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Artículos científicos

Impacto de un curso propedéutico en las competencias matemáticas de estudiantes de nuevo ingreso de licenciatura del TecMM campus Puerto Vallarta

Impact of a propaedeutic course on mathematical competencies in new college students of the TecMM Puerto Vallarta Campus

Impacto de um curso preparatório nas competências matemáticas de novos alunos de graduação no campus da TecMM em Puerto Vallarta

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Resumen

Las universidades imparten un componente formativo de matemáticas, el cual puede ser básico o complejo dependiendo del área de estudios (las ingenierías llevan por lo general una formación más enfocada al desarrollo de estas competencias). Una problemática que se presenta en las instituciones de educación superior es el alto índice de reprobación en matemáticas (con implicaciones en la deserción), lo cual se debe a que los estudiantes ingresan sin contar con las competencias esperadas de los niveles formativos previos. Por eso, el objetivo del presente trabajo fue determinar el impacto de un curso remedial diseñado por la coordinación de ciencias básicas del Instituto José Mario Molina, Pasquel y Henríquez, campus Puerto Vallarta (TecMM), en la formación de competencias matemáticas en estudiantes de nuevo ingreso. Para ello, se utilizó un cuestionario diagnóstico con temas de aritmética y álgebra, el cuál se aplicó mediante un formulario web antes y después del curso remedial a 134 estudiantes. Asimismo, se utilizó una prueba Z dependiente de muestras pareadas para determinar el nivel de significancia en la diferencia de las dos mediciones. Los resultados fueron sometidos a una prueba de hipótesis estadística mediante la cual se demostró que la implementación del curso remedial fue funcional. Se concluye, por tanto, que esta es una estrategia útil de nivelación para estudiantes de nuevo ingreso.

Palabras clave: competencias matemáticas, curso propedéutico, educación superior, estrategia, reprobación.

Abstract

Universities teach a training component in mathematics, which can be from a basic level to a more complex one, depending on the area of study (engineering generally has training more focused on the development of these competencies), a problem that occurs in the college institutions is the high rate of failure in mathematics (with implications for dropout), because students enter without having the skills expected from previous educational levels. The purpose of this work was to determine the impact of a remedial course designed by the basic sciences coordination of the José Mario Molina, Pasquel y Henríquez Institute, Puerto Vallarta campus (TecMM) in the formation of mathematical competencies in new students. To develop the study it was used a diagnostic test with arithmetic and algebra topics which was applied through a Web form before and after the remedial course to 134 students, and a dependent Z test for paired samples was used to determine the level of significance in the

difference of the two measurements. The results show a significant improvement after the implementation of the course, concluding that this is a useful leveling strategy for new students.

Keywords: mathematical competences, propaedeutic course, college education, strategy, failure.

Resumo

As universidades ensinam uma componente de formação em matemática, que pode ser básica ou complexa dependendo da área de estudo (a engenharia geralmente requer uma formação mais focada no desenvolvimento destas competências). Um problema que ocorre nas instituições de ensino superior é a elevada taxa de reprovação em matemática (com implicações para a evasão), que se deve ao facto de os alunos ingressarem sem possuir as competências esperadas dos níveis de formação anteriores. Portanto, o objetivo deste trabalho foi determinar o impacto de um curso corretivo elaborado pela coordenação de ciências básicas do Instituto José Mario Molina, Pasquel e Henríquez, campus Puerto Vallarta (TecMM), na formação de competências matemáticas nos alunos novamente entrada. Para isso, foi utilizado um questionário diagnóstico com tópicos de aritmética e álgebra, o qual foi aplicado por meio de um formulário web antes e depois do curso de reforço a 134 alunos. Da mesma forma, um teste Z dependente de amostras emparelhadas foi usado para determinar o nível de significância na diferença das duas medidas. Os resultados foram submetidos a um teste de hipótese estatística através do qual foi demonstrado que a implementação do curso corretivo foi funcional. Conclui-se, portanto, que esta é uma estratégia de nivelamento útil para novos alunos.

Palavras-chave: competências matemáticas, curso preparatório, ensino superior, estratégia, fracasso.

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Introduction

In Mexico, upper secondary education registers significant lags in various indicators, such as problems of low coverage and terminal efficiency, as well as high failure and dropout rates (Castro, Piñon and Avilés, 2015). These problems have an impact on students who enter a higher level (Gil and Pérez, 2013), who generally have deficiencies in some basic skills, including mathematics. This competence —according to García-Oliveros et al., (2020) - can be defined as "the insightful disposition to act in response to the mathematical challenges of a given situation and in the identification of the capacities that compose it: reasoning, representation, communication, symbolism-form, problem solving and modeling "(p. 252).

In Mexico, the Ministry of Public Education (SEP) applies the PLANEA standardized assessment to upper secondary education students who are in their last semester to determine the level of learning obtained in language and mathematics, which are categorized into four levels: level I corresponds to insufficient knowledge; level II to elementary knowledge; level III to satisfactory knowledge and level IV to outstanding knowledge.

In 2017, the results of Jalisco in mathematics were the following: 54.91% in level I, 26.54% in II, 12.4% in III and 6.15% in IV. On the other hand, at the national level they were located as follows: 66.2% in level I, 23.3% in II, 8% in III and 2.5% in IV (SEP, 2017).

With these results in the PLANEA tests (deficiencies mainly in mathematics), the prelude to a problem that occurs in higher education is identified; that is, a high percentage of new students do not have basic skills in mathematics and logical reasoning, which makes it difficult for them to successfully complete their university studies. On this reality, Zámková, Prokop and Stolín (2016) mention that universities are accepting students with disabilities because there are few eligible candidates. Furthermore, in a study with university students it was found that they consider regulating their handling of relevant prior knowledge (Martínez et al., 1998). The lack of prior knowledge expected in universities is worrisome due to the effect that may be generated in the future on the training quality of human resources (Gaete y Jiménez, 2011).

The investigation of the causes of failure in mathematics reveals factors of various kinds. In this regard, Martínez et al. (1998) categorize the factors into three: social, institutional and individual. Specifically, the authors found that previous competences, teacher and student performance, as well as the emotional aspect of the student, their vocation and the institutional infrastructure can influence failure in mathematics.

Authors such as Romero-Bojórquez, Utrilla-Quiroz and Utrilla-Quiroz (2014) explain that “there are experiential references, which provoke predispositions or attitudes that affect the incorporation of the student into the learning process, and in their academic achievement or failure” (p. 293). Others, in addition, believe that a person's attitude influences her learning, since this factor affects the cognitive, affective and behavioral aspects. On this, Vila and Rubio (2016) mention that “you learn better what produces the greatest pleasure, and an adequate education can improve students' attitudes towards a given subject” (p. 135). Likewise, Shena, Mielea and Vasilyeva (2016), on the persistence of students for learning mathematics, conclude that “the academic mentality of students influences their interpretation of their experiences of solving mathematical problems, as well as their persistence in solving subsequent problems ”(p. 51).

It is worth mentioning that cognitive capacity and attention skills are related to academic performance; Furthermore, the use of advanced strategies is associated with solving mathematical problems. Motivation therefore plays an important role. In this regard, Petriz et al. (2010) used an instrument to evaluate content and another to measure motivation, liking, anxiety, usefulness and confidence. Their conclusions indicate that “the students who showed greater motivation solved the more complex problems” (p. 1238). Also Vargas and Montero (2016) found that negative attitudes towards mathematics are related to a direct (negative) effect on academic performance.

In addition to all the above, it is worth noting that each student has a certain way of learning, hence it requires specific didactic strategies. Therefore, teacher planning is vitally important to generate positive emotional responses through teaching methodologies that facilitate learning processes (Yánez and Nevárez, 2018).

According to Posso (2005), "the teaching process must be adapted to the level of reasoning of the student" (p. 172), which is difficult in higher education classrooms in the area of mathematics due to deficiencies in knowledge previous (Vaca Haro and Estévez, 2017).

For this reason, the present work aimed to determine the impact of a remedial course designed by the coordination of basic sciences of the José Mario Molina, Pasquel and Henríquez Institute, Puerto Vallarta campus (TecMM), for the formation of mathematical competencies in students of new entry.

Materials and methods

This applied research had a quantitative approach, with correlational scope, through a quasi-experimental design with pre-test and post-test. For this, an inductive method was used. The unit of analysis was the TecMM, while the target population was new students. The students who applied the diagnostic test and a closing exam of the preparatory course were taken as a sample.

The variables involved were the preparatory course (independent variable) and mathematical skills (dependent variable).

Information collection instrument and methodological aspects

The instrument used was a questionnaire of mathematical problems that was applied in digital format using a web form as a pre-test (before the preparatory course) and later as a post-test (after the preparatory course) to identify the differences between the two results. This instrument consisted of two dimensions: arithmetic and algebra.

For the selection of the topics of the questionnaire and the contents of the preparatory course, the expected competencies of the upper secondary level were considered, and the prerequisites for the undergraduate subjects of the TecMM, Puerto Vallarta campus. The previous competences that students are required to take in order to take their first mathematics subject at the higher level (considering the different careers and subjects) are arithmetic operations, handle algebraic operations, handle identities and trigonometric ratios, and identify the geometric places of lines and conical.

Because the preparatory course lasts only 20 hours, it was decided to cover the bare minimum, that is, the basics of arithmetic and algebra. In academic meetings through collaborative work between teachers, the subtopics for arithmetic were selected: addition, subtraction, multiplication and division of fractions. In algebra the subtopics were addition, subtraction, multiplication and division of monomials, as well as division of polynomials, powers, roots, binomial squared, binomial cubed, common factor, factoring of a perfect square trinomial, factoring of subtraction of squares (conjugates), factorization of a subtraction or addition of cubes, factorization of the form $ax^2 + bx + c$.

The design of the instrument was prepared by the Head of Division and Coordination of Basic Sciences of the TecMM, with the support of teacher Master Álvaro Sánchez Navarrete. The validation of the problems or items of the questionnaire was carried out by

the Department of the Division of Basic Sciences, the Coordination and some mathematics teachers.

No pilot test was carried out with students, although the questionnaire was applied to academy teachers to review possible errors before its implementation. The questionnaire was applied to the students by the teachers of the Academy of Basic Sciences, from August 10 to 28, 2020 in the city of Puerto Vallarta, Jalisco, Mexico.

The administration of the instrument was done through a Google form shared to the students virtually through Whastapp, email and a link in Classroom, this due to the confinement measures due to the pandemic caused by SARS-CoV-2. This instrument was applied in the six careers that enter the TecMM: Business Management Engineering, Computer Systems Engineering, Electromechanical Engineering, Gastronomy, Architecture and Tourism. The pre and post evaluation contained the same items. The application was scheduled to run asynchronously for only one day for each assessment. Students were not notified that the same instrument would be applied at the end, and as a safety measure no results were shown to students at the end of the assessments.

The preparatory course was applied to all the students who carried out the evaluation at the beginning and at the end. The sample was made up as follows: 25 Architecture students, 19 Gastronomy, 20 Electromechanical engineering, 41 Business Management engineering, 14 Computer Systems engineering and 15 Tourism. The teachers who taught the course were provided with a guide prepared by professors from the Academy of Basic Sciences.

A novel element in the course was the use of technology, that is, the new learning and teaching strategies applied to the course, consisting of videos made by the teacher with the free ScreenCast software, as well as by other teachers, who could be consulted anytime. Likewise, videoconferences were held to clarify doubts or virtual classes when the student needed it, for which electronic whiteboards such as Idroo, OneNote, etc. were used.

The data obtained from the application of the instrument was exported to a Microsoft Office Excel 2007 spreadsheet for processing. With the information from the database, tables and graphs were generated and analyzed. Finally, to support the conclusions, a dependent Z test was applied for paired samples. In this way, the differences between the results before and after the remedial course were compared.

Results

In table 1 it can be seen that in the Computer Systems engineering career the highest results were obtained after the preparatory course, with an increase in the average of 25.1, followed by Gastronomy with 12.6, Tourism with 11, Architecture with 10.4, Electromechanical engineering with 10.3 and Business Management engineering with 0.2. It is appreciated that all the careers present significant differences between the previous and subsequent evaluation. This indicates that the academic level of the students was improved in the area of mathematics.

Tabla 1. Promedio de alumnos en la evaluación previa y posterior por carrera

Carrera	Previo	Posterior	Diferencia
Ingeniería en Sistemas Computacionales	59.38	84.44	25.1
Gastronomía	62.54	75.14	12.6
Turismo	63.64	74.64	11.0
Arquitectura	61.67	72.08	10.4
Ingeniería en Electromecánica	74.32	84.58	10.3
Ingeniería en Gestión Empresarial	67.98	68.18	0.2
Promedio	64.92	76.51	11.6

Fuente: Elaboración propia

Dependent Z test for paired samples

According to the central limit theorem, when the samples are large (n> 30), the distribution of their means is approximately normal; for this reason, a Z test is convenient to analyze the differences of the two measurements. The hypothesis test is carried out on differences between the averages of the evaluations before and after (after less prior) to the preparatory course that were calculated for each of the 134 students. It is dependent for paired samples because we have a previous and a subsequent evaluation result, that is, corresponding pairs. A hypothesis of a queue that uses the upper queue is proposed because if H0 is rejected, it

can be affirmed that the new method (teaching preparatory courses) is superior to the previous one (not teaching preparatory courses). The hypotheses raised are:

Null hypothesis

H0: The course had no impact on improving math skills prior to entering higher education.

Alternative hypothesis

H1: The course had an impact on improving math skills prior to entering higher education.

μ_d is the mean of the differences between the averages before and after the remedial course.

$H_0: \mu_d = 0$

The proposed null hypothesis is that the difference of the arithmetic mean before and after the course of all students is zero (that is, null). This would mean that there was no significant change; therefore, the remedial math course did not lead to any improvement in the students' math skills.

$H_1: \mu_d > 0$

The alternative hypothesis proposed is that the difference in the arithmetic mean before and after the course of all students is greater than zero (that is, there was an increase in the average), which would mean that a significant change was obtained. This would represent that the remedial mathematics course did cause improvement in the students' mathematics skills. For 95% confidence (that is, an alpha of 0.5) there is a critical value of:

$$z_{\propto} = z_{0.05} = 1.645$$

If the calculated value of Z is greater than the critical value, decision: H1 is accepted and H0 is rejected.

If the calculated value of Z is less than the critical value, decision: H1 is rejected and H0 is accepted.

There is an arithmetic mean of the differences equal to 11.6, a standard deviation of 20.14 and a sample size of 134 students, so the value calculated for Z is 6.67.

$$z = \frac{\bar{d} - d_0}{s_d/\sqrt{n}}$$

$$z = \frac{11.6}{20.14/\sqrt{134}} = 6.67$$

Consequently, H1 is accepted and H0 is rejected.

As

d_0 are the differences between the averages of the evaluation before and after the remedial course that were calculated for each of the 134 students.

S_d is the standard deviation.

n is the sample size.

$\bar{d}$ is the arithmetic mean of the differences.

According to the result of the hypothesis test carried out, it can be affirmed with 95% confidence that the preparatory course has a positive effect on improving mathematics skills in new students.

Table 2 shows that before the preparatory course, the grade was most frequently 75, and after the course it was 100. This indicates an improvement in the responses to the mathematics problems posed after receiving the preparatory course and, in consequently, an improvement in the academic level. The median prior to the course was 70, and the median after it was 81, which ends up confirming the same as the mode.

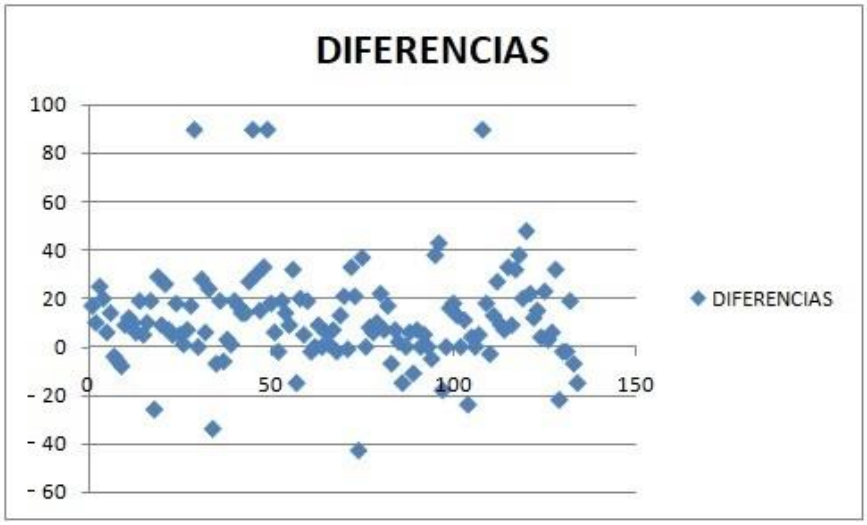
Tabla 2. Otros estadísticos

Otros estadísticos	Previo	Posterior
Moda	75	100
Mediana	70	81

Fuente: Elaboración propia

Figure 1 shows the scatter diagram of the differences in the averages before and after the preparatory course of the 134 students. If the difference is positive, it means that the student's average improved after the preparatory course. Most of the differences are greater than zero (that is, positive), which means a favorable result when implementing such a course.

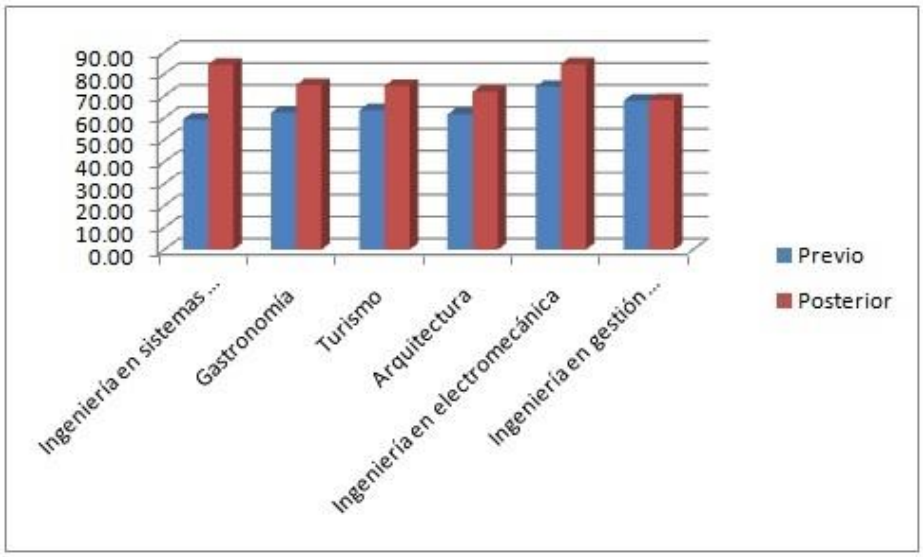
Figura 1. Diagrama de dispersión de las diferencias



Fuente: Elaboración propia

Figure 2 contains the averages before and after the preparatory course. An improvement is identified after the preparatory course taught in all careers. The career with the most notable improvement was Computer Systems, and the career where this difference was not so significant was in Business Management Engineering.

Figura 2. Gráfica de diferencia de promedios por carrera antes y después del curso propedéutico



Fuente: Elaboración propia

Table 3 shows the number of students approved before (69) and after (95) the preparatory course. Likewise, the percentage of approved before and after the course were 51.49% and 70.9%, respectively. For this, it was considered that the minimum passing grade in the institution where the research was carried out was 70. The increase in the percentage of approved students was close to 20%, which accounts for a significant increase in the previous and subsequent grades to the course.

Tabla 3. Alumnos aprobados

Previo	Posterior
69 alumnos	95 alumnos
51.49 %	70.9 %

Fuente: Elaboración propia

Discussion

Vaca Haro and Estévez (2017) identified the importance of the development of formal logical thinking (formal operations of Piaget's stages) as a criterion for developing meaningful learning in university students. These authors argue that students who only manage to develop previous stages in their mental development have difficulties in their academic performance in mathematics, which is congruent with the problem raised in this study, where a large number of students with documented low performance were identified in the PLANEA tests that may be related to a low level of cognitive development and difficulties in pursuing university studies, particularly in the area of mathematics.

On the other hand, Alting and Walser (2006) found that the good preparation in mathematics of new university students is a good predictor of the permanence in the institution. Also Ennis et al. (2013) identified a relationship between high math scores in high school and successful completion of Calculus I in college.

In addition, the low levels of performance in new university students have been documented in various studies and contexts (Aparicio, 2006; Ennis et al., 2013; Gaete and Jiménez, 2011; Martínez et al., 1998; Petriz et al. al., 2010; Posso, 2005; Zámková et al.,

2016), so it is relevant to design strategies that contribute to improving the mathematics skills of new students.

On the other hand, Aparicio (2006) described a problem of permanence and terminal efficiency at the Autonomous University of Yucatán related to deficiencies and lag in algebra and calculus subjects. This author explains that strategies such as preparatory courses or extracurricular workshops had not generated the desired results in the institutional indicators. Even so, the importance of the present study lies in the attempt to test the effectiveness of the preparatory course by analyzing, firstly, its effect on learning (comparison of the initial and final evaluations), and later verifying if this strategy would have a positive impact on the reduction of failure and dropout rates.

In similar studies, various strategies have been proposed to improve the level of mathematical competencies of students who are new to higher education. For example, Zámková et al. (2016) formulated a diagnostic test at the College of Polytechniques Jihlava (Czech Republic) to determine which students can enroll in regular mathematics courses and which require a previous course (mathematics seminar) to reinforce learning at the high school level . This methodology, according to its authors, has generated favorable results in the reduction of failure rates, although it is worth noting that it differs from the one offered in the present work because it was not applied to all new students, but to some previously chosen.

Another innovative strategy is the one implemented at the University of Colorado Boulder, consisting of a web system based on artificial intelligence for learning mathematics with two functions: one function to develop mathematics competencies and the other diagnostic to identify the levels of development of mathematics. students and predict their chances of success in different courses. This serves as a reference to plan a learning path for students and to determine who requires previous courses in the subjects of the study programs (Ennis et al., 2013).

For their part, Yánez and Nevárez (2018) used the free software eXe-Learning at the Pontificia Universidad Católica de Ecuador with new students as a complementary strategy to facilitate learning. The authors conclude that teaching didactics supported with this tool contributes to improving students' academic performance.

In summary, the aforementioned studies reveal options that have a favorable impact to level new students of higher education with respect to the expected learning of upper secondary education. In fact, two studies very similar to this one were documented: one

where it is noted that there were no positive results in a preparatory course (Aparicio, 2006) and another where a course prior to regular subjects has had a positive impact on institutional indicators (Zámková et al., 2016).

In short, the initial results of the preparatory course presented in this study are favorable in terms of the leveling of mathematical competencies. This is a strength of the research, which can be considered as a reference for the design of similar strategies; However, as a limitation, it remains to be analyzed whether the learning obtained will also have a favorable impact on the failure and dropout indicators, with tangible long-term results. To do this, the academic monitoring of the students who participated in this study must be carried out.

Conclusions

The high failure and dropout rates as a consequence of the academic lag in the area of mathematics demand the design of strategies to improve the academic level, as well as to reduce these statistics (failure and dropout). One of these strategies is the preparatory course that the TecMM carries out concentrating on arithmetic and algebra, which are evaluated through a previous and subsequent test, considering the expected competencies of the upper secondary level and the prerequisites of the undergraduate subjects. In this study, it was possible to conclude —through the application of the dependent Z test statistic for paired samples to compare the initial and final evaluation— that "the course had an impact on improving the previous deficiencies in mathematical knowledge in a significant way in new TecMM students with a confidence level of 95% ". Consequently, this strategy is considered valuable and useful, and may have a favorable impact on the institutional indicators of failure, desertion, and terminal efficiency, although in order to verify this, a follow-up is required to determine the impact of the remedial course on these indicators.

Future lines of research

In this research, a proposal was made to combat failure in higher-level mathematics. However, future research should delve into the causes of failure and desertion in higher-level institutions, as well as the learning and teaching strategies used to establish whether they should continue with them or if they should be changed or modified. The results of the

mathematics subjects that the students to whom this strategy was applied should also be reviewed in the future to observe the impact achieved in more detail.

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Software	No aplica
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Adquisición de fondos	No aplica