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Predictor Variables Of Academic Success In Mathematics Under A Binary Logistic Regression Model

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Abstract

In recent years, many investigations have been carried out to identify the different factors that influence academic achievement in mathematics. Although the list is extensive and diverse, this paper focuses on determining whether the affective domain, mathematical processes and pedagogical practices influence academic achievement in mathematics. The research considers a quantitative approach at a cross-sectional descriptive level. The sample consisted of 2,450 students from a Colombian department from fourth to eleventh grade (ages 8 to 20 years). The instrument was composed of 90 items that evaluated the affective domain, mathematical processes, pedagogical practices and academic performance, with responses on a five-level Likert scale. The independent variables considered were affective domain, mathematical processes and pedagogical practices, and the dependent variable was academic performance. The adjustment obtained resulted in a binary logistic model, where the categories considered were pass or fail, which allowed 95% of those who passed to be correctly classified, although, at a global level, its effectiveness was close to l 87%. It should be noted that none of the aspects associated with teachers' pedagogical competencies in their classroom work was significant in constructing the model.

Keywords: academic achievement in mathematics; affective domain; mathematical processes; pedagogical practices; binary logistic regression.

Introduction

Academic performance can be defined as the level of knowledge demonstrated in an area or subject, taking age and academic level as a reference (Jiménez, 1994). The average grade commonly measures in a given educational period (Tejedor, 1998; Edel, 2003). It reflects a student's knowledge of the area or subject under evaluation (Cascón, 2000) and the achievement of predefined objectives (Pita & Corengia, 2005). According to the research reviewed (Garbanzo, 2007; Artunduaga, 2008; Córdoba et al., 2011), there are several interrelated factors, both internal and external to the student, that affect this performance.

In particular, academic performance in mathematics should reflect not only the traditional learning of data and procedures but also the student's ability to manage this and other knowledge according to the demands of the environment. This conception is intended to form autonomous individuals capable of successfully facing problems of different natures as a result of learning mathematical knowledge useful for daily life. Thus, mathematical processes and competence should lead to the ability to use mathematics comprehensively and effectively in various contexts (Alsina, 2014a).

In the search for influential factors on mathematics achievement, some authors have analyzed cognitive factors such as attitudes toward mathematics and science (Preininger, 2017), self-concept (Chiu & Klassen, 2010; Niepel et al., 2014; Lee & Kung, 2017), and performance-related learning strategies (Biggs et al., 2001; Guo & Leung, 2021).

However, few papers jointly analyze the effects of sociocultural, cognitive, and behavioral factors. For example, the work of Pitsia et al. (2017) considered the extent to which students' beliefs in mathematics, motivation to learn mathematics, and attitudes toward school contributed to the prediction of their mathematics achievement, revealing that students' mathematics self-efficacy, anxiety, self-concept, instrumental motivation, and attitudes toward school were statistically significant predictors of their mathematics achievement, even after taking gender and by socioeconomic status as control variables.

Hann (2020) used a hierarchical linear model framework to predict mathematics achievement from three classroom variables, project-based learning, group collaboration, and student-driven curriculum, and two noncognitive factors, mathematics anxiety and self-concept. These findings suggest that mathematics classroom contexts that are student-driven and integrate project-based learning positively impact mathematics achievement and that mathematics anxiety and mathematics self-concept contribute significantly to explaining variation in mathematics achievement after accounting for gender, race, socioeconomic status, truancy, and school-level poverty.

Fernández-Cézar et al. (2021) considered that the student's affective, cognitive and behavioral variables could predict mathematics achievement. Thus, their work focused on determining to what extent self-concept, learning strategies, attitude towards science and mathematics, school environment, and previous grades in science and mathematics predict mathematics achievement. The application of a binary logistic regression model made it possible to identify predictors of mathematics achievement, science achievement, and critical and creative thinking and point out the positive impact of urban schools.

However, until now, the predictive capacity of the affective domain of the individual has not been studied jointly, on the one hand, and on the other, pedagogical variables performed by their teachers and which they experience but which do not depend on themselves, that is, the pedagogical practices and the mathematical processes present in the teaching practice.

Affect and classroom practices

One element to consider in mathematics performance is the affective domain. McLeod (1989) defines the affective domain as a wide range of feelings and moods that differ from pure cognition, expressed in terms of beliefs, attitudes and emotions involved in mathematical problem-solving. Beliefs are cognitive structures that allow students to organize and filter the information received to gradually build their notion of reality and worldview (Caballero et al., 2008). They are part of the knowledge acquired based on their life experiences, subjectively present when the student acts before the object or subject that motivates him/her (Martínez, 2011). In this area, students' demotivation to learn the subject is evidenced in the works of Rodriguez (2012) and Müller et al. (2012). Similarly, the impact of beliefs and attitudes on mathematics learning is analyzed by Vila and Callejo (2004), Maasz and Schlöglmann (2009) and Martínez (2011), evidencing the lack of interest in mathematics on the part of students in the student's opinion, is due to to the lack of its practical use in the environment. Similarly, the work of Prada-Núñez et al. (2020) highlights that students' attitudes and beliefs toward mathematics are determinant variables of academic performance.

Attitudes represent an evaluative predisposition (positive or negative) that determines personal intentions and influences student behavior (Gil et al., 2005). They constitute mental evaluations manifested through liking or disliking some object, subject or situation (Martínez, 2011), with cognitive, affective, conative and behavioral components, without excluding the axiological (Gallego, 2000). Emotions arise in response to an event (internal or external) with positive or negative meaning for the student (Gil et al., 2005). From Calhoun and Solomon (1989), Gomez (2000) and Martinez (2011), emotions are conceived as a complex functional state with physiological and psychological processes. For Goleman (1996), they are associated with thoughts, psychological and biological states and tendencies to act, among other feelings.

However, the ultimate goal of mathematics education is to achieve competent citizens in this area. In this sense, mathematical competence is based on the knowledge derived from the processes that need to be developed together with mathematical content (Alsina, 2014a), with the predominance of method over the content.

Therefore, processes are at the center of mathematical education. In this way, it is possible to develop the ability to think and reason mathematically, as demanded by society (Alsina & Coronata, 2020), strengthening the relationship between thought and action.

Based on the ontosemiotic approach, Godino et al. (2017) define five levels of analysis of mathematics teaching and learning processes, which can help mathematics teachers reflect on their teaching practice. In line with the previous approach, Giacomone et al. (2016) identify and discriminate the types of practices, objects and processes for solving mathematical tasks involving visualizations, while Godino et al. (2017) analyze the diversity of objects and processes involved in mathematical activity, supported by diagrammatic representations. On the other hand, for Alsina (2014b), mathematical processes predominate over contents in the development of mathematical competence since the former highlight the acquisition and use of the latter. However, it is common practice for the excessive instrumentalization of mathematical concepts with negative results before the reduction of the focus on mathematical processes and the mechanization of these, as evidenced by the findings of Pabón (2009), Duque et al. (2013), Flórez and Betancur (2015) and Cortés (2017). Weaknesses in teaching practice in relation to mathematical processes were also observed by Prada-Núñez et al. (2020).

The National Council of Teachers of Mathematics (NCTM, 2000; 2014) proposes five mathematical process standards as guidelines for success in mathematics education. Such processes aim to promote conceptual understanding, mathematical reasoning, and fluency in skills (NCTM, 2014), from the development of mathematics teaching and assessment, as well as a curriculum in line with such purpose. In this way, learning procedures without any relation are left aside to give way to conceptual understanding through mathematical reasoning. For Godino et al. (2004), this is achieved by articulating these processes throughout the teaching of mathematical content by organizing various types of didactic situations. The mathematical processes recognized by the NCTM are problem-solving, reasoning and proof, communication, establishing connections and representation.

The problem-solving process aims to generate new knowledge by students, basing such generation on solving problems beyond the context of mathematics and the school environment, trying to make them transversal to all areas of knowledge. It involves asking and answering questions within mathematics and with mathematics (Niss, 2002). It is based on using resources and tools for posing and solving mathematical problems.

Reasoning and proof involve the student's appraisal of mathematics by investigating, proposing and evaluating various conjectures for formulating logical arguments based on different types of reasoning. Thus, mastery of mathematical thinking leads to argumentation based on mathematical reasoning.

Communication allows the student to understand mathematics as a universal language through diverse semiotic representation systems (Duval, 2006; Alsina, 2014b), understanding that each has its own resources and rules. It is associated with communication in, with and about mathematics. In mathematics education, oral and written communication is recognized as an essential part of learning since, in general terms, it is expressed through symbols (NCTM, 2000).

The process of connections focuses on understanding the relationship and articulation between mathematical ideas in that context and other disciplines and everyday life (Alsina & Coronata, 2020). For Alsina (2014b), from an intradisciplinary approach, connections refer to the relationships between different blocks of mathematical content and between mathematical content and processes. From an interdisciplinary perspective, they are focused on the relationships of mathematics with other areas of knowledge; and from a globalized approach, they focus on the relationships of mathematics with the environment.

Finally, representation serves as a basis for communication as it constitutes a language or means to express the learner's ideas based on the various registers of semiotic representation, which can be efficiently articulated with other types of semiotic registers (Duval, 2006; D'Amore, 2006). Thus, the representation and use of technical, symbolic and formal operations and language allow the analysis and construction of models.

As part of the teaching process, strengthening pedagogical practices leads to improving the teacher's pedagogical competencies. Beyond mathematical and didactic knowledge, a teacher must be competent in the use of these for an ideal performance (Maasz & Schlöglmann, 2009; Pabón, 2009; Cortés, 2017), capable of promoting and enhancing mathematical processes for the achievement of high levels of performance and conceptual appropriation by students.

In the words of Tobón et al. (2018), and based on the approaches of Ambrosio (2018) and Tobón (2017), pedagogical practices are the actions that contribute to the formation of academic communities in the framework of the knowledge society (thus the qualification of individuals) supported by collaborative activities in which all the actors of the educational process participate (teachers, managers, advisors and community) so that students learn to solve problems of the environment, from the management and co-creation of knowledge based on relevant sources, articulation of different knowledge, articulation of different knowledge, and the creation of a new knowledge base, managers, advisors and community) so that students learn to solve problems of the environment, from the management and co-creation of knowledge based on relevant sources, articulation of different knowledge and continuous improvement in a context of inclusion.

The topics proposed by Danielson (2013) in his work Marco Profesoral are taken as a reference for the generation of an adequate learning environment. It defines the aspects to be considered by teachers in their pedagogical process to achieve high levels of academic performance by students, covering four dimensions:

a) Class planning and preparation: it highlights the mastery that the teacher must have over the subject he/she teaches in order to be able to guide the learning of his/her students. Within this knowledge of the discipline, the teacher must master the epistemological evolution of knowledge to highlight its importance in history and its relevance to current issues such as environmental awareness and cultural diversity, for example. From his epistemological mastery should emanate the competence to identify those concepts that usually cause difficulties in their students to, supported by various didactic approaches, promote the understanding of students using the available resources, which, coupled with relevant evaluation processes, can ensure the achievement of the expected results.

b) Classroom environment for learning: the purpose of this is to analyze the teacher's competence associated with the generation of productive classrooms in which respect for differences, the optimal use of time and the physical space of the classroom, together with the generation of work routines, contribute to the consolidation of a learning culture in which the student feels challenged to reach the understanding of contents within challenging contexts.

c) Pedagogical practice, understood as the moment of classroom work, of the operative development of everything planned and organized by the teacher. It corresponds to the moment of the teaching process in which communication between the teacher and the students plays a preponderant role since instructions are given through clear, precise and academic language. It is a period in which the teacher can promote and generate academic community among students, basing it on collaborative work, taking advantage of the strengths of each of them to focus on solving sequenced problems that gradually increase the cognitive demand but improve their living conditions. The teacher also relies on using various reliable didactic resources that contribute to developing critical thinking, individual and community, but with environmental commitment. It is suggested that the teacher's work be based on inquiry and discussion to deepen the student's understanding of knowledge. In this context, the formulation of questions by the teacher guarantees students the establishment of connections between already known knowledge and situations, which facilitates the understanding of new topics within the context of cooperative learning.

d) Teacher's responsibilities. Teachers must be reflective and self-critical about the process they carry out with their students, identifying successes and mistakes and generating a permanent habit of analyzing their work, guaranteeing the permanent improvement of their pedagogical actions. When the teacher reflects on the teaching process, he/she must consider all the stages of the pedagogical process, that is, from the planning to the execution of what was planned. This reflection is generated in light of its impact on student learning, which leads teachers to identify the elements of their pedagogical practice that should be enhanced in terms of their effectiveness in the classroom. This reflection by teachers can be based on their class notes and conversations with students or colleagues.

Models for mathematical performance

Previous studies show that the affective domain is a significant factor or determinant of academic performance in mathematics (Martínez, 2011; Prada-Núñez et al., 2020). For example, Rodríguez (2012) and Müller et al. (2012) found evidence of students' demotivation to learn mathematics. On the other hand, research by Vila and Callejo (2004), Maasz and Schlöglmann (2009), Mato and De la Torre (2009), Martínez (2011) and Fernández-Cézar et al. (2019) studied the impact of beliefs and attitudes on the learning of mathematics, showing the lack of interest on the part of the students, who claim that there is little practical application of these concepts in situations in their environment, resulting in low academic performance in mathematics.

To quantify the affective domain with respect to mathematics, several instruments have been applied, such as the VARK model (Velásquez et al., 2016) or scales like the test of Higher Logical Intelligence by Etchepare et al. (2011) and the Attributional Scale of Achievement Motivation by Ruiz and Quintana (2015) with the interest of validating its correlation with academic performance in mathematics in students of different educational levels. In these studies, it was highlighted that students with good results in this subject also show good cognitive development, interest in the course, dedication and effort, positive perception of the teacher's work and obtaining good results.

Three large groups of tools were found to model the effect of those variables that allow predicting academic achievement in mathematics: the use of Multiple Linear Regression models, Structural Equation causal models and Binary Logistic Regression models.

Regarding the Multiple Linear Regression models used in various countries in Latin America and the Caribbean, which have been conducted with students from secondary and higher education levels and with samples ranging from 54 to 899 students, have led to the conclusion that the predictor variables included in the models are based on the particular characteristics of each research. For example, in Carreño et al. (2020), numerical ability, IQ, reading comprehension and previous results resulting from the student's level of mathematical mastery were influential, while in Ortúzar et al. (2009), the characteristics of the institution (nature and modality of study) and those of the teacher (gender, experience and professional training) were highlighted as influential. On the other hand, García and González (2020) determined as influential factors in academic performance the study techniques and the preliminary results in some state tests- Finally, Mello and Hernández (2019) emphasized the effect on academic performance in mathematics of the activities carried out in the classroom and the self-perception of the participants as mathematics students.

Another aspect of mathematical modeling used by researchers to identify and quantify the effect of factors that influence academic achievement in mathematics corresponds to Structural Equation causal models. These models have been applied to data sets from between 300 and 800 students from different educational levels. The predictive factors have turned out to be diverse, and, as in the previous models, they are adjusted to the research interests. For example, in the works of Castejón et al. (1996) and Vargas and Montero (2016), there is agreement that previous school performance, study habits, self-concept and negative attitudes are determinants of school performance in mathematics, despite developing in two different educational levels and social contexts. Regarding the predisposition that the student may have about the subject, in the work of Cerda et al. (2017), together with that of Prada-Núñez et al. (2020), the importance of this attitude together with the liking for the subject and classroom activities as influential factors in school performance is highlighted, despite being applied in different educational levels. Finally, in the work of Miñano and Castejón (2011), it was identified that previous performance, the student's mathematical abilities and self-concept are strongly linked to mathematics performance.

Concerning the use of Binary Logistic Regression Models in the process of predicting academic achievement in mathematics using other variables, two strands of work were evidenced: a) those authors who combine these binary logistic regression models with another type of modeling technique, such as classification trees (Lizares, 2017), Bayesian asymmetric analysis (Dávila et al., 2015) or a combination of multiple regression, applied in a first phase, and the binary logistic regression applied in a second one (Barahona, 2014).

The structural models mentioned were obtained with university students' participants, determining as predictor variables gender, employment status, their valuation towards the subject, satisfaction with the program they study, results in university or state entrance exams, type of institution and pedagogical resources used in classes. In the case of Lizares' (2017) work, he concluded that classification trees have more classification and predictive power than binary logistic regression models.

From the literature review, which does not pretend to be exhaustive, the studies of Carvajal et al. (2009), Delgado et al. (2014), Heredia et al. (2014) and Arriola et al. (2020) resorted to the generation of binary logistic regression models to identify the determinants of academic performance in mathematics in university students, working with samples of between 150 and 585 students, and reaching levels of correct classification that ranged between 70% and 90%. These studies highlight the level of reading comprehension and mathematical reasoning as determinants of academic performance.

From the above, it can be inferred that multiple linear regression, structural equation and binary logistic models have been obtained to determine the mathematics performance of university students, but the latter has not been studied for modeling performance in non-university students. For this reason, the objective of this study is to determine if there is a model to which the characteristics associated with the affective domain, mathematical processes and pedagogical practices are adjusted as predictor variables of academic performance in mathematics in non-university students.

METHODOLOGY

The approach of the study is quantitative at a descriptive, cross-sectional level, with a field design.

Participants

The population consisted of all students from the fourth to the eleventh grade of eleven educational institutions in the Department of Norte de Santander (Colombia). For the selection of the sample, non-probabilistic sampling was used under the voluntary sampling technique, considering the following inclusion criteria: a) participation in the central headquarters of one of the selected educational institutions; b) being a student enrolled between fourth and eleventh grade; and c) having the consent of the parents or guardians. Applying these inclusion criteria, a sample size of 2,450 students was consolidated, equivalent to 35.8% of a total of approximately 6,846 students. The participants came from eleven educational institutions located in the urban area of a Colombian region and its metropolitan area, two of which were private. Regarding the distribution by grades, 20.6% corresponded to the Primary Basic stage (4th and 5th grades), 59.1% to Secondary Basic grades (6th, 7th, 8th and 9th), and the remaining percentage corresponded to Technical

High School grades (10th and 11th). The average age was 13.6 years (SD=2.3 years), although 69% were between 12 and 16 years old. Of the students surveyed, 49.5% were female.

Instrument.

The form used was composed of four sections. The first section included descriptors of the demographic and academic profile of the students, such as age, grade, sex, taste for mathematics and grades obtained in the last academic period, and of the institution in terms of its nature, public or private.

The second section included the following items (see Annex A):

For the affective domain towards mathematics, and its components, 13 items were taken from the questionnaire for Beliefs proposed by Caballero et al. (2014), 14 items from the questionnaire for Attitudes proposed by Auzmendi (1992), 10 items from the instrument for Emotions used by Fernández et al. (2016). Subsequently, Cronbach's alpha coefficient was determined as a measure of the internal consistency of the instruments, obtaining values of 0.696, 0.819 and 0.763 for beliefs, attitudes and emotions, respectively, which in the opinion of Oviedo and Campos-Arias (2005) is an admissible value of internal consistency.

The instrument for mathematical processes took reference from the works of Alsina (2014a, 2014b), the Basic document Standards of Competences in Mathematics issued by the Colombian Ministry of National Education (Mineducación, 2006) and the NCTM (2000) document on the principles and standards of Mathematics in school. The items considered in this section were distributed as follows: formulation and problem-solving (7 items), reasoning and proof (8 items), communication (9 items), representation (6 items), modeling (8 items) and connections (8 items). The internal consistency for each item was measured by Cronbach's alpha coefficient, obtaining values of 0.779, 0.831, 0.810, 0.781, 0.831 and 0.814, respectively, all considered acceptable (Oviedo & Campo-Arias, 2005).

The instrument to evaluate the characteristics of the practice promoted by the teacher for learning in the classroom was constituted by 7 items taken from Danielson's document (2013), called Teacher Development Framework. The internal consistency value provided by Cronbach's alpha coefficient is 0.734, also considered admissible (Oviedo & Campo-Arias, 2005).

In all the instruments used, the responses were given using Likert-type scales with five levels of response, where a score of 1 is associated with strongly disagreeing, 2 with disagreeing, 3 with neither disagreeing nor agreeing (neutral), 4 with agreeing, and 5 with strongly agreeing. Therefore, the neutral level corresponds to a score of 3, with two levels of favorable perception (4 and 5) above this value and two levels of unfavorable perception (1 and 2) below it.

Academic performance in mathematics was collected using the grade in the mathematics subject of the previous year provided by the teacher. This grade was taken on a standard scale from zero to five, where a grade higher than or equal to three is considered a pass. Since some educational institutions use different rating scales, it was necessary to calculate equivalent values to standardize the measurement scale.

Procedure

The instrument was applied in various educational institutions during the second semester of the 2019 school year.

Initially, each educational institution's principal was contacted to request a space in which the presentation of the project, the scopes and the objectives pursued were made to obtain their endorsement that would facilitate the entrance to the institution that each one of them leads. Once permission was obtained from the director of the educational institution, the parents of each student were asked for informed consent that their children would be part of a research of academic nature, for which they were given a document explaining what was intended to be done along with the authorization. The whole process was carried out following the Declaration of Helsinki. For the process of obtaining the grade in mathematics, the teachers of this subject in each educational institution were contacted and provided the report card for the second academic period of the school year. Due to the desire to maintain the anonymity of the informants, in more than 75% of the visits, it was guaranteed that the questionnaire would be applied during the mathematics class so that the teacher could identify the student and provide the grade obtained. In some cases where it was impossible to coincide with the math teacher, each student placed their roll number at the top of their questionnaire in the classroom, and with this data, the grade of their performance was then obtained. This process was carried out for two months, during which time the group of informants for the research was completed.

Data analysis

The mean value of each instrument was evaluated considering beliefs, attitudes, emotions, problem formulation and resolution, reasoning and testing, communication, representation, modeling, connections and the teacher's pedagogical practice in the classroom as independent variables, and performance as the dependent variable. Each independent variable was tested for normality using the Kolmogorov-Smirnov test, the results of which are shown in Table 1. Given the asymptotic significance, all variables are non-normal, which requires the use of nonparametric statistics.

Table 1. Results of the K-S Test for Normality.

Variable	Test Statistic	Asymptotic sign (bilateral)
Beliefs	0, 075	0, 000
Attitudes	0, 060	0, 000
Emotions	0, 069	0, 000
Formulation	0, 063	0, 000
Reasoning	0, 078	0, 000
Representation	0, 072	0, 000
Communication	0, 076	0, 000
Modeling	0, 071	0, 000
Connections	0, 050	0, 000
Pedagogical Practice	0, 078	0, 000

Non-compliance with normality affected the condition of equal variances and, therefore, the variables' linearity. Therefore, the application of a binary logistic regression model was considered. In this model, the performance variable (dependent) was taken as a categorical variable. To apply a binary logistic regression, a dichotomous variable was constructed, Y, indicating whether the student passed the mathematics course ($Y=1$) for a $\text{grade}\geq3$; or did not pass the subject ($Y=0$), for a $\text{grade}<3$. Logistic regression is a nonlinear model used to model the probability of academic success in mathematics in this research.

The relationship between the independent variables and performance is analyzed using Spearman's correlation, since this is a categorical variable.

RESULTS

Approximately 77% of the participants declared that they liked mathematics and about half (51%) presented, concerning their grade in mathematics, an average performance (grade between 3.0 and 3.9). Slightly more than a third (37%) achieved a high performance (grade between 4.0 and 5.0). Three percent of the students achieved a maximum grade of 5.0 points. The average grade in mathematics was 3.64 (SD = 0.68).

Table 2 shows the results of the correlation analysis between the variables that were statistically significant for the model in their relationship with the independent variable, where the null hypothesis validates the non-correlation of the variables.

Table 2. Correlation analysis report between predictor variables and academic performance.

Item	Rho Spearman	Sig. (bilateral)
Belief_12	0, 257**	0,000
Attitude_14	0, 096**	0, 000
Emotion_2	0, 053**	0, 009
Reasoning_2	0, 119**	0, 000
Communication_7	0, 052**	0, 010
Communication_8	0, 067**	0, 001
Connections_1	0, 073**	0, 000
Connections_2	0,031*	0,039
Connections_7	0, 114**	0, 000

***p<0, 05; **p<0, 01**

Table 3 shows the results of the Omnibus test of coefficients of the model, verifying that the Chi-square value is large so that the model is statistically significant, allowing to conclude that there are significant differences between a model with only the constant (β_0) and the model that includes all the explanatory variables.

Table 3. Omnibus tests of coefficients of the binary logistic regression model.

		Chi-square	gl	Sig.
Step 11	Step	9, 872	**4**	**0, 036**
	Block	302 ,557	44	**0, 000**
	Model	302, 557	44	0, 000

Table 4 shows the summary of the model employing three measures that allow an overall assessment of its validity. First, the Nagelkerke R-squared coefficient is bounded between zero and one, indicating the significance of the model. Therefore, it is affirmed that the predictor variables explain 22.4% of the variability of the response variable.

Table 4. Summary of the binary logistic regression model.

Step	Logarithm of the likelihood -2	R square of Cox and Snell	R square of Nagelkerke
11	1491, 387	**0, 116**	**0, 224**

Table 5 reports the results of the Hosmer and Lemeshow test, which evaluates the goodness of fit of the logistic regression model after comparing the expected values (estimated by the model) and the observed values, validating the null hypothesis that there is no difference between these two values.

Table 5. Hosmer and Lemeshow test in the binary logistic regression model**.**

Step	Chi-square	gl	Sig.
11	5, 736	**8**	**0, 677**

Table 6 shows the probability of classification as pass or fail of the students with the proposed model, which offers 87.2% of success at the general level, showing that 94.5% of the students who passed mathematics were classified in this way through the use of the binary logistic regression model proposed in this research.

		B	Standard error	Wald	gl	Sig.	Exp(B)	95% C.I. for EXP(B)	
								Lower	Upper
Step 11	Belief_12			120,416	4	,000			
	Belief_12(1)	**,574**	,227	6,395	1	**,011**	1,776	1,138	2,772
	Belief_12(2)	**1,030**	,202	25,894	1	**,000**	2,802	1,884	4,167
	Belief_12(3)	**1,800**	,218	67,963	1	**,000**	6,052	3,945	9,285
	Belief_12(4)	**2,807**	,307	83,848	1	**,000**	16,557	9,080	30,193
	Attitude_14			15,602	4	,004			
	Attitude_14(4)	**,807**	,260	9,588	1	**,002**	2,240	1,345	3,732
	Emotion_2			9,505	4	,050			
	Emotion_2(2)	**-,917**	,335	7,518	1	**,006**	,400	,207	,770
	Emotion_2(4)	**-,671**	,329	4,177	1	**,041**	,511	,268	,973
	Reasoning_2			12,345	4	,015			
	Reasoning_2(1)	**,890**	,318	7,818	1	**,005**	2,434	1,305	4,542
	Reasoning_2(3)	**,642**	,285	5,075	1	**,024**	1,901	1,087	3,323
	Reasoning_2(4)	**,819**	,288	8,064	1	**,005**	2,268	1,289	3,992
	Communication_7			13,915	4	,008			
	Communication_7(1)	**-,747**	,281	7,077	1	**,008**	,474	,273	,821
	Communication_7(2)	**-,633**	,264	5,759	1	**,016**	,531	,316	,890
	Communication_8			14,038	4	,007			
	Communication_8(1)	**,699**	,304	5,294	1	**,021**	2,011	1,109	3,648
	Connections_1			12,277	4	,015			
	Connections_1(2)	**,669**	,242	7,644	1	**,006**	1,953	1,215	3,139
	Connections_1(3)	**,512**	,249	4,224	1	**,040**	1,668	1,024	2,718
	Connections_2			13,100	4	,011			
	Connections_2(1)	**-,829**	,343	5,843	1	**,016**	,437	,223	,855
	Connections_2(3)	**-1,004**	,320	9,840	1	**,002**	,366	,196	,686
	Connections_2(4)	**-,911**	,315	8,372	1	**,004**	,402	,217	,745
	Connections_7			11,790	4	,019			
	Connections_7(3)	**,690**	,242	8,141	1	**,004**	1,994	1,241	3,204
	Connections_7(4)	**,675**	,263	6,590	1	**,010**	1,963	1,173	3,287
	Constant	,437	,437	1,001	1	,317	1,548		

Table 6. Classification table in the binary logistic regression model.

Academic Performance		Forecast		Percent correct
		Suspense	**Approved**	
Observed	Suspense	98	195	33, 4
	Approved	118	2039	94, 5
Percentage Global				**87, 2**

Figure 1 shows the variables of the binary logistic regression model that were significant in the equation according to the interpretation of the significant modalities. To understand the information, the study analyzed the statement of Belief_12: I consider myself skilled and capable in mathematics, where its five levels of response on the Likert scale were significant (see column Sig.) assuming as a reference level to be in total disagreement with the statement identified with the code Belief_12 while being in disagreement corresponds to the code Belief_12(1), Neither disagree nor agree to the code Belief_12(2), agree to the code Belief_12(3) and agree to the code Belief_12(4).

Figure 1. Variables of the binary logistic equation.

DISCUSSION

Based on the literature reviewed, mathematics performance can be predicted by affective, cognitive, and behavioral variables (Parker et al., 2014; Jansen et al., 2016; Pitsia et al., 2017; Hann, 2020; Fernández-Cézar et al., 2021).

Therefore, the objective of this study is to determine whether the affective domain (beliefs, attitudes and emotions), mathematical processes (problem formulation and solving, reasoning and proof, communication, representation, modeling, and connections) and pedagogical practices, taken as independent variables, influence academic achievement in mathematics, which was taken as the dependent variable. For this purpose, we worked with 2,450 students from fourth to eleventh grade from eleven educational institutions in the Department of Norte de Santander (Colombia).

Table 2 shows the items of the instrument used that are significant for the model, whose significance coefficients are shown in Tables 3 and 4, where it is verified that the Chi-square value is large so that the model is statistically significant with the items in Table 2 as explanatory variables, and the Nagelkerke coefficient of 22.4%. Of the initial 90 items, only eleven items were significant in the suggested model, of which 36.4% were associated with the affective domain construct towards mathematics (beliefs, attitudes, emotions), while the remaining percentage were associated with the mathematical processes that the teacher promotes in classroom work (formulation, reasoning, communication and connections).

However, no item related to the classroom environment was significant. These findings are in line with the works of Castejón et al. (1996) and Vargas and Montero (2016), who contemplated attitudes as an independent predictor variable of performance, among others, and with those of Cerda et al. (2017) and Prada-Núñez, et al. (2020), who also highlight the fundamental role of attitude in determining academic performance in mathematics.

On processes as independent variables, our findings are in line with those of Carvajal et al. (2009), Delgado et al. (2014), Heredia et al. (2014) and Arriola et al. (2020), who found mathematical reasoning as a determinant of performance, also with binary logistic models.

To interpret the model obtained for each item (independent variable), we refer to Figure 1, where we take the (Odds ratio) $OR_j = Exp(b_j)$. Values of $OR < 1$ imply a decrease in the probability of passing mathematics, and $OR > 1$ imply an increase in the probability, always comparing the category of interest with the reference mode (which in all cases has been *Strongly Disagree*).

Thus, from the table of statistically significant coefficients 5%, it can be seen that for the item Belief_12, which corresponds to $(p < 0{,}05)$, it can be observed that for the item Belief_12, which corresponds to, *I consider myself skilled and capable in mathematics*, it obtains a $OR_1 = 1{,}776$which can be interpreted as approximately 1.78 times more likely to pass mathematics if they *disagree* with *considering themselves skilled and capable in mathematics* than if they responded *totally disagree.*

Similarly, in the case of Attitude_14, the level Attitude_14(4) is significant, which allows us to conclude that students who stated that they *totally agree* that *people who are good at mathematics are also good in other areas are* 2.2 times more likely to pass mathematics than those who stated that they *totally disagree* with this statement.

Continuing with the interpretation, Emotion_2 states that I am *curious to know the response to a proposed situation*, and the following modalities or levels of response were significant: Emotion_2(2), because $b_6 = -0{,}17$ and a $OR_6 = 0{,}400$In this case, due to the negative sign of the coefficient, there is a decrease in the probability of passing mathematics, so it could be affirmed that those students who expressed *neither agreeing nor disagreeing* with feeling curious to know the answer to a proposed situation have a 60% (obtained from $1 - 0{,}4 = 0{,}6$) less likely to pass mathematics than those who stated that they *totally disagreed*. For Emotion_2(4), since $b_6 = -0{,}671$ and $OR_6 = 0{,}511$, then it could be affirmed that those students who stated that they *totally agree with* knowing the answer to a proposed situation have approximately 49% (obtained from $1 - 0{,}511 = 0{,}489$) less likely to pass mathematics than those who expressed *total disagreement.*

Regarding the interpretation of the mathematical processes considered in the instrument, the item Reasoning_2, which states that the teacher *solves exercises in different ways*, has been identified as significant. $OR_9 = 2{,}268$This can be interpreted as meaning that there are approximately 2.27 times more possibilities of passing mathematics if one *totally agrees* (corresponding to code Reasoning_2(4)) with the fact that the teacher uses different methods to solve exercises concerning those who declare to be *in total disagreement.*

In a complementary way, the item identified as significant is Communication_7, which states that *the teacher asks questions related to the topic,* since $b_{11} = -0{,}633$ and a $OR_{11} = 0{,}531$. In addition, due to the negative sign of the coefficient, there is a decrease in the probability of passing mathematics, so it could be affirmed that those students who stated that *they were indifferent* for whether the teacher asked questions related to the subject have approximately 47% (obtained from $1 - 0{,}531 = 0{,}469$) less probability of passing mathematics than those who stated that they *totally disagreed.*

In summary, with the model obtained, the participants can be classified as pass or fail with an efficacy of 87.2%, being this an index of the effectiveness of the model somewhat higher than that of other binary logistic models for mathematics performance (Prada et al., 2021) that also take effect as a predictor variable, but not the processes. Likewise, it coincides with other models that consider one of the processes studied here, reasoning, as a predictor variable, among others (Carvajal et al., 2009; Delgado et al., 2014; Heredia et al., 2014; Arriola et al., 2020). However, analyzing it in detail, it is observed that although the model classifies almost 95% of the students who pass, it has a lower sensitivity than other binary logistic models (Prada et al., 2021) to classify those who fail (33.4%).

Conclusions

It can be concluded that the model obtained with items belonging to the affective domain and the mathematical processes present in the teaching practice has a good goodness of fit, guaranteeing the correct classification of 87% of the students at a general level, offering 95% of correct classification with those who passed the subject. Therefore, it seems that it can be affirmed that the relationship between the constructs of affective domain of the student towards mathematics and the mathematical processes promoted by the teacher in the classroom work influence academic performance in mathematics (grade in mathematics), although not in a linear way, as evidenced by the proposals of both binary and multinomial logistic regression models. The main finding derived from this research was that, in the opinion of the students surveyed, the characteristics of classroom organization in the academic and physical aspects, together with the didactic and evaluative aspects, were not significant in academic performance in the course.

The main limitation of this research was accessing a sample through probabilistic techniques, which restricts the generalization of the results in the eleven participating educational institutions.

However, this does not delegitimize the aforementioned findings. On the other hand, it is suggested as future research to increase the number of items in each of the constructs identified as significant, in order to be able to advance in the construction of a structural equation model in which the relationships and their intensities between constructs are schematized.

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Annex A. Relation of items associated with the Affective Domain

Beliefs 1.	Mathematics is useful and necessary in all aspects of life.
Beliefs 2.	Mathematics is difficult, boring and far from reality.
Beliefs 3.	In Mathematics, it is essential to learn by heart the concepts, formulas and rules.
Beliefs 4.	Math exercises are quickly solved if you know the formula, rule or procedure.
Beliefs 5.	In order to learn Mathematics I must devote extra time to study on my own.
Beliefs 6.	When I solve a mathematical exercise, they value the result more than the process used.
Beliefs 7.	How I solve mathematical exercises in class is different from how I need to solve situations in everyday life where mathematics is required.
Beliefs 8.	I look for different ways and means to solve exercises in Mathematics.
Beliefs 9.	I can invent my own math exercises from the exercises done in class.
Beliefs 10.	Understanding Mathematics helps me to solve doubts in other subjects.
Beliefs 11.	When I solve an math exercise, I feel confident that the answer is correct.
Beliefs 12.	I consider myself very capable and skilled in Mathematics.
Beliefs 13.	To obtain good mathematics results, intelligence and creativity are necessary.
Attitudes 1.	When I try to solve math exercises, I usually come up with the correct answer.
Attitudes 2.	Luck plays a role in successfully solving a mathematics exercise.
Attitudes 3.	Mathematics is easier for me when the teacher in class uses different examples that allow me to relate it to everyday situations.
Attitudes 4.	When I observe the teacher's willingness to clarify doubts during class, I am more interested in Mathematics.
Attitudes 5.	Having a good communication with the Mathematics teacher, awakens my interest in studying the subject.
Attitudes 6.	If the teacher explains with clarity and joy it makes me like Mathematics.
Attitudes 7.	I feel engaged in Mathematics, when the teacher is interested in my academic performance.
Attitudes 8.	I feel engaged in Mathematics, when the teacher values my effort in the subject.
Attitudes 9.	Having a family member who likes mathematics, I am attracted to its study.
Attitudes 10.	I feel different from others because I like Mathematics.
Attitudes 11.	Learning more Mathematics makes me feel a competent person in society.
Attitudes 12.	I feel confident when solving math exercises.
Attitudes 13.	Mastering Mathematics will enable me to succeed in my further studies.
Attitudes 14.	Being good at Mathematics helps me to perform well in other subjects.
Emotions 1.	I give up easily when I am asked to solve an mathematical exercise, even without finding the solution.
Emotions 2.	I am curious to know the answer when the teacher asks me to solve a math exercise.
Emotions 3.	I feel nervous when the teacher asks me by surprise to solve a math exercise on the board.

Emotions 4. When I solve math exercises in a group I feel calmer.
Emotions 5. When I don't get the solution to a math exercise, I start to feel insecure, anxious and nervous.
Emotions 6. If I don't find the solution to an exercise in Mathematics, I feel I have failed and wasted my time.
Emotions 7. I feel happy when I solve an exercise correctly in Math.
Emotions 8. When I fail to solve an exercise in Mathematics, I try again, but using another solution method.
Emotions 9. Solving an exercise in Mathematics requires effort, perseverance and patience.
Emotions 10. I am calm and collected when solving math exercises.

Annex B. List of items associated to Mathematical Processes

Form, Reso 1. The teacher gives me examples and problems using different types of support such as the board, drawings, manipulative material, among others.
Form, Reso 2. The teacher proposes me problematic situations that involve Mathematics in my daily life.
Form, Reso 3. The teacher proposes me problematic situations on the same topic and to solve them he uses different ways of solution.
Form, Reso 4. The teacher asks me questions in order for me to propose a possible solution to the problem.
Form, Reso 5. The teacher motivates me to use concrete and/or pictorial material to solve problems in Mathematics.
Form, Reso 6. The teacher promotes discussion among my peers around different problem solving strategies and results.
Form, Reso 7. The teacher proposes problematic situations in which there is too much or too little information for me to ask questions.

Raz and Prue 1. The teacher asks me to propose my own conjectures (guesses) by employing the trial and error technique.
Raz and Prue 2. The teacher allows me to discover, analyze and propose different ways to solve mathematical exercises and problems.
Raz and Prue 3. The teacher asks me to explain (justify or argue) the strategies or techniques I use to solve math exercises and problems.
Raz and Prue 4. The teacher poses questions to help me explain the answer obtained in the solution of exercises and problems in Mathematics.
Raz and Prue 5. The teacher asks me to check assumptions (conjectures) that occur daily but are supported by mathematical concepts seen in class.
Raz and Prue 6. The teacher motivates me to think and reason logically.
Raz and Prue 7. The teacher uses a variety of resources to provide feedback on mathematical concepts.

Raz and Prue 8. The teacher proposes possible answers to an exercise or problem in order for me to accept or reject them by giving my own explanations (arguments).

Communication 1. The teacher promotes communication with all students.

Communication 2. The teacher encourages dialogue among students in order to understand mathematical concepts.

Communication 3. The teacher encourages me to use different languages (spoken, gestures, drawings, diagrams, symbols) to exchange mathematical ideas.

Communication 4. The teacher asks me to use appropriate mathematical language to explain my answers.

Communication 5. The teacher asks me to respect other classmates' ways of thinking and of presenting reasons and arguments of mathematical content.

Communication 6. The teacher asks me to listen carefully to my classmates' points of view.

Communication 7. When in the classroom, the teacher asks questions associated with the topic instead of giving explanations about the topic.

Communication 8. The teacher uses various forms of representation (spoken, drawings, tables, symbols) of mathematical content in class.

Communication 9. The teacher invites me to use different representation registers (spoken, drawings, tables, symbols) around a mathematical concept.

Representation 1. The teacher asks me to talk, listen and reflect on Mathematics from everyday life, and then represent it using the appropriate mathematical symbols.

Representation 2. The teacher uses materials that I can manipulate to represent the mathematical ideas.

Representation 3. The teacher uses different models or forms to solve mathematical problems.

Representation 4. The teacher asks me to outline or draw the problem situation to be solved.

Representation 5. The teacher asks me to use the appropriate mathematical symbols to represent the problem situation to be solved.

Representation 6. The teacher in class uses manipulative material to later represent it symbolically on the board; in other situations, the teacher starts from what is expressed symbolically on the board to represent it with manipulative material.

Modeling 1. The teacher uses diagrams or models to represent real-life situations.

Modeling 2. The teacher uses diagrams or models to understand a mathematical idea or concept.

Modeling 3. The teacher uses different forms of representation (graphs or symbols) to formulate and solve mathematical problems.

Modeling 4. The teacher uses the formulation of questions to help me understand the context of a problem in order to facilitate its representation by means of a model or scheme.

Modeling 5. The teacher asks me to identify all the data found in a problem statement.

Modeling 6. The teacher asks me to identify the relationships between the different data in the statement when proposing a problem.

Modeling 7. It is important to the teacher that I solve mathematical problems using models and diagrams.

Modeling 8. It is important to the teacher that I construct my own models and schemes to solve mathematical problems.

Connections 1. The teacher explains mathematical concepts from everyday situations in my life.

Connections 2. The teacher explains new mathematical concepts based on others that have already been seen.

Connections 3. The teacher explains mathematical concepts from musical contexts.

Connections 4. The teacher explains the mathematical concepts from the literature on the topic.

Connections 5. The teacher explains mathematical concepts from different artistic expressions.

Connections 6. The teacher explains mathematical concepts from sports, physical and recreational activities.

Connections 7. The teacher asks me to apply Mathematics to situations in my daily life.

Connections 8. The teacher asks me to apply Mathematics in situations of caring for the environment and nature.

Annex C. List of items associated with the classroom environment.

Environment 1. The teacher establishes rules and instructions for the smooth running of the class.

Environment 2. The teacher is organized during the development of the class.

Environment 3. The teacher organizes groups of students to solve the activities in class.

Environment 4. The teacher makes use of school spaces other than the classroom to develop mathematical concepts.

Environment 5. The teacher uses only written assessments to evaluate my learning.

Environment 6. The teacher, based on the questions we ask in class, proposes complementary reinforcement activities.

Environment 7. The teacher motivates us to perform self-evaluation of our performance in class.