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BETWEEN SINES AND COSINES: AN X-RAY OF UNIVERSITY ADMISSIONS

ENTRE SENOS E COSSENOS: UMA RADIOGRAFIA DAS ADMISSÕES UNIVERSITÁRIAS

ENTRE SENOS Y COSENOS: RADIOGRAFÍA DEL INGRESO UNIVERSITARIO

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ABSTRACT

The purpose of this study is to describe the prior knowledge of trigonometry among students entering higher education in basic sciences and engineering. A diagnostic test was administered to 21 students at the Autonomous University of Nayarit, using a 10-item instrument that assessed fundamental concepts: radians, conversion of angular units, trigonometric ratios, trigonometric functions, the Pythagorean theorem, and trigonometric identities. The results reveal significant deficiencies in the mastery of trigonometric content essential for academic performance in exact sciences and engineering careers. The average percentage of correct answers was 48.6%, with particular weakness in converting degrees to radians (38.1% correct), applied trigonometric ratios (38.1%), trigonometric functions (38.1%), and the Pythagorean theorem (38.1%). These findings highlight the need to implement academic leveling strategies that strengthen basic mathematical skills prior to the start of higher-level courses, thus ensuring better academic trajectories and reducing failure and dropout rates.

Keywords: Trigonometry. Diagnosis. Higher Education. Engineering.

RESUMO

O objetivo deste estudo é descrever o conhecimento prévio de trigonometria entre alunos que ingressam no ensino superior em ciências básicas e engenharia. Um teste diagnóstico foi administrado a 21 alunos da Universidade Autônoma de Nayarit, usando um instrumento de 10 itens que avaliou conceitos fundamentais: radianos, conversão de unidades angulares, razões trigonométricas, funções trigonométricas, teorema de Pitágoras e identidades trigonométricas. Os resultados revelam deficiências significativas no domínio do conteúdo trigonométrico essencial para o desempenho acadêmico em ciências exatas e carreiras de engenharia. A porcentagem média de respostas corretas foi de 48,6%, com fraqueza particular na conversão de graus para radianos (38,1% corretos), razões trigonométricas aplicadas (38,1%), funções trigonométricas (38,1%) e teorema de Pitágoras (38,1%). Essas descobertas destacam a necessidade de implementar estratégias de nivelamento

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acadêmico que fortaleçam as habilidades matemáticas básicas antes do início dos cursos de nível superior, garantindo assim melhores trajetórias acadêmicas e reduzindo as taxas de reprovação e evasão.

Palavras-chave: Trigonometria. Diagnóstico. Ensino Superior. Engenharia.

RESUMEN
El presente estudio tiene como propósito describir los conocimientos previos en trigonometría de estudiantes que ingresaron a nivel superior en Ciencias Básicas e Ingenierías. Se aplicó un examen diagnóstico a 21 estudiantes de la Universidad Autónoma de Nayarit, mediante un instrumento de 10 ítems que evaluó conceptos fundamentales: radianes, conversión de unidades angulares, razones trigonométricas, funciones trigonométricas, teorema de Pitágoras e identidades trigonométricas. Los resultados revelan deficiencias significativas en el dominio de contenidos trigonométricos esenciales para el desempeño académico en carreras de ciencias exactas e ingenierías. El porcentaje promedio de respuestas correctas fue del 48.6%, con particular debilidad en conversión de grados a radianes (38.1% de aciertos), razones trigonométricas aplicadas (38.1%), funciones trigonométricas (38.1%) y teorema de Pitágoras (38.1%). Estos hallazgos evidencian la necesidad de implementar estrategias de nivelación académica que fortalezcan las competencias matemáticas básicas previo al inicio de cursos superiores, garantizando así mejores trayectorias académicas y reduciendo índices de reprobación y deserción.

Palabras clave: Trigonometría. Diagnóstico. Educación Superior. Ingeniería.

1 INTRODUCTION

Entering university education represents a crucial moment in the academic trajectory of students, especially in the areas of Basic Sciences and Engineering, where mathematics is an essential foundation of the curriculum (Artigue, 2004). Within mathematics, trigonometry offers the essential conceptual and procedural bases for the study of subjects such as calculus, physics, and analytical geometry, among others (Bressoud et al., 2015). However, several studies have shown recurrent deficiencies in the mastery of these contents by students who start careers in exact sciences and engineering.

The research problem addressed by this work focuses on identifying the level of trigonometric knowledge with which students enter the academic programs of the Academic Unit of Basic Sciences and Engineering, recognizing that these deficiencies constitute a risk factor for academic failure, recurrent failure and, eventually, school dropout (Cabrera et al., 2006). Mathematics, and specifically trigonometry, functions as a "filter" that largely determines the chances of academic success in scientific-technological careers (Ma & Johnson, 2008).

The relevance of this study lies in the fact that it allows the identification of specific areas of weakness in trigonometric knowledge, providing valuable information for the design of pedagogical intervention strategies, preparatory courses, or leveling programs that strengthen the mathematical competencies necessary for successful performance at the higher level (Faulkner et al., 2013). Academic diagnoses in mathematics are essential to understand the characteristics of students entering university and to design relevant strategies for academic accompaniment (Castillo Márquez et al., 2025). In addition, this work contributes to the body of knowledge on the challenges of educational transition in the Latin American context, specifically in Mexico.

From the theoretical framework of mathematical knowledge for teaching proposed by Ball et al. (2008), trigonometry requires not only the procedural mastery of formulas and algorithms, but also the deep conceptual understanding of the relationships between angles, functions and their graphical representations. Significant learning of trigonometry, according to Ausubel (2002), requires the existence of solid prior knowledge and the ability to establish connections between geometric, algebraic and analytical concepts. Difficulties in trigonometry are often related to the transition from geometric to analytical-functional thinking, as well as to the understanding of the multiple representations of trigonometric concepts (Kendal & Stacey, 1997).

Various studies have documented the difficulties faced by students with trigonometric content. Weber (2005) identified that many college students have difficulty connecting geometric definitions of trigonometric functions with their analytic representations.

Martín-Fernández et al. (2016) found that students present persistent confusions in understanding the school meaning of elementary trigonometric reasons, as well as difficulties in establishing connections between different representations of trigonometric concepts. In the Latin American context, studies such as that of Martínez-Planell and Gaisman (2012) have shown that deficiencies in trigonometry significantly affect performance in differential and integral calculus. This work provides specific empirical evidence on the areas of greatest weakness in the trigonometric knowledge of Mexican students entering scientific-technological careers.

The context of this research is the Autonomous University of Nayarit, a public institution located in the state of Nayarit, Mexico, which receives students from various subsystems of upper secondary education with different curricula. This diversity in previous training represents a challenge to guarantee equitable conditions for the start of academic programs in science and engineering, where mathematics plays a fundamental role from the first semester.

The objective of this research is to describe the main results obtained when applying a diagnostic examination of trigonometry topics: radians, conversion of degrees to radians, trigonometric ratios, trigonometric functions, Pythagorean theorem and trigonometric identities to students who entered the Academic Unit of Basic Sciences and Engineering at a higher level, in order to identify the areas of knowledge that require further reinforcement.

2 METHODOLOGY

The present research adopted a quantitative descriptive-diagnostic approach, aimed at characterizing the level of trigonometric knowledge of students new to careers in Basic Sciences and Engineering. The design was non-experimental, cross-sectional, performing a single measurement at the time of university admission.

According to Hernández Sampieri (2018), the quantitative approach is characterized by the measurement and collection of numerical data through standardized instruments, seeking objectivity and precision in the analysis. Likewise, the cross-sectional non-experimental design refers to the collection of data at a single time point without manipulation

of variables, with the purpose of describing and analyzing the variables in their natural context at the time of the study"

The study population was made up of new students entering the academic programs of Basic Sciences and Engineering of the Autonomous University of Nayarit during the corresponding school year. We worked with a non-probabilistic convenience sample of 21 students who were in their first semester in these areas. The inclusion criterion was to be enrolled in a Basic Sciences or Engineering program of the institution; no exclusion criteria were established.

As a data collection technique, evaluation was used by means of a diagnostic test designed specifically for this study. The instrument consisted of 10 items that evaluated fundamental knowledge of trigonometry distributed in the following conceptual categories: radians and their meaning, conversion of sexagesimal degrees to radians, trigonometric ratios in right triangles, trigonometric functions and their properties, application of the Pythagorean theorem, and basic trigonometric identities. Each item allowed three possible outcomes: correct answer, incorrect answer or no answer.

The exam was administered in the first week of class at the beginning of the semester, before taking any mathematics subject at a higher level, with the purpose of obtaining a real measurement of prior knowledge without the intervention of university learning. The application was face-to-face, with a certain time for its resolution, and under standardized conditions for all participants.

For data analysis, descriptive statistics were used, calculating absolute frequencies of correct, incorrect and unanswered answers for each item. Subsequently, performance percentages were determined by item and the general average of correct answers of the group. This information made it possible to identify the thematic areas with the greatest weakness.

Among the ethical considerations of the study was the confidentiality of the individual data of the participants, using the information exclusively for the purposes of academic diagnosis and educational research. The students were informed about the purpose of the exam and its diagnostic nature, without repercussions on official grades.

One limitation of the study is the small sample size, which prevents generalizing the results to broader populations. However, the findings provide valuable information on trends in trigonometric knowledge of this specific group and can guide institutional interventions of academic leveling.

3 RESULTS AND DISCUSSION

The results of the trigonometry diagnostic exam applied to 21 new students at the Academic Unit of Basic Sciences and Engineering reveal a somewhat worrying panorama regarding the mastery of fundamental contents for successful academic performance in these disciplinary areas.

Global performance analysis:

The analysis of absolute frequencies shows that, of the total of 210 expected answers (21 students for 10 items), 101 correct, 89 incorrect and 20 unanswered answers were obtained. This represents an average percentage of correct answers of 48.6%, which indicates that, in general, students barely reach half of the trigonometric knowledge evaluated. This finding is consistent with what was reported by Weber (2005) and Fi (2003), who documented persistent deficiencies in the understanding of trigonometric concepts among students entering university.

Analysis by item:

Table 1 presents the detailed results for each item of the diagnostic test.

Table 1

Absolute frequencies and percentages of responses by item

Item	Correct	% Correct	Wrong	% Incorrect	He didn't answer	% did not answer
1	14	66.7%	6	28.6%	1	4.8%
2	8	38.1%	12	57.1%	1	4.8%
3	12	57.1%	7	33.3%	2	9.5%
4	8	38.1%	10	47.6%	3	14.3%
5	11	52.4%	7	33.3%	3	14.3%
6	10	47.6%	8	38.1%	3	14.3%
7	10	47.6%	9	42.9%	2	9.5%
8	10	47.6%	10	47.6%	1	4.8%

Item	Correct	% Correct	Wrong	% Incorrect	He didn't answer	% did not answer
9	8	38.1%	12	57.1%	1	4.8%
10	10	47.6%	8	38.1%	3	14.3%

Source: Authors.

In Table No.1, it can be seen that item 1 presented the best performance with 66.7% of correct answers, suggesting that students are relatively familiar with this basic concept, referring to the trigonometric sine ratio. However, even this better result indicates that one in three students are not proficient in this foundational content.

Items 2, 4 and 9 showed the most deficient performance, with only 38.1% of correct answers each. These items probably evaluated the conversion of degrees to radians, the application of ratios and trigonometric functions, respectively. These findings coincide with what was reported by Kendal and Stacey (1997), who identified that the conversion between angular measurement systems and the understanding of trigonometric functions represent significant cognitive obstacles.

Items 3, 5, 6, 7, 8 and 10 showed intermediate performances, ranging between 47.6% and 57.1% of correct answers, which indicates that approximately half of the students do not master these contents. This pattern of results suggests widespread shortcomings in trigonometric knowledge, rather than weaknesses in specific isolated topics.

Analysis of unanswered answers:

A relevant aspect is the percentage of unanswered items, referring to (conversions of degrees to radians and trigonometric functions) that reaches its maximum in items 4, 5, 6 and 10 with 14.3% each. This absence of response can be interpreted as an indicator of total ignorance of the content or inability to address the problem posed (Martínez-Planell & Gaisman, 2012). The fact that some students prefer not to answer rather than attempt a solution suggests significant insecurity regarding their trigonometric knowledge.

Theoretical and practical implications:

From the perspective of significant learning proposed by Ausubel (2002), these results indicate that students lack the solid prior knowledge necessary to anchor new higher-level mathematical learning. Deficiencies detected in fundamental concepts such as radians,

ratios, and trigonometric functions compromise students' ability to understand more complex contents of calculus, physics, and other disciplines that require trigonometric mastery.

The theory of mathematical knowledge for teaching by Ball et al. (2008) suggests that these deficiencies are not only procedural but also conceptual. The low percentages of correct answers in items that evaluate application and relationship of concepts (items 2, 4, 9) compared to slightly better performance in more procedural items (item 1) support this interpretation.

These findings have important practical implications for the institution. The general average of 48.6% of correct answers indicates the need to implement leveling programs or preparatory courses in trigonometry before the formal start of higher mathematics subjects. As Cabrera et al. (2014) point out, mathematical deficiencies are significant predictors of failure and dropout in science and engineering careers. Diagnostic assessment is thus a fundamental tool for identifying students' specific needs and designing timely intervention strategies that promote successful academic trajectories (Castillo Márquez et al., 2025).

It is particularly worrying that more than 60% of students do not master concepts such as angular conversion and trigonometric functions (items 2, 4, 9), since these contents are essential requirements for differential and integral calculus. This situation configures a scenario of high academic risk for these students if timely interventions are not implemented.

The results also suggest the need to review the mathematics curriculum at the upper secondary level and strengthen the articulation between this educational level and the university, promoting agreements on minimum graduation standards in mathematical competencies, particularly in trigonometry.

Comparing these results with international studies, it is observed that deficiencies in trigonometry are not exclusive to the Mexican context. However, the level of performance observed in this study is particularly low, which merits priority attention from the institutional educational authorities.

The heterogeneity in performance between items suggests that not all students have the same areas of weakness, which supports the need for individualized diagnoses that allow the design of personalized academic leveling trajectories.

4 CONCLUSIONS

The results of this diagnostic study reveal significant deficiencies in the mastery of fundamental trigonometric knowledge among students entering the academic programs of

the Academic Unit of Basic Sciences and Engineering at the Autonomous University of Nayarit. With an overall average of only 48.6% of correct answers, it is evident that approximately half of the essential trigonometric contents are not mastered by new students, which constitutes a considerable academic risk factor.

The areas of greatest weakness identified correspond to the conversion of degrees to radians, application of trigonometric ratios in specific contexts and understanding of trigonometric functions, with success percentages of only 38.1%. These contents are fundamental pillars for subsequent subjects of calculus and physics, the lack of mastery compromises the chances of academic success in the university trajectories of these students.

These findings support the imperative need to implement institutional strategies for early intervention, such as mandatory preparatory courses, specialized tutoring programs in mathematics or leveling workshops before the formal start of semesters. The evidence presented provides valuable information for the design of these interventions, allowing efforts to be focused on the thematic areas that present the greatest shortcomings.

This study opens up multiple questions for future research. It would be valuable to explore the underlying causes of these deficiencies: Are they due to curricular weaknesses at the upper secondary level? To the heterogeneity in the previous training of students from different educational subsystems? Likewise, it would be very useful to carry out longitudinal studies that relate performance in this diagnosis with subsequent academic performance in basic science and engineering subjects, which would validate the predictive value of the instrument and strengthen evidence-based institutional decision-making.

Finally, other researchers in the field of mathematics education are invited to replicate this study in different contexts, expanding the samples and deepening the qualitative analysis of the specific conceptual errors made by students, in order to design more effective and pertinent pedagogical interventions that guarantee successful academic trajectories in the scientific-technological areas.

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