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RECEIVED 19 July 2023

ACCEPTED 29 November 2023

PUBLISHED 08 January 2024

CITATION

Prada Núñez R, Rabelo Procopio MV,
Fernández-Cézar R and Solano-Pinto N (2024)
Affective domain and mathematics
achievement of Colombian students under
multiple correspondence analysis.
Front. Educ. 8:1261829.
doi: 10.3389/educ.2023.1261829

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Affective domain and mathematics achievement of Colombian students under multiple correspondence analysis

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The literature review indicates that age is a variable related to the students' affect toward mathematics in such a way that the older they are, the less affection they feel for mathematics. In the case of the Department of Norte de Santander, the administration is going to carry out an educational program for 2050, whose aim is to make this region a science, technology, engineering, arts, mathematics (STEAM) territory, for which it is necessary for students, regardless of the grade, to reach optimum levels in the management of mathematical competencies. Therefore, having a picture of the department's situation in this respect is relevant. To this end, this research aims to apply a quantitative and descriptive methodology on the affective domain and achievement in mathematics to determine whether these vary with the students' grade level. A non-probabilistic sample of 2,729 students from fourth to eleventh grades (9 to 18 years old) from 13 educational institutions in a region of northwestern Colombia was used. The instrument used characterized the affective domain toward mathematics (attitudes, beliefs, and emotions) and math achievement, taking grade as the independent variable. A multiple correspondence analysis (MCA) was carried out to depict the affective domain toward mathematics in relation to grade level, considering whether students like the subject and achievement as factors. The results allow us to identify that for beliefs and attitudes, the favorable values are located toward the positive axis of the abscissae, contrary to what is found for emotions. It is noteworthy that students in the lowest grade, fourth grade, show positive beliefs, attitudes, and emotions toward mathematics as well as high achievement, while those in the last grade, eleventh grade, show low values of the three components, besides low performance. This situation is worrying as mathematical knowledge is integral to everyday life and is necessary for citizens in the development of any profession. For this reason, relevant administration should take this into consideration when developing the STEAM program in order to promote an improvement in mathematical performance by supporting students in developing their affect toward mathematics.

KEYWORDS

beliefs, attitudes, emotions toward mathematics, basic education, quality education, mathematics achievement

Introduction

Managing emotions is a fundamental aspect of human life, influencing virtually every facet of existence, from personal interactions to professional performance and overall wellbeing. The ability to effectively manage emotions is essential for maintaining and preserving good mental and physical health. Unmanaged negative emotions, such as anger, anxiety, or sadness, can lead to mental disorders, such as depression, anxiety, or chronic stress, which, in turn, can trigger a variety of health problems, such as heart disease, diabetes, and a weakened immune system.

On a personal level, affect significantly influences how people handle their daily tasks and face challenges. Positive emotions not only contribute to improving a person's overall health but also enhance their ability to set goals, plan, and execute tasks, among other things. A positive mood is associated with greater persistence, creativity, and a proactive approach to problem-solving. In contrast, negative emotions can lead to decreased self-esteem and a reduced ability to cope with challenges.

In education, the link between affect and performance is particularly significant. Emotions play a fundamental role in students' learning and academic performance. On the one hand, positive emotions, such as interest and curiosity, can stimulate active participation and the desire to explore new concepts, enhancing creativity and innovation in students. On the other hand, negative emotions, such as anxiety and boredom, can be significant barriers in the learning process. Less is known about the causes of these either positive or negative emotions, or factors that relate to them. Among them, sociocultural context and school factors possibly are the causes of these emotions, besides possible learning difficulties without a diagnosis, like dyscalculia (Devine et al., 2018).

Within the school curriculum, mathematics is one of the subjects that foster a diversity of affects located at opposite poles. For more than two decades, various researchers, including McLeod (1988, 1992, 1994), Gómez (1997, 1998, 2000), Gil Ignacio et al. (2005), Martínez (2005), Gil et al. (2006), Caballero et al. (2008), and Blanco (2012), among many others, have recognized the importance of affect or emotions in the educational processes surrounding the learning of mathematics. In this regard, Caballero Carrasco et al. (2014), citing Gómez (2000), state that "a persistent problem in the understanding of affect in the teaching and learning of mathematics has been to find a clear definition of what affect, or the affective domain is" (p. 234). In Gil Ignacio et al. (2005), it is stated,

[T]he relationship between affect and learning is cyclical: on the one hand, the student's experience of learning mathematics provokes different emotional reactions and influences the formation of beliefs; on the other hand, the beliefs held by the subject have a direct consequence on their behavior in learning situations and on their ability to learn. (p. 17)

For the purpose of this research, and based on Krathwohl et al. (1973), McLeod (1989), and Gómez-Chacón (1997), the affective domain in mathematics education encompasses the beliefs, attitudes, and emotions that students experience around the mathematical activity in their learning process. Paraphrasing

Gil Ignacio et al. (2005), it can be stated that in the process of learning mathematics, students frequently receive a variety of stimuli that lead to emotional reactions conditioned by the beliefs they hold about mathematics and about themselves. As these reactions become recurrent, they become automated and are consolidated in the form of attitudes (more stable) and emotions (less stable).

A line of research that is becoming increasingly relevant in the academic environment of mathematics is the role of beliefs and emotions in non-conventional problem-solving, as mentioned in Goldin (2000) and Hannula (2015), since they could bias cognitive processes, affecting the disposition toward the subject and, therefore, reducing the probability of performing a mathematical task correctly or the intention to be perseverant.

For Caballero et al. (2008), beliefs "are cognitive structures that allow the individual to organize and filter the information received, and which construct their notion of reality and their vision of the world. They allow the learner to make anticipations and judgements about reality; they provide personal meaning" (p. 158). In the opinion of Gil Ignacio et al. (2005), beliefs "are therefore defined in terms of the subjective experiences and knowledge of the learner and the teacher" (p. 18). McLeod (1992) defines four categories in which beliefs are grouped: (a) beliefs about mathematics and its teaching and learning process, (b) beliefs about oneself as a learner of mathematics, (c) beliefs about the teaching of mathematics, and (d) beliefs raised by the social context. Subsequently, Bermejo (1996) defines two types of categories of beliefs differentiated by the intensity of affect: beliefs about mathematics itself and students' beliefs about mathematics. All the reported authors recognize the importance of self-concept as a determining factor in academic achievement.

In this sense, Bandura (1997) defined perceived self-efficacy as "beliefs in one's own abilities to organize and execute the courses of action necessary to produce certain achievements" (p. 3). Then, in the educational context, success derived from past experiences enhances students' self-efficacy, while failures weaken it.

Skaalvik and Skaalvik (2011) and Hannula et al. (2016) highlight the relationship that students' self-efficacy exhibits with academic performance, achievement, and persistence in the educational process. The same work by Hannula et al. (2014) identifies the need to carry out studies that analyze the relationship between self-efficacy beliefs and their behavior over time, as well as the effect of collective efficacy beliefs in mathematics students.

Schukajlow et al. (2012) emphasize the need to propose instruments to measure affects in the educational context, considering the influence of teachers and the overall setting. In this regard, the impact of teachers and their pedagogical practices in shaping these beliefs is recognized. For instance, Cross (2009) highlights the existing coherences and inconsistencies between teachers' beliefs and their pedagogical practices, so it is also necessary to investigate the influence that the context, experience, and knowledge could have on teachers' beliefs.

Continuing with the review of the basic descriptors of the affective domain, Gil Ignacio et al. (2005) define attitude as "an evaluative predisposition (positive or negative) that determines personal intentions and influences behavior" (p. 20). Hannula et al. (2016), citing Di Martino and Zan (2001), propose "a three-dimensional definition that recognizes three components of

attitude: emotional disposition, set of beliefs about mathematics and mathematics-related behavior” (p. 4).

When analyzing the definition of attitude settled in the study, one observes its coherence with the executed research method. Thus, in [Hannula et al. \(2016\)](#), citing authors such as [Karsenty and Vinner \(2000\)](#), [Hannula \(2002\)](#), [Kaasila \(2007\)](#), and [Di Martino and Zan \(2011\)](#), it is stated that “much of the research on attitude has been developed through narratives such as essays, diaries and interviews” (p. 5). They have adopted a narrative approach since it highlights what is fundamental for the respondent, which is contrary to the traditional implementation of attitude measurement scales where the respondent just expresses his or her level of satisfaction with the attitude scale. That is, they have adopted a narrative approach since it highlights what is fundamental for the respondent.

[Gil Ignacio et al. \(2005\)](#) propose two main categories of attitudes, with mathematics as the object of study:

- (a) Attitudes toward mathematics, where more importance is given to the affective component than to the cognitive component, manifesting the first as curiosity, interest, or satisfaction toward the following aspects: interest in mathematical work, attitude toward mathematics and mathematicians, attitude toward mathematics as a subject, attitude toward teaching methods, and attitude toward certain parts of mathematics.
- (b) Mathematical attitudes, markedly cognitive in nature, referring to the way in which general skills such as flexibility of thought and critical thinking, among others, are used.

In this regard, [Di Martino and Zan \(2011\)](#) propose a three-dimensional model in which attitudes are the bridge between beliefs and emotions. In their research, the authors claim that many teachers attribute their didactic incompetence to the negative attitude toward mathematics of students. These authors suggest the need to investigate the attitudes of students in different countries, cultures, and/or educational systems in order to make comparisons that provide a better characterization of the different profiles of attitudes toward mathematics. In addition, they suggest analyzing the attitudes of trainees and practicing teachers, as well as conducting longitudinal studies to validate attitude change through the implementation of corrective interventions.

Regarding the third descriptor, emotions, [Gil Ignacio et al. \(2005\)](#) argue that emotions “are organized responses beyond the boundaries of psychological systems,... they arise in response to an event, internal or external, that has a positive or negative meaning for the individual” (p. 23). [Gómez-Chacón \(2001\)](#) recognizes two difficulties in the development of research on emotions: the absence of a theoretical framework that prevents the design of suitable instruments to measure them.

There are two theories for the cognitive perspective of emotion within the field of mathematics education: (a) [Mandler \(1980, 2019\)](#)’s theory highlights that emotion is a complex interaction between the cognitive and biological systems when considering problem-solving. He points out that when the indications given in class are different from those expected by the students, they experience emotional responses; (b) [Weiner \(1986\)](#)’s theory proposes that when an event occurs, there is a primitive emotional

reaction that is dependent on the result and independent of the attribution; then, when analyzing the result and the affective reaction, a causal ascription will be sought in the function of the attribution, which will lead to a series of emotions.

Based on the theoretical framework mentioned in the previous paragraphs, potential research avenues have been identified to elucidate the relationship between the basic descriptors of the affective domain defined by [McLeod \(1992\)](#) and the academic performance of students in different sociocultural contexts. It is worth noting that the majority of this research is identified in Western sociocultural contexts, so there is a need to explore these relationships in developing countries.

The study

Today’s society exhibits several characteristics that reflect changes and trends in different environments ([Sassen, 2013](#)). Globalization has generated a process of interconnection through communications, means of transport, and digital networks, which has led to greater economic, cultural, and social integration between different countries and regions or communities within the same country ([Porter, 2000](#)). This has been possible, thanks to rapid technological advances such as the use of mobile devices, the internet, social networks, artificial intelligence, and other technologies, which have changed the way people communicate, work, access information, and relate to the world in general. These changes have led to transformations in educational proposals oriented toward the internationalization of their curricula ([Knight, 2004](#); [Altbach and Knight, 2007](#)).

Within this constantly changing context, exceptional events have brought about new challenges that demand new and efficient competencies from society in general, forcing systems, organizations, and professionals to evolve. Such was the case of the COVID-19 pandemic that demanded an abrupt transformation of people’s daily routines ([Ayala García et al., 2020](#); [Hernández Vergel et al., 2021](#); [Prada Núñez et al., 2021b](#)), where it became clear that social interactions, commerce, entertainment, education, and many other aspects of daily life could be carried out in digital environments or at least supported by information and communication technologies ([Lee, 2020](#); [Rincón Leal et al., 2021](#)).

Another characteristic aspect of today’s society is its cultural diversity, as migration, mobility, and the mixing of ethnicities have contributed to greater plurality and multiculturalism ([Alba, 1999](#); [Rodríguez, 2000](#); [Bauböck and Rundell, 2018](#)). This is added to changes in family structure that have led to new social dynamics and challenges, along with a permanent concern for the care of the environment, fauna, and flora, among many other aspects ([Ulloa Cubillos, 2015](#)).

All these issues, among others, must be addressed in different formative scenarios such as the school, the family, or the social context in which the individual interacts. Focusing on one of these scenarios, the school, understood as the educational center where students undergo their training process within the education system ([Ascorra Costa et al., 2017](#)), it is important to define what is considered as education. In this regard, it can be stated that education is a comprehensive process that seeks to promote the

growth and development of individuals, providing them with the knowledge, skills, and values necessary to actively participate in society and contribute to the common good (Mann et al., 2009; Guyas Fitch et al., 2015).

But the educational process takes place inside a context where other factors coexist. Therefore, it can be affected by a variety of factors, both internal and external to the education system, among which the following stand out:

- (a) Factors specific to each student, such as motivation level, skills and prior knowledge, learning style, special needs, self-esteem, and self-confidence, among others (Correa Mejía et al., 2019; Ontoria et al., 2023), affect students' participation, engagement, and learning ability.
- (b) Family environment has a significant impact on the educational process, since family support and expectations, the availability of educational resources at home, emotional stability, and socioeconomic status can affect students' performance and motivation (Lastre Meza et al., 2018).
- (c) Students' socioeconomic status can influence their access to educational resources, various learning opportunities, support services, and general living conditions. Socioeconomic inequalities can lead to disparities in educational outcomes, as students from disadvantaged backgrounds may face greater challenges and have more difficulty accessing fewer learning opportunities (Cruz et al., 2014; Agualongo Quelal and Garcés Alencastro, 2020).
- (d) Teaching quality plays a key role in the educational process, as competent and motivated teachers, innovative teaching strategies, appropriate learning environments, and timely feedback have a significant impact on student learning and achievement (Trigueros Ramos and Navarro Gómez, 2019).
- (e) Social policies related to education financing, equity, assessment, and curriculum can influence the quality of education and the opportunities available to students, as many of them limit the availability and quality of educational resources (Rodríguez et al., 2015; Caro and Núñez, 2018), such as textbooks, learning materials, technology, and access to libraries and laboratories.

Apart from the aforementioned factors, to comply with the comprehensive education of students, it is necessary to propose a school curriculum contemplated as a study plan that establishes the objectives, contents, and teaching and learning methodologies in educational institutions, which, in turn, becomes a clear and coherent guide for educators to guarantee a quality and relevant education for students (Lockyer et al., 2017). The Colombian Ministry of National Education (MinEducación) has developed a series of documents that define the educational guidelines at each level of the school process and for each discipline included in the school curriculum; however, teachers have the autonomy to make the adjustments that better fit their classroom according to the needs of the specific context in which they carry out their pedagogical activity (Hernández-Suárez et al., 2021).

Within the school curriculum, mathematics plays a fundamental role since it fosters the development of logical thinking, reasoning, and problem-solving (García and Izquierdo,

2017). When students face mathematical challenges, they need to analyze, organize, and process information systematically, which helps them develop cognitive skills and apply critical thinking in different situations.

The Basic Standards of Competences in Mathematics (Ministerio de Educación Nacional, 2006) organize mathematical knowledge into five senses (random, variational, numerical, spatial, and metric), recognize five mathematical processes (formulating and solving problems; modeling processes and phenomena of reality; communicating; reasoning; and formulating, purchasing, and exercising procedures), and identify three contexts of application (mathematics itself, in its relation to other areas of knowledge, and in contextualized situations).

From the aforementioned discussion, there is a long list of mathematical concepts (according to various senses) that should be brought into the classroom in such a way that the student recognizes and values their importance for the foundation and development of other disciplines since mathematical skills are essential in making informed decisions and solving practical problems in the real world. At present, in the age of technology and information, mathematical skills are increasingly important. The ability to understand and analyze data, use digital tools, solve complex problems, and make evidence-based decisions is recognized as a key skill for the 21st century (Krüger Mariano and Chiappe, 2021), and mathematics plays a crucial role in their development.

The Colombian border city where the study has been carried out is affected by internal violence caused by the actions of illegal armed groups that trigger the internal displacement of people. Moreover, public educational institutions are experiencing a massive influx of Venezuelan citizens. These facts make this research meaningful, although it only provides a snapshot of a particular moment in time because schools in this Colombian city form a multicultural environment with a diversity of needs and capacities, on which little research has been conducted.

In addition to the earlier discussion, the achievement in mathematics is influenced by several factors, among which the following stand out:

- (a) Attitude toward mathematics and intrinsic motivation play an important role, since a negative attitude toward mathematics or a lack of motivation can affect the student's willingness to actively participate, engage in learning, and overcome challenges (Ma, 1999; Naya-Riveiro et al., 2015; Fernández-Cézar et al., 2019).
- (b) Mathematical skills developed in earlier stages are fundamental because if students have gaps in their understanding or misconceptions of basic concepts and skills, they may have difficulties progressing to more advanced topics, so it is important to build a solid foundation in mathematics from the early stages (Prada-Núñez et al., 2020; Gamarra Astuhuaman and Pujay Cristóbal, 2021).
- (c) A teaching approach that encourages active participation, critical thinking, problem-solving, and practical application of mathematical concepts tends to be more effective than an approach focused on memorization and repetition of formulas (Sáez López, 2018).

- (d) Students benefit when the teacher provides clear guidance, adequate explanations, constructive feedback, and opportunities to practice and apply what they learn (Alonzo Rivera et al., 2015).
- (e) The confidence students exhibit in their own mathematical skills is crucial, as in its absence, they may experience anxiety and avoid facing challenging problems (Casis et al., 2017).

Considering all the aforementioned discussion, the affects or feelings that students experience toward mathematics are an influential aspect of math achievement. In this sense, evidence from the Colombian context is provided in Prada Núñez et al. (2021a), where it is highlighted that the affective domain toward mathematics is a line of research in mathematics education that “arises as a response to the constant negative attitude, apathy or rejection toward Mathematics that a considerable number of students show, regardless of the stage of the educational system they are in” (p. 205). Also in this context, Fernández-Cézar et al. (2019) depicted and verified the descriptors of the affective domain toward mathematics and gender among students from vulnerable contexts. In this region, the affective domain is also studied for mathematics teachers, as compared to Spain by Fernández-Cézar et al. (2020), who carried out a comparative study of beliefs and anxiety toward mathematics, concluding that Colombian teachers exhibited lower levels of anxiety.

Given the lack of literature on the context of interest detected, this research aims to validate (or not) the following research hypothesis:

As students progress through the various courses of the educational system, they tend to lose interest and fondness for mathematics, which is reflected in low academic performances and behaviors of apathy and rejection.

The novelty of the study lies not only in the examination of the affective domain in mathematics education in an underrepresented context but also in the method of analysis used to depict it. For this purpose, the statistical technique called correspondence analysis (CA) is employed as a multivariate analytical tool for exploratory purposes (San Martín Fernández, 2011; Algañaraz Soria, 2016), without strict requirements on the structure of the data (León, 2008). This analysis is aimed to shed light on the study situation by identifying the relationships between various categorical data such as beliefs, attitudes, and emotions toward mathematics, along with the level of academic performance and the academic grade the student is enrolled in. The goal is to discover possible student profiles as underlying categories.

Materials and methods

This research is framed within a positivist paradigm, following a quantitative approach with a non-experimental and cross-sectional design (Palella and Martins, 2010; Hernández et al., 2014).

Participants

The sample consisted of 2,729 students from 13 educational institutions selected on a non-probabilistic basis, based on compliance with the following inclusion criteria:

- Offering all grades from the first grade of primary basic education to the eleventh grade of vocational high school;
- Voluntary expression to be part of the research;
- Being geographically located in the city of San José de Cúcuta or its metropolitan area, which corresponds to the northeastern border of Colombia bordering Venezuela.

Instrument

The instrument was a form composed of *ad hoc* questions created for this research to collect demographic and academic aspects of the participants, along with the assessment of the components of the affective domain toward mathematics. For the latter, the following process was followed: after reviewing the literature, the instrument with the greatest acceptance within the academic community was identified for each of the components of the affective domain. Then, an analysis of the cultural sensitivity of each item was carried out, after which a preliminary version of each scale was obtained. A pilot test was then applied to a group of students to determine the discrimination index (DI) of each item, with the criterion for item inclusion being $DI \geq 0.60$.

To characterize beliefs, the questionnaire by Caballero et al. (2014) was used, from which 13 of the 36 proposed items were extracted ($\alpha = 0.86$). For attitudes, 14 of the 25 items extracted from the questionnaire proposed by Auzmendi (1992) were considered ($\alpha = 0.89$), and for emotions, 10 items suggested by Fernández et al. (2016) were used ($\alpha = 0.88$). In all cases, the wording of the statements was adjusted according to the characteristics of the context, and answers were provided using a Likert scale with five levels of agreement. This instrument has been used in previous research with participants from the same context, as reported in Núñez et al. (2023).

With respect to the reliability of each of the basic descriptors or components in the questionnaire, Fernández-Cézar et al. (2021) reported a comprehensive analysis of the cultural sensitivity of the questionnaire items, accompanied by an exploratory factor analysis that allowed contrasting the results with the theoretical references analyzed, such as McLeod (1992) for beliefs, Callejo (1994) for attitudes, and Weiner (1986) for emotions. Additionally, supported by SPSS version 25 software, Cronbach's alpha coefficients of 0.743, 0.835, and 0.872 were obtained for beliefs, attitudes, and emotions, respectively, toward mathematics. These values are considered acceptable for the instrument, according to Oviedo and Arias (2005). Since authors like Ventura-León and Caycho-Rodríguez (2017) recommend the use of the omega coefficient, which is less affected by the number of items, it has also been calculated, providing values of 0.764, 0.821, and 0.865 for beliefs, attitudes, and emotions, respectively, toward mathematics. These values fall between 0.70 and 0.90, which is considered admissible according to Campo-Arias and Oviedo (2008).

Procedure

The selection of key informants took place among the participants whose parents or representatives signed the informed consent form. At the same time, the students were informed about the aim of the study. The research procedure followed the guidelines of the Declaration of Helsinki. The evaluation was carried out in person at each educational institution.

Data analysis

MCA is used, which, unlike other techniques, does not impose assumptions on the structure of the data, nor does it require linear relationships between variables, nor does it necessitate that they are measured on a ratio or interval scale (León, 2008). CA is a versatile method from the family of statistical data visualization tools applied to contingency tables. The results include a mapping of points (similar to a scatterplot) representing the rows and columns of the table. When a contingency table with more than two qualitative variables is analyzed using CA, it is known as MCA (Algañaraz Soria, 2016). Its field of application is mainly constituted by the analysis of surveys with multiple-choice questions.

The variables are categorized since the answers, for each item, are provided following a Likert scale of five points, from totally disagree (1) to totally agree (5), crossing neutrality (3). For the achievement, the categories created are high, medium, and low, corresponding to the following ranges: low for performance between 0.0 and 2.9, medium for performance between 3.0 and 3.9, and high for scores between 4.0 and 5.0.

To perform this analysis, the responses were integrated into an Excel data sheet, and the XLSTAT add-in was subsequently used to generate the correspondence graphs. The Statistical Package for Social Sciences v. 29 was used to obtain reliability coefficients (alpha and omega).

Results

In this section, each of the basic descriptors of the affective domain and various characteristics of the students' academic profile in mathematics is analyzed separately to identify hidden structures between categorical variables through graphical representation. For each scale, tables are provided, including the item, the wording sense (positive or negative), and the label.

Beliefs toward mathematics

Table 1 lists the items, the wording sense, and the identification label.

The first two factors of the plane shown in Figure 1 explain 12.1% of the total inertia (Factor 1 explains 6.3%, while Factor 2 explains 5.8%), a value that is low but common in MCA due to factoring the original space R^{65} into the best possible projection in R^2 (León, 2008). Looking at the graph of the CA variables, it is observed that the first factor orders the responses associated

with the beliefs toward mathematics dimension by mathematics achievement and by grade level.

To the right of the abscissa axis (Factor 1), students characterized by high mathematics achievement, a liking for mathematics, and enrollment in grades 4, 5, and 6 are positioned. Conversely, to the left of this factor are students with low achievement, a disliking for mathematics, and enrollment in grades 7, 8, 9, 10, and 11.

With these characteristics, it is possible to visualize how certain groups of responses form associations with specific profiles of participating students, enclosed within geometric figures on the plane for easier visualization.

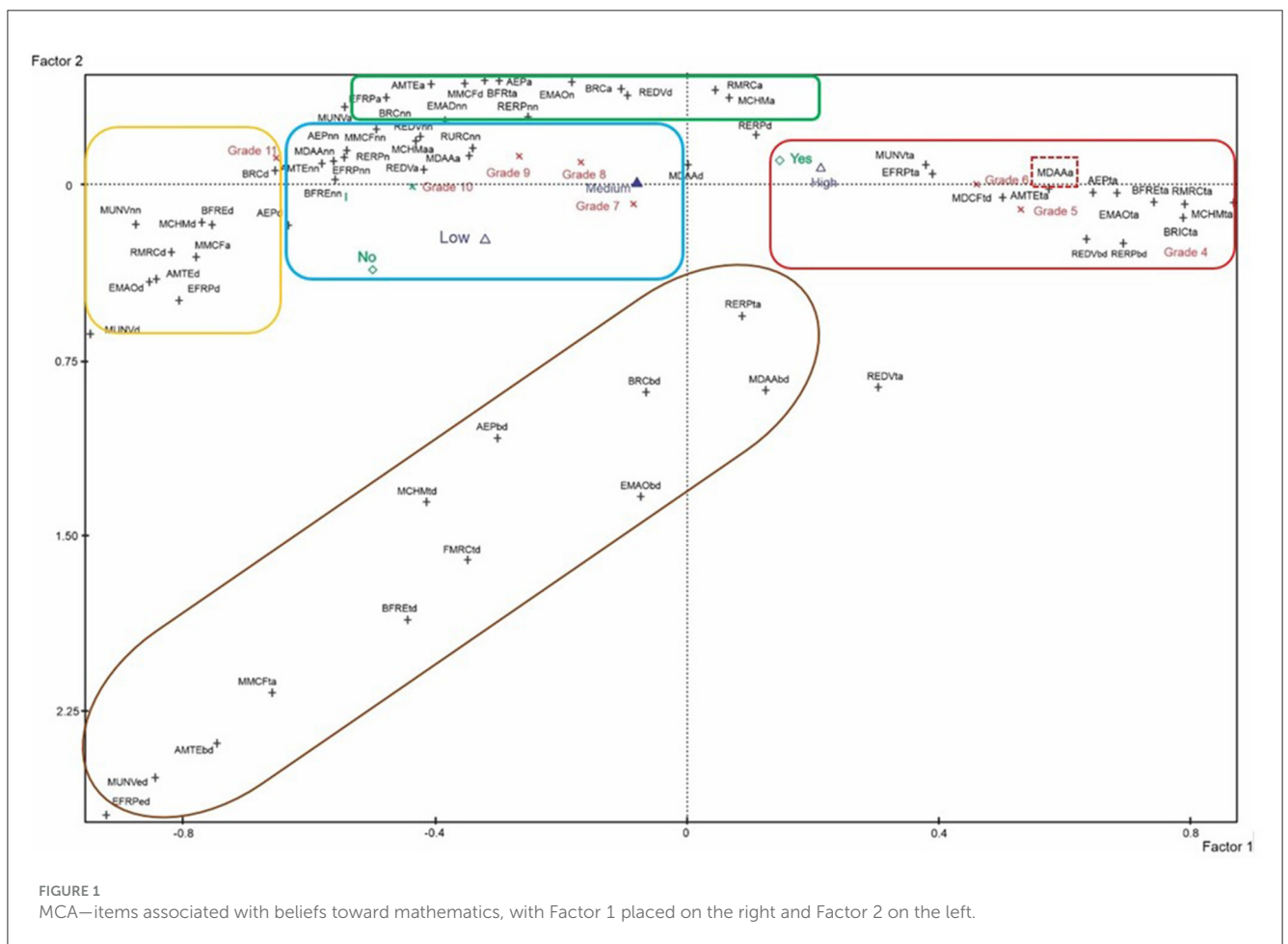
(a) It is observed that responses on items indicating very favorable beliefs toward mathematics—those expressing total agreement (ta) on items with positive wording and total disagreement (td) on items with negative wording—are predominantly positioned toward the positive part of this factor (enclosed in a red figure). Therefore, it can be interpreted that students in grades 4, 5, and 6, in general, exhibit very positive beliefs toward mathematics compared to those enrolled in other grades. They also tend to like mathematics and perform well in this subject. The positioning of the category corresponding to item 2, “Mathematics is difficult, boring, and far from reality,” with the response option total agreement (identified with the label MDAAta and enclosed within a red-dotted rectangle), is striking. This response stands out as an exception to the rest of the items in this dimension, indicating a very unfavorable belief toward mathematics and being located next to the rest of the very favorable opinions. Therefore, it is interpreted that there are students with high achievement in mathematics who like this subject but tend to think *that mathematics is difficult and boring*. In particular, there is an inclination to associate fifth and sixth graders with this type of perception, which is influenced by the pedagogical activity carried out by the teacher.

(b) On the far left of Factor 1 (enclosed in a yellow figure), there is a tendency for responses with a moderately negative perception of creativity in mathematics, indicating disagreement (d) with statements in a positive direction and agreement with items in a negative direction (a). Students with these opinions, in general, are characterized by disliking mathematics, having low math achievement, and being enrolled in the eleventh grade.

(c) Enclosed in a green figure, there is a moderately positive position in beliefs toward mathematics that tends to be located on the top of Factor 2 or the axis of the ordinates. In contrast, on this same axis, students exhibiting an extremely negative position are placed toward the bottom side of this factor and enclosed in the brown figure. These two groups of individuals are not clearly characterized. However, when the group with a moderately positive perception is compared with its projection on the abscissa axis, it is observed that they present variable achievement levels: low, medium, or high. Students whose answers are placed around the tags RMRCa, MCHMa, and RERPd (corresponding to items 11, 12, and 6, respectively) tend to indicate that they like mathematics and show medium or high achievement. Those who present the remaining discreetly positive opinions on beliefs show performance in mathematics between medium and low; this group comprises students enrolled between seventh and eleventh grades; in addition, some indicate that they do not like mathematics, particularly those

TABLE 1 Items associated with beliefs toward mathematics.

| Items | Wording sense | | Label |
|---|---------------|----------|-------|
| | Negative | Positive | |
| 1. Mathematics is useful and necessary in all aspects of life. | | X | MUNV |
| 2. Mathematics is difficult, boring, and far removed from reality. | X | | MDAA |
| 3. In mathematics, it is essential to learn by heart the concepts, formulas, and rules. | X | | MMCF |
| 4. Mathematics exercises can be solved quickly if you know the formula, rule, or procedure. | | X | EFRP |
| 5. In order to learn mathematics, I must spend extra time studying on my own. | | X | AMTE |
| 6. When I solve a mathematical exercise, the value of the result is more important than the process used. | X | | RERP |
| 7. The way I solve mathematical exercises in class is different from the way I need to solve situations in everyday life where mathematics is required. | X | | REDV |
| 8. I look for different ways and methods of solving exercises in mathematics. | | X | BFRE |
| 9. From the exercises done in class, I can invent my own mathematical exercises. | | X | AEIP |
| 10. Understanding mathematics helps me to solve doubts in other disciplines. | | X | EMAO |
| 11. When I solve an exercise in mathematics, I feel confident that the answer is correct. | | X | RMRC |
| 12. I consider myself very capable and skilled in mathematics. | | X | MCHM |
| 13. To do well in mathematics, you need to be intelligent and creative. | | X | BRIC |



who answer MMCFa, EFRPa, and AMTEa (corresponding to items 3, 4, and 5, respectively).

The extremely negative beliefs, located toward the bottom of the second factor, are presented by middle- and low-achieving students who do not like math. However, some of those students with a very negative perception who answered RERPta and REDVta (corresponding to items 6 and 7, respectively) declared medium and high achievement.

Attitudes toward mathematics

Table 2 lists the items, the sense, and the identification label.

The first factorial plane of the variables, obtained by conducting MCA on the 14 items of this dimension, can be seen in Figure 2, explaining 15.1% of the total inertia, with Factor 1 accounting for 8.1% and the second factor for 7.0%.

For the attitudes toward mathematics dimension of the applied questionnaire, it can be observed that the first factor orders the modalities of responses to the items according to academic achievement in mathematics, with low achievement toward the left, medium achievement toward the center, and students with high achievement further to the right. It is also observed that the grade level is distributed from the right to the left of Factor 1 or equivalently from the positive end (fourth grade) to the negative end (eleventh grade). To the right of Factor 1 are the modalities that do like mathematics, and to the left are those students who do not like mathematics.

Thus, students in the fourth, fifth, and sixth grades tend to exhibit high achievement in mathematics and indicate that they do like the subject. These individuals show a very favorable attitude toward mathematics, indicating total agreement with the items in a positive sense and total disagreement with item 2 stated in a negative sense (SIREtd), framed within the plane in a light-blue box. In opposition to them, there is a group of students characterized by low achievement in the tenth or eleventh grades, toward the far left of the first factor (enclosed in a red oval).

The *undecided group* (neither accept nor reject [nn], inside the green oval) is somewhat dispersed near the center of the plane but always to the left of Factor 1. These are students distinguished by medium to low math achievement, who report not liking mathematics while in grades 7 to 11.

In orange, responses that tend to be moderately favorable to the items in this dimension (response option agree [a]) are enclosed. Individuals who tend to state this type of response exhibit medium or high math achievement, have a liking for mathematics, and are in grade 8 or 9.

A group with a very unfavorable attitude toward mathematics (response option totally disagree [td]) is delimited within the yellow figure. These response options are positioned quite dispersed toward the bottom of the ordinate axis or Factor 2. Students with these types of responses tend to dislike mathematics and mostly perform poorly. Some individuals who responded SDGMtd and SIREta (very unfavorable attitude toward items 10 and 2, respectively) tend to report average performance.

Emotions toward mathematics

Table 3 lists the items, the wording sense, and the identification label.

In the factorial plane obtained through the MCA in Figure 3, the different positions taken by the answers to the statements of each of the items of this dimension and the characteristics that the students who gave those answers tend to present are observed. This plane captures 14.9% of the total variability of the data, where 8.2% corresponds to Factor 1 and 6.7% to Factor 2.

In contrast to the two previous dimensions, in the case of emotions toward mathematics, it is observed that the responses are positioned opposite to the extremes of Factor 1. The five response options to the items that tend to be grouped together in any way are enclosed in geometric figures.

Liking or disliking mathematics and the different levels of academic achievement are located very close to the center, so they are not relevant explanatory variables in this case to characterize the responses in this dimension.

In the first quadrant of the factorial plane are located the most emotionally favorable responses toward mathematics associated with the positively worded items (2, 4, 7, 8, 9, and 10) at the strongly agree response level (ta) or the negatively worded items (1, 3, 5, and 6) at the strongly disagree response level (td), which are associated with students in grades 4 to 6 but more strongly with those in grade 4 (light-blue figure).

The second quadrant is dominated by moderately favorable responses to emotions toward mathematics (response levels of agree [a] and neither accept nor reject [nn]) for eighth graders enclosed in the yellow oval.

In the third quadrant, the responses of the undecided (neither reject nor accept [nn] enclosed in a green figure) are located at the top. Eleventh graders are mainly associated with this type of response, although ninth and tenth graders also tend to do so. Further toward the bottom of this third quadrant are the moderately unfavorable responses (response option disagree [d]), where the profile of the respondents is similar to that of the *undecided* (inside the red rectangle).

In the fourth quadrant, all highly unfavorable responses to emotions toward mathematics [response options strongly agree (ta) with the negatively worded items and strongly disagree (td) with the positively worded items] are placed within an orange circle. The profile of these students is not clear, provided that some fourth graders tend to show a very unfavorable perception of this dimension, while others fourth graders tend to show a very favorable one.

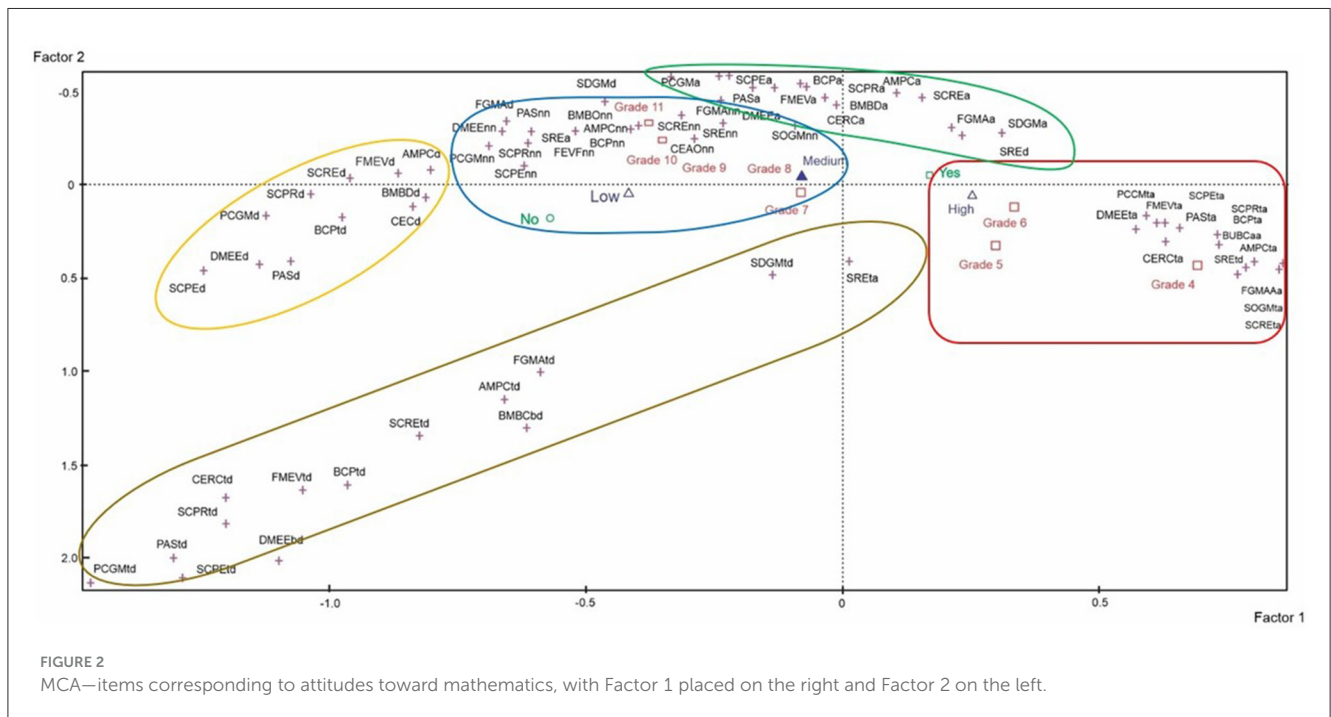
Discussion

The aim of this research was to validate, or not, this hypothesis.

As the student progresses through the various courses of the educational system, he/she loses interest and liking for mathematics, which is reflected in low academic performances and behaviors of apathy and rejection.

TABLE 2 Items corresponding to attitudes toward mathematics.

| Items | Wording sense | | Label |
|--|---------------|----------|-------|
| | Negative | Positive | |
| 1. When I try hard to solve mathematics exercises, I usually arrive at the correct answer. | | X | CERC |
| 2. Luck plays a role in the success of a mathematics exercise. | X | | SIRE |
| 3. Mathematics becomes more comprehensible for me when the teacher in class uses different examples that enable me to relate mathematics to everyday situations. | | X | FMEV |
| 4. When I see the teacher's willingness to clarify doubts that arise during class, I become more interested in mathematics. | | X | PASI |
| 5. Establishing good communication with the mathematics teacher sparks my interest in studying the subject. | | X | BCPI |
| 6. If the teacher explains concepts clearly and enthusiastically, it fosters my appreciation for mathematics. | | X | PCGM |
| 7. I feel engaged in mathematics when the teacher takes an interest in my academic performance. | | X | SCPR |
| 8. I feel committed to mathematics when the teacher appreciates my effort in the subject. | | X | SCPE |
| 9. Having a family member who enjoys mathematics attracts me to study it. | | X | FGMA |
| 10. I feel unique because of my fondness for mathematics. | | X | SDGM |
| 11. Increasing my understanding of mathematics makes me feel like a competent person in society. | | X | AMPC |
| 12. I feel confident when solving mathematics exercises. | | X | SCRE |
| 13. Mastering mathematics will enable me to succeed in my further studies. | | X | DMEE |
| 14. Proficiency in mathematics helps me perform well in other disciplines. | | X | BMBD |



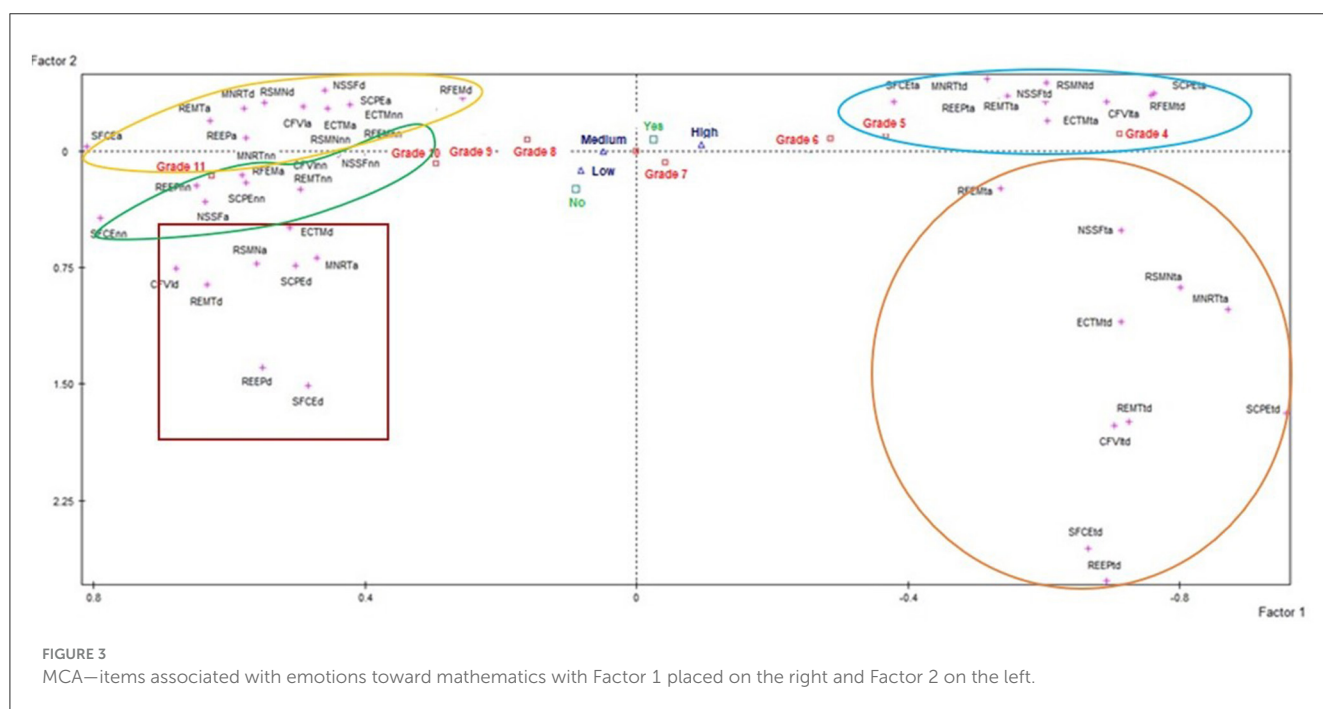
For that purpose, we have identified the relationships between categorical data, such as beliefs, attitudes, and emotions toward mathematics, and mathematics achievement and the student's grade in order to discover possible student profiles in the region of interest. The sample consisted of 2,729 students chosen with a non-probabilistic sampling from 13 educational institutions. They were administered a form with sociodemographic data, three scales for beliefs toward

mathematics, attitudes, and emotions toward mathematics, as well as mathematics achievement, and the grade as an independent variable.

Although the sample is big, the lack of probabilistic sampling weakens the conclusions of this study and avoids generalization of results. Meanwhile, the following results derived from this research allowed us to characterize two groups of students based on the relationship between beliefs, attitudes, and emotions toward

TABLE 3 Items corresponding to emotions toward mathematics.

| Items | Wording | | Label |
|---|----------|----------|-------|
| | Negative | Positive | |
| 1. I give up easily when I am asked to solve a mathematics exercise, even without finding the solution. | X | | RFEM |
| 2. I am curious to know the answer when the teacher asks me to solve a math exercise. | | X | SCPE |
| 3. I feel nervous when the teacher unexpectedly asks me to solve a math exercise on the board. | X | | MNRT |
| 4. When I solve math exercises in a group, I feel more at ease. | | X | REMT |
| 5. When I cannot find the solution to a math exercise, I start to feel insecure, anxious, and nervous. | X | | RSMN |
| 6. If I cannot find the solution to a mathematics exercise, I feel that I have failed and wasted my time. | X | | NSSF |
| 7. I am happy when I solve a mathematics exercise correctly. | | X | SFCE |
| 8. When I fail to solve a mathematics exercise, I try again, using a different method of solution. | | X | CFVI |
| 9. Solving a mathematics exercise requires effort, perseverance, and patience. | | X | REEP |
| 10. I am calm and tranquil when solving mathematics exercises. | | X | ECTM |



mathematics with math achievement and the grade the student is enrolled at:

- (a) Students with high academic performance who express their liking and enjoyment for the study of the subject, appreciating its knowledge and valuing its importance, and who are in the fourth, fifth, or sixth grade.
- (b) Students with low academic performance who reject the subject because they consider it to be boring, unpopular, and difficult and who are in the seventh grade and beyond.

The characterized students' profiles underscored the importance of various factors within the affective domain for academic success in mathematics, as outlined by Martínez Padrón (2013), paraphrasing Polya, Schoenfeld, and Goleman to highlight

the importance of emotions in mathematical activity. Specifically, it is stated “that solving a problem is not merely an intellectual matter, but an emotional one” (p. 3). The findings facilitated the identification that as students progress through different grades of the educational system, there is a shift from liking mathematics to the generation of feelings of rejection and apathy. These results are aligned with the observations of Rosario Perdomo and García Martínez (2018), who stated:

As young people advance in their academic training, the degree of difficulty in the area of mathematics increases. If children do not have a good foundation from previous grades, they will begin to lose their love for this area, so much so that their academic performance in relation to mathematics will decrease (n.p.).

Despite not being a longitudinal study, the findings of this research showed that students in higher grades exhibit more

negative beliefs and attitudes toward mathematics compared to students in the first grades, who display greater comfort and a more positive attitude toward the study of this discipline. Nonetheless, these results could be permeated by the characteristics of the sociocultural context and teaching practices, as reported by Skott (2009), who highlighted the influence of context on teacher beliefs, or by any learning disability, such as dyscalculia, which could be responsible for low achievement, potentially causing an excess of anxiety (Devine et al., 2018). Although evidence from different countries is reported in the literature (Álvarez Pérez et al., 2003; Lozano Díaz, 2003; Navarro et al., 2006; Molera Botella, 2012; Cruz et al., 2014; Naya-Riveiro et al., 2015; Casis et al., 2017; Fernández-César et al., 2019, 2021; Agualongo Quelal and Garcés Alencastro, 2020; Gamarra Astuhuaman and Pujay Cristóbal, 2021), suggesting that several factors contribute to poor academic results in mathematics, this could be considered a generalizable statement, aligning with our results. Also, the works by Lee (2009), Foley et al. (2017), and Lau et al. (2022) found a relationship between emotions and students' academic performance, coinciding with our findings, as well as the relationship identified between mathematics anxiety and low performance in mathematics in the work by Devine et al. (2018).

Therefore, despite the absence of probabilistic sampling in our research, as well as in most of the studies referenced, these results then provide valuable information that allows us to validate the hypothesis suggested in this research. We can highlight the conclusions on the identification of the relationship between the basic descriptors of the affective domain toward mathematics, the grade, and the liking for the subject, with the level of academic performance achieved by a group of Colombian students. Groups of students with opposite profiles have been obtained, where the liking for mathematics and high academic performance occurs in the first three grades of the educational system, changing to the contrary from grade 7 until grade 11.

This situation would be the subject of future research, given that, from the literature review, some possible variables are suggested. These include the increase in the level of complexity and abstraction of mathematical concepts, inadequate teaching practices, and the presence of gaps in pre-skills that prevent their progression to higher levels of complexity, among many others.

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Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Author contributions

RP: Data curation, Investigation, Methodology, Software, Writing—original draft. MR: Visualization, Writing—review & editing. RF-C: Conceptualization, Funding acquisition, Validation, Writing—review & editing. NS-P: Funding acquisition, acquisition, Supervision, Writing—review & editing.

Funding

The author(s) declare financial support was received for the research, authorship, and/or publication of this article. Castilla-La Mancha University under Faculty of Education of Toledo financial program.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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