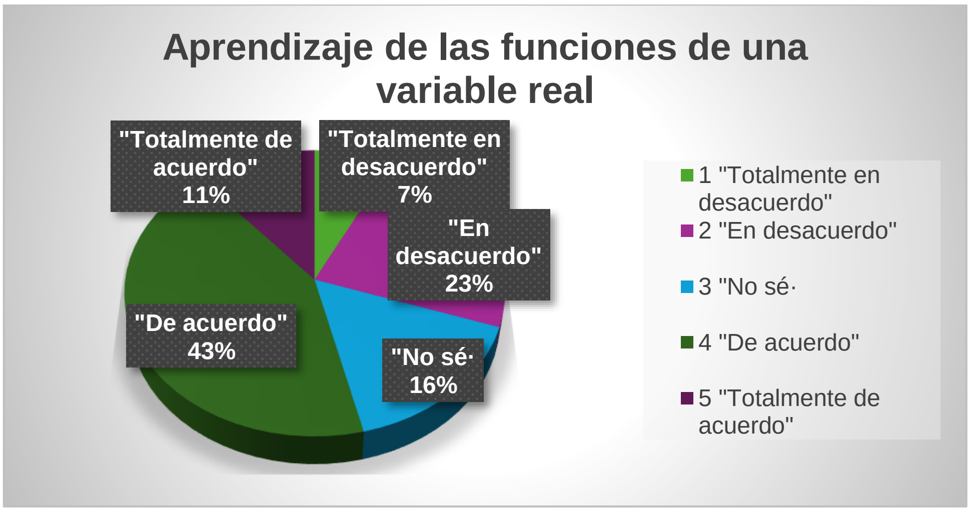

Figure 2: Student perception of learning about functions of a real variable

Academic Performance

Figure 3 shows how the average final grade varied over the five years of the study, with values of 3.59, 3.67, 3.15, 3.63, and 4.15, respectively. There was an increase from 2020 to 2021, a decrease from 2021 to 2022, and gradual growth from 2022 to 2023 and from 2023 to 2024, showing the last year the best results.

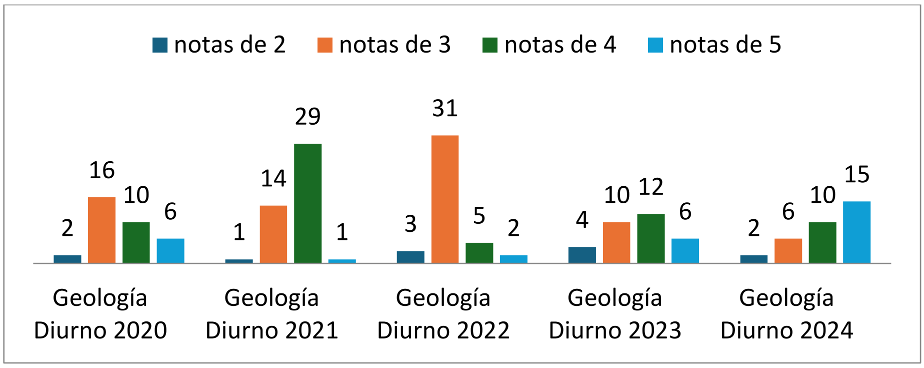

Figure 3. Student grades for the period 2020-2024.

Definition and structure of the proposed didactic strategy

The proposed didactic strategy contributes to students' preparation and fosters their participation in social development. Furthermore, it bases its foundations on developmental learning and allows students to appropriate content and the system of skills useful for function representation.

According to Sepúlveda and Véliz (2013), the didactic strategy is conceived as the structure of activity through which objectives and contents become real. Parra and Paucar (2019) and Rodríguez (2021) argue that they are sequenced, ordered, and planned activities to provide flexibility and adaptability in understanding specific topics.

In addition to being described as a set of sequential and interrelated actions, as posited by Torres, Suárez, and Ocampo (2017), a didactic strategy is a guide for action aimed at obtaining the results intended to be achieved through the learning process, giving meaning and coordination to everything done to advance student development. It has three important moments: opening, procedure, and closure.

These stages begin with problem definition and the regulation of bibliographic sources, and move through teaching methods and learning assessment strategies (Arteaga, Meneses, & Luna, 2015).

DISCUSSION

Didactic strategy for teaching Calculus I subject in the Geological Engineering major

The didactic strategy has three phases: initial, development, and final. Its design is intended for the full-time course Geological Engineering major and addresses Topic I of the Calculus I subject.

Initial phase: this initially involves a preparatory stage based on a diagnosis of basic skills in working with functions from previous education. This work is complemented by a two-week propaedeutic course, where students systematize the general forms for defining functions and handling basic properties through algebraic functions.

The professor promotes cooperative work by creating groups whose mission is to critically examine individual learning and evolve toward collective forms of solving posed problems.

What does the professor do?

- ✓ Develops or selects already-created problematic situations that allow developing the competencies outlined in the course syllabus.
- ✓ Defines the problematic situations that lead to modeling functions of a real variable and, consequently, to the need for their graphical representation.
- ✓ Defines and systematizes work groups to generate interactions beneficial to meaningful learning.
- ✓ Diagnoses mastery of working with basic algebraic-type functions and their main properties.

What do the students do?

- ✓ Must specify the graphical representation of the different real variable functions studied.
- ✓ Consolidate problem-solving strategies applicable to Geological Engineering.

Development phase: five theoretical activities are proposed (trigonometric functions, exponential and logarithmic functions, inverse functions, limit theory, continuity). Additionally, two integrative practical classes and three laboratory classes are proposed for the computational solution of the presented problems and to support decision-making.

What does the professor do?

- ✓ Establishes work rules and roles after group formation, ensuring they are clear and shared by all members.
- ✓ Monitors group work, considering the different stages they must complete.
- ✓ Defines ten activities involving theory, practice, and learning control based on the graphical representation of functions of a real variable, mediated by a computational approach.

What does the student do?

- ✓ Reads and analyzes the scenario or problematic situation. Identifies expected learning outcomes and recognizes what they know and do not know in relation to the problem.
- ✓ During solution execution, reproduces graphical situations shown by the professor.
- ✓ Creates new forms based on new problems where knowledge construction by analogy is applied.

- ✓ Reinforces mathematical modeling by understanding notable points of functions.
- ✓ Performs an initial approach to the problem solution in the form of a work algorithm.
- ✓ Presents results and examines their ability to respond to the posed problem and integrate learning.

Final phase: the levels of evaluation are consolidated, favoring individual, small-group, and collective assessment.

What does the professor do?

- ✓ Organizes the presentation of problem solutions that different groups must present to moderate the discussion.
- ✓ Verifies the practical skills developed during graphical representation of functions, ensuring that students produce a complete graphical product capable of characterizing all aspects of a model based on functions of a real variable.
- ✓ Evaluates the progress of groups and individual students at different times or regular intervals.

What does the student do?

- ✓ Develops feedback processes that lead them to consider new hypotheses for solving the posed problems.
- ✓ Provides feedback on group work through their individual performance, enhancing collaborative work and interaction with the engineering world and its real applications.

- ✓ Develops skills such as self-assessment, peer-assessment, and hetero-assessment, thereby reflecting on their own performance and acquired learning, promoting a critical and self-evaluative view of their educational experience.

Assuming the position of Arteaga, Meneses, and Luna (2015), the implementation of didactic strategies requires an organized, staged process where the system of content and skills manifests gradually, with increasing meaningfulness, becoming an effective training tool, providing action plans to improve the teaching-learning process.

At the time of this proposal, the subject’s analytical syllabus allocated a time fund of 20 hours for Topic I (Real Functions of a Real Variable), distributed as 4 hours for theoretical activities, 14 for practical activities, and 2 for seminars.

The solution proposed in this research promotes five theoretical activities to present the knowledge system, followed by two integrative practical activities to enhance problem-solving related to the geological profile, and three laboratory classes to integrate analytical and approximate solutions, aiming to fulfill the formative objectives of the year and the program.

The appropriate didactic treatment of each category of the teaching-learning process positioned the proposed didactic strategy as a viable alternative for fostering meaningful learning.

An evaluation of the proposed strategy for applying the Problem-Based Learning method in Calculus I subject for Geological Engineering major at UMoa was conducted, where the opinions of those involved was taking into account: tutors, professors, and specialists.

Five professors from the referred major participated in the socialization workshop, holding academic ranks of Associate Professor and Full Professor, as well as five professors from the Mathematics Department, three of whom hold a Master’s degree and one a Doctor of Sciences. These professors also hold higher academic ranks.

The workshop participants considered that the activities contribute to:

- ✓ Adequate didactic orientation of student work, thereby fostering better learning acquisition of Calculus I content, especially the representation of functions of a real variable.

- ✓ Adequate linking of the content learned by students with the activities and occupations they will have according to the major profile.

- ✓ The development of actions favoring the transition from theoretical appropriation of knowledge to practical application through solving professional problems.

- ✓ Deepening modeling skills, as a result of mathematical competence derived from representing functions of a real variable and their application in interacting with the real physical world.

The proposed didactic strategy aligns with current trends in higher education, which promote active learning, knowledge contextualization, and the development of 21st-century skills. The results suggest that PBL can be an effective tool to overcome the identified difficulties in teaching Calculus I subject in the Geological Engineering major at UMoa.

The implemented didactic strategy based on PBL positively impacts the teaching-learning process of Calculus I subject, resulting in:

- ✓ Improved understanding of subject concepts.

- ✓ Increased motivation and interest in the subject.

- ✓ Development of critical thinking and problem-solving skills.

- ✓ Greater capacity for mathematical modeling of geological phenomena.

CONCLUSIONS

The didactic strategy based on PBL demonstrates significant potential to improve the teaching-learning process of Calculus I subject in the Geological Engineering major at UMoa. Its implementation and evaluation validate its effectiveness and contribute to improving the training of future geological engineers.

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