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# MATHEMATICAL KNOWLEDGE AND ITS RELATIONSHIP WITH THE PROFESSIONAL TRAINING OF ENGINEERING STUDENTS IN COLOMBIA.

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**Abstract**
This article presents an analysis of basic mathematical knowledge and its relationship to the professional training of engineering students. The study was planned through a mixed approach, using a task-based interview strategy. Through the application of a diagnostic test, results were obtained from which difficulties and errors in basic mathematical concepts and procedures were evident. The results highlight the challenges to be assumed in the incorporation of mathematics teaching and learning methodologies, since weaknesses in mathematical competencies become a factor that promotes student desertion.

**Keywords:** Mathematical knowledge, engineering students, mathematical competencies.

## 1. Introduction

This paper presents an analysis of the results obtained from a diagnostic test applied to first-year students of a Colombian engineering school that consists of questions on basic mathematical knowledge. The results show the difficulties and errors in basic mathematical concepts and procedures. This factor promotes student desertion because of low academic performance.

To generate didactic and pedagogical alternatives to minimize the high percentages of repetition in courses such as Differential Calculus, Integral Calculus and Vectorial Calculus, it is important to know the conceptual origin of the errors, as an input for decision making, and to enable continuous improvement in this aspect. Considering that, from the activation of previous knowledge, students have the opportunity to connect new knowledge with previous knowledge and thus advance in the levels of knowledge and skills necessary in the initial training of the engineer.

The pertinence of the present study lies in the importance of mastering mathematics for a future engineer, in line with Rodriguez (2017), who documented the problem of training engineering professionals from a mathematics education perspective. This author highlights the negative impact of a lack of mathematical competencies on the decrease in graduates in engineering programs.

Mathematical competencies are an indispensable tool for developing skills in modeling, solving complex problems, designing safe and efficient structures, innovation, and the development of new technologies. Engineers can analyze data, identify patterns, and make informed decisions to optimize

their designs using equations, algorithms, and statistical techniques. This also supports an effective communication. This implies changes from traditional teaching practices to dynamic methodologies in the STEM approach, the advances of which have been reported in engineering education (Rodriguez, 2017).

The University of Sucre is located in the Caribbean Region, and is immersed in a socioeconomic context with high levels of poverty. Thus, in the Faculty of Engineering, students enter conditions of vulnerability, a fact that is directly related to the limited access to quality education, especially related to the learning of mathematics. As a result, the case of students from rural schools is latent, which presents greater gaps in the mastery of basic mathematical pre-knowledge, which motivated the present problem question: What basic mathematical knowledge do first-year students of the Faculty of Engineering possess and what relationship do they have with their professional training?

## 2. Theoretical Framework

### 2.1 An at-risk student

An at-risk student is "one who is in danger of not completing his or her education with an adequate level of skills (Slavin and Madden (1989); cited in Prediger et al.,2023). These authors include the risk factors of low achievement, grade retention, behavioral problems, and poor attendance. Three decades later, large-scale assessments still showed a high prevalence of students reaching a risky proficiency level (OECD, 2016). On the other hand, all student learning progressions should cover both conceptual understanding and procedural skills, for both current topics and foundations from previous years (Rojas & Chacon, 2023; Rojas, 2023; Prediger et al.,2023).

Conceptualize teacher expertise to build the capacity of at-risk students' understanding of basic concepts. To present our conceptual model of teacher expertise in building the capacity of at-risk students.

### 2.2 Mathematical competencies

The curricular guidelines proposed by the Colombian Ministry of National Education (MEN, 1998) propose the development of competencies and conceptualization by students as necessary elements to face current challenges, such as the complexity of life and work. Likewise, Basic Competency Standards (MEN, 2006) distinguish two basic types of mathematical knowledge: conceptual knowledge and procedural knowledge. These two types of knowledge point to new guidelines to approach a robust interpretation of the concept of being mathematically competent. This integrating notion of competence is related to knowing what to do and knowing how, when, and why to do it (MEN, 2006).

### 2.3 Conceptual knowledge

It is close to reflection; it is characterized as theoretical knowledge obtained through the production of cognitive activity, very rich in relations among its components, and with other knowledge. It has a declarative character and is associated with knowing what and why (MEN, 2006, p.50).

### 2.4 Procedural knowledge

Procedural knowledge is closer to action and is related to the techniques and strategies to represent concepts and to transform such representations, to the abilities and skills to elaborate, compare, and exercise algorithms, and to argue convincingly. Procedural knowledge helps in the construction and refinement of conceptual knowledge and allows the effective, flexible, and in-context use of mathematical concepts, propositions, theories, and models; therefore, it is associated with knowing how.

### 2.5 General processes of mathematical activity

These correspond to the general processes present in all mathematical activities that make explicit what it means to be mathematically competent. The Curricular Guidelines propose five processes:

formulating and solving problems; modeling processes and phenomena of reality; communicating, reasoning, and formulating, comparing, and exercising procedures and algorithms.

## 3. Methodology

The study is framed within a mixed approach, which, according to Hernández and Sampieri (2014), is a continuous process in which quantitative and qualitative approaches are mixed, and the present study focuses more on the qualitative approach. A task-based interview strategy was followed (Camargo 2021). In the second academic period of 2022 and in the first period of 2023, a diagnostic test was conducted to determine the level of competencies in mathematics that first-time students of engineering faculty programs have, based on the minimum mathematics standards established by the MEN. The test evaluates operations using real numbers, percentages, algebraic expressions, remarkable products, and linear equations.

### 3.1 Methodology for the collection of information

The research has the following phases: the elaboration of the test, for which the experience of the teachers who have developed the Differential Calculus subject and some components of the curricular standards for Mathematics of the MEN were considered, the diagnostic test was applied to a sample of 64 students in 2022 and 134 in 2023.

Analyzing the grade history of the engineering programs, it was observed that Differential, Integral and Vectorial Calculus courses have the highest failure rate, which in the first three semesters may lead students to drop out or to continue their academic career with high grade repetition, which translates into more years before graduation.

### 3.2 Evaluation Criteria

The diagnostic test was graded based on the following criteria:
Low level: score less than 3.0
Basic level: score greater than or equal to 3.0 and less than 4.0.
High level: Rating greater than or equal to 4.0 and less than or equal to 4.5.
Higher level: Rating greater than or equal to 4.5

## 4. Results

### 4.1 Analysis of results

The analysis was performed based on theoretical elements of frequent errors (Del Puerto et al., 2006; Gamboa et al., 2019; Messina et al., 2018). The results obtained confirm the deficiencies, difficulties, and errors that the incoming students of the Faculty of Engineering have emphasized in the elementary level that each question formulated in the diagnostic test had. It was observed that students entered with a high percentage of apparent learning, without significant content. It was confirmed that the proportion of errors committed was high in what we call "typical errors." The following is a description of the most frequent errors specific to the test.

**Item 1.** Given that $(a+b)^2 = a^2 + 2ab + b^2$. Then $(5x+3y)^2$ giving 4 answer choices the two answers with the highest frequency was: $25x^2 + 9y^2$ and $5x^2 + 3y^2$ evidencing a linearity error and a linearity error combined with an error due to lack of prior knowledge, by omitting to raise the number 5 and the number 3 squared.
**Item 2.** The result of -4-3 is: the answer with the highest frequency was 7, which is presumed by the sign of the answer that the student assumes the law of signs for multiplication, that is to say $(-) * (-) = +$, but at the same time performs an addition and not a multiplication, when what he should really do is a sum of two negative integers.
**Item 3.** Solve -5x=20. For this item, 80% of students adhered to the answers shown in Figure 1

| | |
|---|---|
| $x = 20 + 5$<br>$x = 25$ | $x = \frac{20}{5} = 4$ |

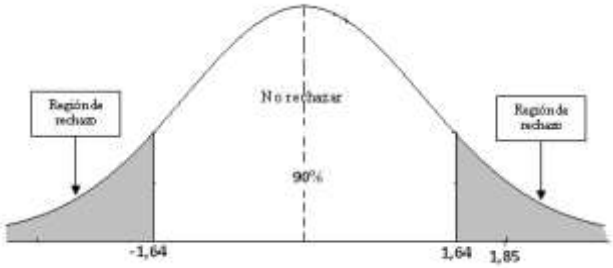
**Figure 1.** Incorrect answers from students.

### 4.2 Comparison of results in two terms

With a 90% confidence level, it was estimated that there was a significant difference between the average grade of the students who entered the second period of 2022 (average grade 2.32) and the average grade of the students who entered the first period of 2024 (average grade 2.04) (see Figure 2).

Likewise, the results show an 11% increase in the percentage of students entering areas with a low level of mathematical knowledge between the second and first periods of 2022 and 2023, respectively. The basic level decreased by 7%, the high level decreased by 5%, and the higher level experienced a slight increase of 1% (see Figure 3).

**Figure 2.** Difference in means



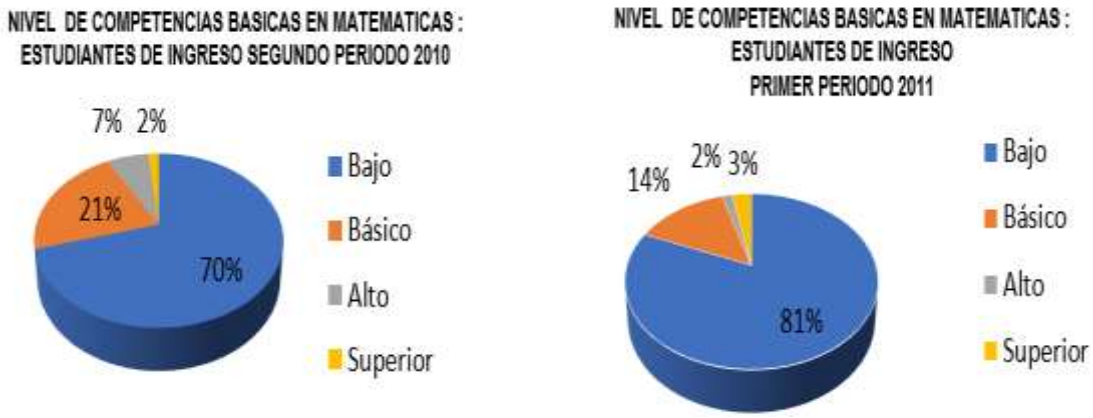




**Figura 1.** Estadística descriptiva del nivel de conocimientos matemáticos de estudiantes de primer ingreso de la Facultad de Ingeniería.

## 5. Conclusions

The results obtained inform about the deficiencies and difficulties that first-entry students of the Faculty of Engineering have, considering the elementary level of the applied test. In the classification of the results of the test, an increase in the percentage of low level in basic mathematical competencies is evidenced, which implies that the tendency is that students entering university in the future will have a low level of these competencies, so the implementation of strategies that improve the level of competence in this area of knowledge is required. The challenges in the professional training of engineers in Colombia are highlighted, as from the perspective of learning outcomes (MEN, 2022), the educational process must meet the needs of each student to help them achieve the declared graduation profile.

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