Mexican secondary students' image of mathematics

A imagem da matemática de alunos mexicanos do ensino secundário

María del Socorro García-González
Autonomous University of Guerrero
Mexico
msgarcia@uagro.mx

Cynthia Ivonne Martínez-Merino
Autonomous University of Guerrero
Mexico
13486766@uagro.mx

José Antonio Juárez-López
Meritorious Autonomous University of Puebla
Mexico
jajul@fcfm.buap.mx

Lidia Aurora Hernández-Rebollar
Meritorious Autonomous University of Puebla
Mexico
lidia.hernandez@correo.buap.mx

Abstract. This article aims to understand Mexican students' images of mathematics. The image of mathematics is defined as a mental representation of mathematics and in order to identify it four focal points were established: (1) descriptions of the mathematics learning process; (2) beliefs about the nature of mathematics, (3) appraisals of mathematics, and (4) emotions. Drawings were used as a data collection tool. A group of 138 students drew a picture as a response to the question: What is mathematics? The students' drawings indicate that mathematics is considered as operations and geometric representations, and value it as a subject to be applied. Furthermore, it was found that students experience emotions of distress and satisfaction due to mathematics. Regarding the learning process, the role of the teacher is prominent in the drawings. Lastly, the article concludes with possible implications for teaching.
Keywords: images of mathematics; secondary students; mathematics education.

Quadrante: Revista de Investigação em Educação Matemática 32(2) 153-174
https://doi.org/10.48489/quadrante.31946
Received: April 2023 / Accepted: December 2023

Resumo. Este estudo tem como objetivo compreender as imagens da matemática dos estudantes mexicanos do ensino secundário. A imagem da matemática é definida como uma representação mental da matemática e, para a identificar, foram estabelecidos quatro pontos focais: (1) descrições do processo de aprendizagem da matemática, (2) crenças sobre a natureza da matemática, (3) apreciações da matemática e (4) emoções. Foram utilizados desenhos elaborados pelos alunos como instrumento de recolha de dados. A cada aluno, de um conjunto de 138 estudantes, foi solicitado um desenho como resposta à pergunta: O que é a matemática? Os desenhos dos alunos indicam que a matemática é vista como constituída por operações e representações geométricas, e valorizam-na como uma disciplina a aplicar. Além disso, verificou-se que os alunos experimentam emoções de angústia e satisfação decorrentes da matemática. Relativamente ao processo de aprendizagem, o papel do professor é proeminente nos desenhos. Por fim, o artigo conclui com possíveis implicações para o ensino.
Palavras-chave: imagens da matemática; alunos do ensino secundário; educação matemática.

Introduction

"How do young children engage in the work of a mathematician?" (Fuys & Huinker, 2000, p. 341). This is how the introduction of a series of articles published by the National Council of Teachers of Mathematics (NCTM) began at the start of the millennium. The articles reflected various concerns for investigating images or visions that students held about mathematicians and mathematics.

School mathematics is highly prestigious in society and has become a filter for students to advance in their educational journey at each educational level. However, the answer to the question "what is mathematics?" has many different nuances and, depending on the relationship someone has had with it, there can be an answer that values these nuances favourably or unfavourably. Research on the Affective Domain has sought to understand the relationship that students, teachers, and society have with mathematics. Such inquiries have been developed based on different affective constructs, including attitudes, beliefs, and emotions towards mathematics (Masz & Schlöglmann, 2009; McLeod, 1989).

Some results of our studies (Martínez-Sierra & García-González, 2017; García-González & Martínez-Padrón, 2020) show that, if these factors are indeed positive, the students will have a positive relationship with mathematics that will ultimately end with a learning experience. On the other hand, if the student is constantly exposed to negative emotional experiences and does not accomplish to be resilient, the student is at risk of developing an attitude of rejection towards mathematics and of developing a belief of mathematics being difficult, which in turn, would lead him, or her, to think of themselves as being a failed mathematics student.

One of the domains that have been thoroughly explored is the images that students have of scientists, particularly regarding their drawings (Chionas & Emvalotis, 2021; Picker & Berry, 2000; Thomas et al., 2001; Thomas et al., 2006). All these studies have stressed the

importance of using drawings for a detailed understanding of the different visions that students have of science related individuals. A review of the students' images when drawings are used as a means of study can be seen in the work of Chang et al. (2020).

The direct answer to the previously posed question lies in the image of mathematics construct. A review on this construct has led us to the realization that there is no consensus about its meaning (a synthesis of the literature on this construct can be found in Hatisaru, 2019 or Piatek-Jimenez et al., 2020). The most extended definition of image of mathematics is the mental representation or vision of mathematics. Additionally, the results of the studies show that the referred image is constructed based on school experiences, but also on the relationship students have with their parents, classmates, and society in general (Hatisaru, 2019; Hatisaru & Murphy 2019; Hoyles, 1982; Lane et al., 2014). Even when this definition seems to be close to a belief, it is actually not because, according to some authors, this vision is formed based on different factors. For example, a theoretical framework for the study of the image of mathematics is presented in Lane et al (2014); it consists of three domains, the affective domain (attitudes, self-image, emotions), the cognitive domain (beliefs), and the conative domain (motivation).

Despite there not being a consensus, several studies have been developed in different countries regarding two types of images of mathematics: one related to mathematics as a school subject (Hatisaru, 2019; Lane, 2017; Lim & Ernest, 2000; Martin & Gourley-Delaney, 2014; Stiles et al., 2008), and the other related to the mathematical profession (Castañeda et al., 2019; Grevholm, 2010; Piatek-Jimenez, 2008; Piatek-Jimenez et al., 2020; Picker & Berry, 2000; Berry & Picker, 2000; Rock & Shaw, 2000; Sánchez et al., 2016). Out of these two schools of thought, the one related to the image of mathematicians is the most numerous. Many different techniques, including drawing, Likert-type scales, and interviews have been used to develop both types of study. The use of all these tools in the same study as a manner of triangulation has been suggested by some authors (Piatek-Jimenez et al., 2020; Picker & Berry, 2000; Takeuchi et al., 2016).

It is important to note that few studies have focused themselves on the images students have while learning mathematics (Hatisaru, 2020; Turgut & Turgut, 2020). An important result that came out of these investigations is that students generally perceive mathematicians' gender as masculine, and those that value the feminine, although in a smaller percentage, are female students (Grevholm, 2010; Piatek-Jimenez, et al., 2020; Picker & Berry, 2000; Sánchez et al., 2016). However, specifically talking about mathematics teachers, there seems to be a bias towards considering it a feminine profession (Hatisaru, 2019).

As a whole, research on the topic of images of mathematics suggests that their significance lies in revealing valuable insights into the connection students are establishing with school mathematics, including their level of enjoyment or rejection of the subject.

These findings have important educational implications, as they offer the opportunity to improve a negative relationship with mathematics and further enhance a positive one.

In the Mexican context, we have identified only two studies that focused on the images of mathematicians (Sánchez et al., 2016; Castañeda et al., 2019), leaving the exploration of the image of mathematics largely scarce. Therefore, the aim of this research is to explore and understand the image of Mexican students regarding mathematics through the analysis of drawings. Our intention is to contribute to the current knowledge about the visual representations of mathematics in the Mexican educational context, addressing a relatively understudied area.

A review about the images of mathematics

Images of mathematics

Public images of mathematics from 548 adult members of public of the United Kingdom were analysed by Lim and Ernest (2000) based on five rubrics, (a) attitudes towards mathematics and its learning, (b) beliefs regarding the interviewees' own mathematical abilities, (c) descriptions of the mathematics learning process, (d) epistemology and perspectives of the nature of mathematics, and (e) values and goals in Mathematics Education.

Three types of attitudes were identified: positive ('mathematics is interesting/rewarding'), negative ('mathematics is boring'), and indifferent (some individuals consider mathematics irrelevant and of little use). As for the beliefs, they were associated to the students' own abilities and experiences with mathematics. Some believed that mathematics was hard, but that success could be reached; while others thought of it as difficult, inexplicable, or confusing. Regarding the descriptions of the mathematics learning process, the citizens pointed out that mathematics learning is a cognitive process that requires logical and analytical reasoning to solve problems.

Regarding epistemology or the nature of this field, mathematics was identified as numbers and formulas, rules and procedures, patterns and structures. It was also considered as a practical tool, a model, a language, a science, or a field of study. Finally, regarding the values and goals in Mathematics Education, the responses showed appreciation for the values in mathematics or its beauty; for example, some pointed out that "mathematics is like a sunset: unique and beautiful". Regarding the goals, mathematics was considered a challenging activity.

Students' images of mathematics in USA daily life were analysed by Martin and Gorley-Delaney (2014). Thirty-five sixth grade children participated in the study. The results showed images of mathematics related to activities involving arithmetic and counting as a mathematic activity, while setting aside geometry. Furthermore, most of the students associated the image of mathematics with activities related to their contexts; for example,

children from higher-status backgrounds tended to associate mathematical activities with roles like running an office, whereas children from families engaged in activities like farming tended to exclude mathematics from such types of work.

In Turkey, Hatisaru (2019) examined lower secondary students' images of mathematics, and for that purpose, she focused on drawings that depicted a mathematician who was a mathematics teacher. According to the results, the drawings showed mathematics teachers were predominantly female, had a positive image, incorporated lectures, explanations, and demonstrations; and used whiteboards and books as tools of the profession. According to the author, this gender bias is due to the geographical context. In Turkey, it is not uncommon to have more female than male teachers in schools, including mathematics teachers. Moreover, although teaching is also a sought-after career path for males, the school teaching profession is viewed more as a female profession in Turkish society.

The impact of the parents' job in the image of mathematics has also been explored. Regarding this subject, Piatek-Jimenez (2008) examined this impact in 356 students aged between 15 and 18. The findings of this study suggest the existence of a relationship between the parents' jobs and the students' image of mathematics since it was found that the children of parents with jobs involving mathematics (financial banking, accountancy, mathematics teacher) reported a bigger enjoyment of mathematics, in addition to a high motivation regarding mathematics, a higher mathematics concept and lower levels of mathematics anxiety.

Lastly, we mention some studies that explored the attitudes of students through drawings. Stiles et al. (2008) examined the attitude towards mathematics of 129 American students of ages between 11 and 17. As a result, many strong emotions towards mathematics were found ranging from positive, such as liking it, to negative, such as rejecting it. This result aligns more closely with the perception of mathematics, as the conceptualization of mathematics is intertwined with attitudes (Lane et al., 2014). According to the authors, the drawings provided a good source of information about teenagers' opinions towards mathematics since they were capable of expressing their emotions about the subject. Additionally, they indicated that, in most cases, the drawings were thought provoking and detailed, and that students participated enthusiastically and appreciated the opportunity of illustrating their own perspectives. Consequently, this study demonstrated that teenager drawings provide a good medium on which to analyse the perspectives and emotions of students, as already suggested in this study (Belbase, 2013; Turgut & Turgut, 2020). Particularly, the study made by Belbase (2013) provides evidence regarding the relationship between images, anxiety, and attitudes towards mathematics.

Takeuchi et al. (2016) examined oral and written mathematics autobiographies together with drawings of how students feel when doing mathematics and what they think mathematics is. They conducted interviews with 39 students (25 boys and 14 girls) from

kindergarten to Grade 2 classrooms in Alberta. The majority of these students reported positive relationships with mathematics, 75.7 % of the students drew pictures to indicate positive feelings, though some described negative relationships with school mathematics learning. However, by the time students reached Grade 2, their feelings towards mathematics were not as uniformly positive. They noticed that many Grade 2 students described their feeling towards mathematics in relation to their perceived competence.

In summary, several studies have examined the images of mathematics in different contexts, such as the United Kingdom, the United States, and Turkey. Their findings reveal different attitudes, perceptions, and influences related to mathematics. However, in the case of Mexico, there has been no specific empirical research conducted on the images of mathematics. Therefore, it is crucial to carry out studies in this context to gain a better understanding of Mexican students' perceptions of this school subject. Doing so could allow for the development of more effective and contextualized strategies in the teaching and promotion of mathematics in Mexico, as well as help to combat negative stereotypes and to foster a positive attitude towards the discipline.

Images of mathematicians

One of the pioneer studies about images of mathematicians is that made by Picker and Berry (2000), in which the images of mathematicians provided by 476 students between the ages of 12 and 13 in USA (201), UK (99), Finland (94), Sweden (49), and Romania (33) were analysed. The results revealed a negative image of mathematicians, seen as badly mannered beings, and threatening and oppressive teachers. These same authors conducted a study where seventh graders in three schools of USA participated (Berry & Picker, 2000). Students were asked to draw a picture of a mathematician. According to the results, the images of mathematicians were primarily of males; all were white; the majority had glasses or a beard; most were balding or had weird hair, and they were invariably at a chalkboard or computer. In another similar study, Hatisaru & Murphy (2019) classified the Turkish students' drawings in two groups: those that represented a mathematician while in work, and those that represented a mathematician as a mathematics teacher. It was possible to establish that more students that represented teachers did not like mathematics and had negative emotions towards its learning.

In another study (Moreau et al., 2009), it was found that students who were interviewed saw mathematics in a similar light to how they are represented in movies, TV, books, or other media. In their study, Piatek-Jimenez (2008) interviewed five female students from the university in United States; the study deduced that the images of mathematicians are of beings: (a) extremely intelligent, (b) obsessed with their work in mathematics, and (c) not fitting in with social norms. In Norway, Grevholm (2010) investigated about the images of

mathematicians from upper secondary school students. The results show that mathematicians were perceived as men, old, lonely, generally using glasses, and occasionally with beard. In contrast, Yazlik and Erdogan (2018) observed a prevailing perception of mathematicians as male in drawings, with female students predominantly depicting female mathematicians. Students generally envision mathematicians aged between 20 and 49 years, illustrating them in suits, gowns, and sportswear. These representations reflect how gender stereotypes influence high school students' perceptions of mathematicians.

In Mexico, only studies regarding the image of mathematicians have been reported. Sánchez et al. (2016) investigated the high school students' images of mathematicians. In their results it was found that most students drew a mathematician without eyeglasses, with a casual outfit, and few students drew people wearing a lab coat. Regarding the hairstyle, most drawings were of mathematicians with formal hairstyles, and few students drew bald people. Their findings were consistent with those from Yazlik and Erdogan (2016), since the participants of this study perceived the mathematicians in a classroom or an office. By comparison, the results discussed in the study of Sánchez et al. (2016) differ from those reported by Picker and Berry (2000) and Grevholm (2010). One explanation for this difference is the type of students who participated in the study, the Mexican students were enrolled in a high school focused on providing special academic training for students who want to pursue studies related to physics, mathematics or engineering; therefore, they received a greater amount of mathematics and physics education than students from other research settings.

Castañeda et al. (2019) focused on identifying and describing the representations of mathematicians contained in Mexican textbooks of lower secondary level. The results show that the representations that most frequently appear in the textbooks are white male mathematicians (mainly Europeans), who lived in ancient times; and the representations of female mathematicians are almost nil. Another study that was made with help of Mexican students revealed that the images shown in the test seemed to be similar to those reported in the literature; namely where most of the mathematicians are thought of as men (Sánchez et al., 2012).

As previously shown, some images of mathematicians have been corroborated by different investigations, such is the case of perceiving it as a masculine profession; and some others vary, such as the image of a man with glasses or beard, balding or with weird hair. The explanation to these coincidences and differences seems to be mediated by the cultural context and educational level of the students.

Theoretical position regarding the image of mathematics

Based on the literature review, this investigation defines the image of mathematics in the sense of Lane et al. (2014, p. 81) as "a mental representation or view of mathematics,

presumably constructed as a result of past experiences, mediated through school, parents, peers or society". From the point of view of the cited authors, the image of mathematics includes three domains:

- The affective domain: dealing with attitudes, emotions and self-concept regarding mathematics and mathematics learning experiences.
- The cognitive domain: dealing with beliefs regarding mathematics and mathematics learning experiences.
- The conative domain: dealing with motivation regarding mathematics and mathematics learning.

Considering these domains, the image of mathematics was identified through the analysis of the drawings, focusing on four predetermined focal points, (1) descriptions of the mathematics learning process; (2) beliefs about the nature of mathematics, (3) appraisals of mathematics, and (4) emotions.

The four predetermined focal points are related to the three domains as follows. The criterion of emotions directly aligns with affective domain as it pertains to emotions regarding mathematics and mathematics learning experiences. The analysis of drawings can reveal the emotional aspects students associate with mathematics. The criteria of descriptions of the mathematics learning process and beliefs about the nature of mathematics are connected to the cognitive domain. Descriptions of the learning process reflect students' cognitive understanding of how they perceive and approach mathematics. Beliefs about the nature of mathematics provide insights into students' cognitive frameworks and conceptualizations of the subject. Finally, the criterion of appraisals of mathematics relates to the conative domain, as it involves students' motivation and engagement with mathematics. The analysis of drawings can shed light on students' levels of interest, enthusiasm, and motivation towards the subject.

Below are the descriptions of each of the 4 criteria, intended to help the reader understanding the guidelines from which the drawings were analysed.

1) Descriptions of the mathematics learning process: refers to the experiences that students have regarding the process of learning mathematics, such as the difficulty or ease they experience, the teaching methods used, among others.
2) Beliefs about the nature of mathematics: refers to the ideas and conceptions that students have about mathematics, such as its usefulness, real-life applications, its logic and structure, among others.
3) Appraisals of mathematics: refers to students' perceptions of the value of mathematics, in terms of its importance for their academic and professional future, its usefulness in everyday life, among others.

4) Emotions: refers to the emotions that students experience when learning mathematics, such as anxiety, boredom, interest, satisfaction, among others.

These criteria provide an objective and structured framework to guide the interpretation of the drawings, offering clear guidelines and specific methods to identify and understand the most significant elements present in the drawings. This approach helps to mitigate subjectivity and ensures a consistent foundation for analysis.

Furthermore, through investigator triangulation and author discussion, efforts were made to ensure consistency and validity in the interpretation of the drawings. By involving multiple researchers in the analysis process, different perspectives and interpretations can be considered, reducing the potential for individual biases.

Materials and Methods

Participants

In the framework of the support program to "college education 2019", a motivation workshop on science, technology, engineering, arts, and mathematics with duration of four hours was developed in the Autonomous University of Guerrero on November 29th, 2019. It is a public university with its main facility in the state of Guerrero, located in the south of Mexico. This university offers more than 50 careers, among them mathematics.

Approximately 300 secondary students (12-15 years old) from different schools, all from the public sector and located in the capital of Guerrero, attended the workshop. They are three general schools, General Wilfrido Massieu (E1), Galo Soberón y Parra (E2), and José Agustín Ramírez (E3), and an industrial and technical secondary school, Aarón M. Flores Moctezuma (E4). The difference between a general and a technical secondary is that the first one prepares students to continue with their studies, and the latter, besides preparing the student, also certifies him or her in being suited for a job in the field of industrial technology. It is worth mentioning that there was no previous relationship with the students that could interfere with data collection.

The students were taken by their teachers to the workshop during school hours. In the workshop, the first author developed, with a colleague, a talk to motivate students to study to become mathematicians. As a detonating activity for the workshop, the first author suggested to make a drawing of the image of mathematics. 138 students accepted to participate in this activity and approved of their drawings to be used as part of an investigation.

The use of drawings as a data collection method

Henrion (1997) suggested that images not only reveal beliefs, but underlying assumptions and expectations, giving ideas of what we feel. In the case of studies about images of

mathematics, the literature has shown the potential of the drawings and there is evidence that supports the idea of drawings providing a reliable source of information about teenager opinions towards mathematics (Sánchez et al., 2016; Stiles et al., 2008). This is the reason why we use drawings as a data collection tool.

Students were asked to draw, individually, to respond to the question "what is mathematics?". Furthermore, the students were asked to write their age, sex, and school in the drawing. They were given 15 minutes to finish the drawing. There were some students that delivered the drawing before the time limit. Drawings were collected and scanned afterwards for their analysis.

The decision to focus solely on the analysis of drawings without complementing it with interviews was based on the following reasons. Firstly, by using only drawings as a data collection method, it allows for a direct exploration of the student's mental image through their own visual representation. This provides a more authentic and genuine understanding of how they perceive and represent mathematics. Furthermore, by avoiding interviews, potential biases or influences that may arise during the interview process are eliminated. Interview questions can guide or influence students' responses, potentially altering the true representation of their mental images of mathematics. By solely focusing on the drawings, a purer and uninfluenced perspective is obtained. Another advantage of drawing as a data collection method is its accessibility and comprehensibility for a large number of students. Drawing is a visual and tangible way of communicating ideas, which can facilitate student engagement and expression, particularly for those who may feel uncomfortable or insecure expressing their thoughts in a verbal interview.

Data analysis

The data analysis involved four stages:

1. Familiarization with the Drawings: Initial observation of the drawings to identify elements related to the mental representation of mathematics.
2. Identification of a Pattern: Recognition of a consistent pattern in the drawings, linked to the four criteria: (1) descriptions of the mathematics learning process; (2) beliefs about the nature of mathematics; (3) appraisals of mathematics; and (4) emotions.
3. Grouping of Similar Drawings: Grouping of coherent drawings for a more detailed analysis of specific criteria.
4. Creation of Categories: Identification and creation of categories to address diversity within each aspect of the criteria, enabling a more refined analysis of visual representations.

Out of the 138 productions created by the students, only 2 drawings were excluded due to difficulties in interpreting the representation of mathematics in the initial stage. The

remaining 136 drawings underwent analysis by the second author, who established an initial categorization. This categorization was subsequently discussed with the rest of the authors as a form of investigator triangulation (Rothbauer, 2008).

To identify a student's production, we used the following codification: Sex-Age-School they came from. For example, Woman-14-E1, indicates that the drawing was made by a female student of age 14 from the school General Wilfrido Massieu.

Results

Six categories capturing various student perceptions of mathematics were identified (see Table 1). Each category is detailed below.

Table 1. Categories of images of mathematics

Descriptions of the mathematics learning process	Beliefs about the nature of mathematics	Appraisals of mathematics	Emotions
C1. Role of the teacher (7)	C2. Mathematics is arithmetic and algebra (72)	C4. Mathematics is used (6)	C5. Mathematics distresses me (20)
	C3. Mathematics is geometry (21)		C6. Mathematics brings me satisfaction (10)
7	**93**	**6**	**30**

Based on the criterion 'Descriptions of the mathematics learning process' (referring to the experiences that students have regarding the process of learning mathematics, such as the difficulty or ease they experience, the teaching methods used, among others), we proposed the category 'Role of the Teacher' (C1). This category was formed based on a specific set of 7 drawings. These drawings highlight the figure of the teacher, who consistently appears at the chalkboard, either explaining concepts or solving mathematical operations.

Criterion 2, 'Beliefs about the nature of mathematics', refers to the ideas and conceptions that students hold regarding mathematics, including its usefulness, real-life applications, logic, and structure. We identified two categories that reflect beliefs about the nature of mathematics, specifically related to distinct areas of the subject. Most notably, we found drawings that simultaneously referenced Arithmetic and Algebra (C2, 72 drawings), evidenced by the use of numbers and variables such as 'x'; while a smaller number of drawings depicted Geometry concepts (C3, 21 drawings), including flat and sparsely three-dimensional geometric figures such as the cylinder, cube, and pyramid. We assert that these categories emerged as a result of the curriculum content taught to the students.

The criterion 'Appraisals of mathematics' refers to students' perceptions of the value of mathematics, in terms of its importance for their academic and professional future, its usefulness in everyday life, among other aspects. Here, we found only 6 drawings that depicted the application and use of mathematics. We named this category "Mathematics is used" (C4). The fifth and sixth categories are derived from the 'Emotions' criterion, where we identified Distress (C5, 20 drawings) and Satisfaction (C6, 10 drawings). In identifying emotions within the drawings, our focus was on facial expressions or symbols conveying emotion. Additionally, we took into account instances where students used emotionally charged words. The categories are presented in Table 1.

It is important to note that, although the drawings in the emotions category may exhibit connections with descriptions of the mathematics learning process and beliefs about the nature of mathematics, since emotion is the most prominent aspect, it was decided to include them in that category.

Next, we give a detailed description of the categories, accompanied by the evidence obtained from students' productions. It is worth mentioning that the drawings aim to showcase representativeness, and due to space constraints, only 1 or 2 are displayed.

C1 – The role of the teacher

The drawings within this category provide valuable insights into how students perceive the teaching methods employed during the mathematics learning process. The recurring theme of confusion among the students (Figure 1) suggests that the explanation provided by the teacher might not be effectively conveyed or comprehended. It is important to note that these drawings primarily focus on the students' perception of the teaching methods rather than their emotional responses.

Figure 1. Woman-14-E2

The depiction of the teacher explaining the topic indicates that the teacher is actively engaged in delivering the lesson. However, the students' confusion suggests that there may be a mismatch between the teaching approach and the students' understanding. It could imply that the teacher's explanations are either unclear, overly complex, or lacking relevance to the students' prior knowledge.

These drawings highlight the need for a thorough evaluation of the teaching methods used during mathematics instruction. It is crucial to identify the factors contributing to the students' confusion and address them effectively. Possible strategies to consider might include simplifying explanations, utilizing visual aids or real-life examples, and encouraging active student participation through discussions or problem-solving activities.

C2 – Mathematics is arithmetic and algebra

The drawings consist of visual representations that reflect the students' perceptions of mathematics. These illustrations contain symbols associated with arithmetic operations, such as plus, minus, multiplication, and division signs. Furthermore, there are elements related to algebra, such as variables and equations.

The presence of arithmetic symbols in the drawings (Figure 2), along with the association of mathematics with basic operations, suggests that the students perceive mathematics primarily as a tool for performing calculations. This belief aligns with the foundational understanding of mathematics in its practical aspects.

Figure 2. Woman-14- E1

The inclusion of algebraic elements, specifically variables and equations (Figure 2), is less surprising considering the stage of education these students are in. Secondary school marks the beginning of algebraic concepts, and linear equations are often among the initial topics covered. The appearance of these elements in the drawings indicates that the students are starting to grasp the idea of mathematical abstraction and the use of variables to represent unknown quantities.

The coexistence of arithmetic and algebraic elements in the drawings highlights the transitional nature of students' understanding as they progress from concrete arithmetic to more abstract algebraic thinking. It is encouraging to see these elements present in the students' perceptions, as it suggests their growing awareness of the broader applications and logical structure of mathematics.

C3 – Mathematics is geometry

In this category, we have compiled drawings that highlight geometric elements, specifically in the field of surface area and volume calculations. Figure 3 serves as an example of this type of drawing. In Woman-14-E3's drawing, she represents various geometric shapes such as squares, cones, cubes, circles, and triangles, while also including formulas like the surface area of a circle. The drawing includes tools such as a ruler, a set square, and a protractor. Additionally, there is a notebook labelled 'theorems' present. The drawing features multiplications with fractional numbers and even includes the square root symbol. She draws herself next to the whiteboard.

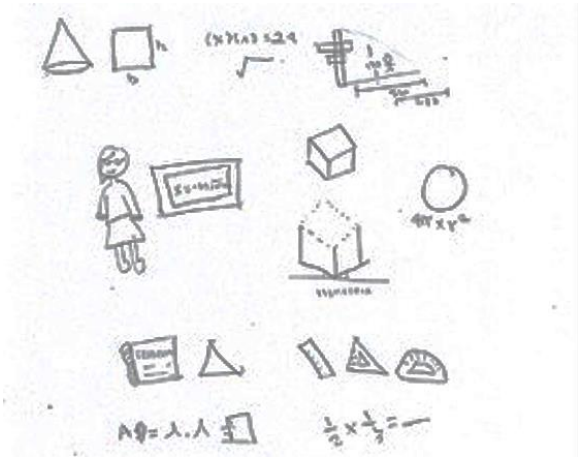

Figure 3. Woman-14-E3

The previous drawing provides a visual representation of geometric concepts related to surface area and volume calculations. The inclusion of various geometric shapes demonstrates understanding of these figures and her ability to visually represent them. Additionally, by including formulas such as the surface area of a circle, she displays knowledge of the mathematical formulas associated with geometric shapes.

The presence of tools like the ruler, set square, and protractor indicates a methodical and precise approach in the drawing. These tools suggest that Woman-14-E3 is utilizing specific techniques and instruments to construct the geometric shapes accurately.

The notebook labelled 'theorems' shows that Woman-14-E3 is aware of the importance of theorems in geometry and their application in calculating area and volume. This indicates a deeper level of understanding and the ability to apply theoretical concepts to practical

problem-solving. The presence of multiplications with fractional numbers and the square root symbol suggests that Woman-14-E3 is working with more advanced mathematical concepts. These elements indicate a level of skill and knowledge in calculating areas and volumes that goes beyond basic concepts.

Overall, Woman-14-E3's drawing reflects a solid understanding of geometric concepts related to surface area and volume calculation. Her ability to represent geometric shapes, use appropriate formulas and tools, as well as work with more advanced mathematical concepts, demonstrates a level of proficiency in this area. Additionally, her position facing the whiteboard could indicate an active and engaged attitude towards learning geometry.

C4 – Mathematics is used

Under criterion 3, Appraisals of mathematics, the drawings compiled in this category shed light on students' perceptions of the value of mathematics. These perceptions encompass its importance for their academic and professional future, as well as its usefulness in everyday life and other aspects.

In Figure 4, Man-14-E3 employs a metaphor highlighting the role of mathematics in science and technology development. The depiction of floating cars and the statement "Future is on its way" conveys the student's perception of mathematics as a driving force behind progress and innovation. This suggests an awareness of the instrumental role of mathematics in shaping the future and advancing of society.

Figure 4. Man-14-E3

These drawings reflect students' appraisals of mathematics as a valuable and influential discipline. They recognize its significance not only for academic and professional pursuits but also for its practical utility in everyday life. By using metaphors and visual representations, the students convey their understanding of mathematics as a powerful tool that transcends traditional boundaries and has wide-ranging implications.

This type of drawings provides valuable insights into students' perceptions of the value and importance of mathematics. It showcases their recognition of mathematics as a foundational discipline that offers opportunities for personal growth, academic achievement, and practical problem-solving. These appraisals of mathematics could indicate a positive attitude towards the subject and a realization of its relevance in various contexts.

C5 – Mathematics distresses me

In the drawings we identified two types of emotions according to the cognitive structure of emotions (Ortony et al., 1996): one negative, labelled as distress (displeased about an undesirable event), and one positive labelled as satisfaction (pleased about the confirmation of a prospect of a desirable event).

In Figure 5, the student's drawing represents distress in relation to not knowing certain topics such as square roots, pi number, Pythagoras' theorem, and the area of a triangle. The student's facial expression, depicted with a frown and the presence of question marks above their head, conveys a feeling of displeasure. This distress arises from the undesirable event of failing in understanding these mathematical concepts. However, there are also indications of resilience and problem-solving in the drawing, as symbolized by the presence of a lightbulb above the student's head and the representation of the world. These elements suggest that the student is making efforts to overcome negative emotions towards the class and find solutions to their difficulties, demonstrating resilience in the face of challenges.

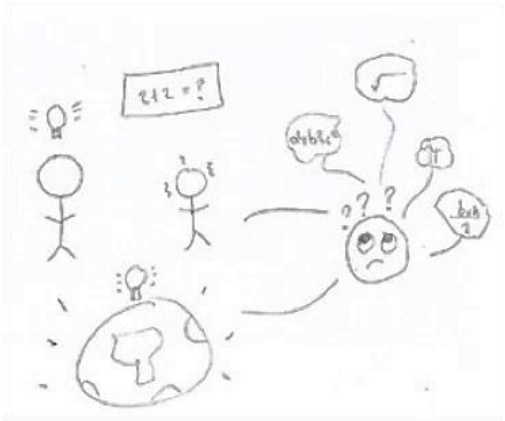

Figure 5. Woman-14-E3

Other students explicitly expressed their perspective on mathematics. For instance, in Figure 6, Woman-14-E4 conveyed that "For me, mathematics is like the Nun because it scares and tortures me", accompanied by a sad face. In this drawing, there is a manifestation of distress related to mathematics. The comparison of mathematics to a nun that instils fear and inflicts suffering, along with the depicted sad facial expression, reflects a negative perception and a feeling of discomfort towards the subject. This representation illustrates

the negative emotions that the student experiences when confronted with mathematics, where the sense of fear and torment are present.

Figure 6. Woman-14-E4

C6 – Mathematics brings me satisfaction

In contrast to distress, students experience satisfaction when they successfully solve problems or have an understanding of the solution (confirmation of a prospect of a desirable event). Figures 7 and 8 depict students realizing their own ability to think and engage with mathematics. In the case of Man-14-E4, he represents himself with a smile while contemplating numbers, letters, addition, subtraction, angles, set squares, protractors, notebooks, and equations (Figure 7).

Figure 7. Man-14-E4

Similarly, Woman-14-E1 portrays herself smiling and immersed in thoughts, with the general formula for quadratic equations written in her notebook (Figure 8). This may be an expression of her proficiency in utilizing the formula.

The drawings not only showcase the students' satisfaction but also reflect a sense of accomplishment and confidence in their mathematical abilities. They provide evidence of the students' belief in their capacity to understand and engage with mathematical concepts.

By depicting themselves smiling and contemplating various mathematical elements such as numbers, letters, equations, and geometric tools, the students demonstrate a positive emotional response towards mathematics.

Figure 8. Woman-14- E1.

These drawings suggest that the students perceive mathematics as a subject in which they can excel and find personal fulfillment. The inclusion of symbols and representations related to mathematics in their artwork indicates their recognition of the value and importance of mathematical knowledge. It is evident that they feel a sense of achievement and pride when they are able to apply mathematical principles and solve problems.

Discussion and conclusion

In the Mexican context, only two studies have focused on the images of mathematicians, leaving the exploration of the image of mathematics largely unaccomplished. Therefore, the present study aimed to expand our understanding of this topic by examining the images of mathematics held by Mexican students. Our objective was to contribute to the existing knowledge and shed light on this understudied aspect within the Mexican context.

The study identified six categories related to the images of mathematics held by Mexican secondary school students. The first category (C1) was associated with the role of the teacher and provided valuable insights into how students perceive the teaching methods employed during the mathematics learning process. The recurring representations of confusion suggest that the explanations provided by the teacher may not be effectively conveyed or understood. This highlights the need for a comprehensive evaluation of the teaching methods used during mathematics instruction in order to identify and address factors contributing to student confusion.

Categories two (C2) and three (C3) helped recognize beliefs about the nature of mathematics. The drawings reflected operations and symbols related to arithmetic and algebra,

suggesting that students perceive mathematics primarily as a tool for calculations. As far as our research is concerned, this result partially overlaps with that of Martin and Gorley-Delaney (2014), who reported an image of mathematics as arithmetic and counting in elementary school children. Additionally, drawings of geometric shapes were identified, indicating an emerging understanding of geometry. This finding differs from the study conducted by Martin and Gorley-Delaney (2014) with sixth-grade students in the United States, where images of mathematics focused on activities related to arithmetic and counting, while geometry was neglected.

This difference in findings could be attributed to the participants' grade level. High school students, being at a more advanced educational level, are likely to have received a more comprehensive mathematical education and had the opportunity to explore and learn about various aspects of mathematics, including geometry. Therefore, their understanding of geometry may be more solid compared to sixth-grade students in the United States, who may still be in the early stages of learning this area.

These findings highlight the importance of considering the educational level when analysing students' images of mathematics. The curriculum and content taught at each level can influence students' perceptions and understandings of mathematics. It is crucial to design appropriate educational strategies that align with the level and needs of the students to promote a more comprehensive and enriching understanding of mathematics in all aspects, including geometry.

The fourth category (C4) is related to the application and utility of mathematics. Students demonstrated the application of mathematics in their drawings, reflecting their understanding of the importance and practical use of the discipline. This finding is consistent with previous studies conducted by authors such as Martin and Gorley-Delaney (2014) and Piatek-Jimenez (2008). These studies have also reported similar observations regarding students recognizing the real-world applications and relevance of mathematics.

The fifth (C5) and sixth (C6) categories are related to students' emotions. Category C5, named Distress, revealed students' distress when lacking understanding of certain mathematical concepts. On the other hand, category C6, named Satisfaction, showed the satisfaction and sense of achievement when students solved problems and had an understanding of the solutions. This finding aligns with the study conducted by Takeuchi et al (2016), who examined the emotions and perceptions of students towards mathematics. They found that many Grade 2 students described their feelings towards mathematics in relation to their perceived competence. This suggests that when students experience success and a sense of competence in mathematics, they are more likely to feel satisfied and accomplished. The positive emotions associated with solving problems and understanding mathematical concepts can contribute to a greater enjoyment and engagement with the subject. It emphasizes the importance of creating an environment where students can

experience success and build confidence in their mathematical abilities, ultimately fostering a positive attitude towards mathematics.

These six categories provide valuable insights into the images of mathematics held by Mexican students. The study reveals both negative and positive perceptions of students towards mathematics, helping us better understand their relationship with the discipline. Furthermore, these categories illustrate the importance of evaluating and addressing teaching methods, fostering a broader understanding of mathematics, and cultivating a positive attitude towards the discipline.

References

Belbase, S. (2013). Images, anxieties, and attitudes toward mathematics. *International Journal of Education in Mathematics, Science and Technology, 1*(4), 230–237. https://ijemst.net/index.php/ijemst/article/view/14

Berry, J. S., & Picker, S. H. (2000). Your pupils' images of mathematicians and mathematics. *Mathematics in School*, *29*(2), 24–26. https://www.jstor.org/stable/30212098

Castañeda, A., Sánchez, M., Gómez-Blancarte, A. L., Romo-Vázquez, A., Lezama-Andalón, J., & Miranda-Viramontes, I. (2019). Representations of mathematicians in lower secondary mathematics textbooks. *EURASIA Journal of Mathematics, Science and Technology Education, 15*(7), 1–13. https://doi.org/10.29333/ejmste/106056

Chang, H. Y., Lin, T. J., Lee, M. H., Lee, S. W. Y., Lin, T. C., Tan, A. L., & Tsai, C. C. (2020). A systematic review of trends and findings in research employing drawing assessment in science education. *Studies in Science Education, 56*(1), 77–110. https://doi.org/10.1080/03057267.2020.1735822

Chionas, G., & Emvalotis, A. (2021). How Peruvian secondary students view scientists and their works: Ready, set, and draw! *International Journal of Education in Mathematics. Science and Technology*, *9*(1), 116–137. https://doi.org/10.46328/ijemst.1099

Fuys, D., & Huinker, D. (2000). Children as Mathematicians. *Teaching Children Mathematics, 6*(6), 341.

García-González, M. S., & Martínez-Padrón, O. (2020). Conocimiento emocional de profesores de matemáticas [Emotional knowledge of mathematics teachers]. *Educación Matemática*, *32*, 157–177. https://www.revista-educacion-matematica.org.mx/descargas/vol32/1/07REM32-1.pdf

Grevholm, B. (2010). Norwegian upper secondary school students' views of mathematics and images of mathematicians. In K. Kislenko, (Ed.), *Current state of research on mathematical beliefs. XVI Proceedings of the MAVI-16*. (pp. 120–136). Tallin, Estonia. https://www.mathematical-views.org/wp-content/uploads/sites/10/2020/06/proceedings_mavi16.pdf

Hatisaru, V. (2019). Lower secondary students' view about mathematicians depicted as mathematics teachers. *International Journal on Mathematics, Science and Technology Education, 7*(2), 27–49. https://doi.org/10.31129/LUMAT.7.2.355

Hatisaru, V. (2020). School student's depictions of mathematics teaching and learning practices. *International Electronic Journal of Elementary Education, 13*(2), 199–214. https://doi.org/10.26822/iejee.2021.184

Hatisaru, V., & Murphy, C. (2019). "Creature" Teachers "Monster" Mathematicians: Students' views about mathematicians and their attitudes to mathematics. *International Journal of Education in Mathematics, Science and Technology, 7*(3), 215–221.

Henrion, C. (1997). *Women in mathematics: the addition of difference*. Indiana University Press.

Hoyles, C. (1982). The pupil's view of mathematics learning. *Educational Studies in Mathematics, 13*(4), 349–372. https://www.jstor.org/stable/3482321

Lane, C. (2017). Student's images of mathematics: The role of parent's occupation. In T. Dooley & G. Gueudet, (Eds.), *Proceedings of the Tenth Congress of the European Society for Research in Mathematics Education*, (pp. 1130–1137). ERME. http://hdl.handle.net/10344/8793

Lane, C., Stynes, M., & O'Donogue, J. (2014). The image of mathematics held by Irish post-primary students. *International Journal of Mathematical Education in Science and Technology, 45*(6), 879–891. https://doi.org/10.1080/0020739X.2016.1170899

Lim, C. S., & Ernest, P. (2000). A survey of public images of mathematics. *Research in Mathematics Education, 21*(1), 193–206. https://doi.org/10.1080/14794800008520076

Martin, L., & Gourley-Delaney, P. (2014). Students' images of mathematics. *Instructional Science: An International Journal of the Learning Science, 42*(4), 595–614. https://doi.org/10.1007/s11251-013-9293-2

Martínez-Sierra, G., & García-González, M. S. (2017). Students' emotions in the high school mathematics classroom: The appraisals in terms of a structure of goals. *International Journal of Science and Mathematics Education, 15*(2), 349–369. http://doi.org/10.1007/s11251-013-9293-2

Masz, J., & Schlöglmann, W. (2009). *Beliefs and Attitudes in Mathematics Education*. Sense Publishers.

McLeod, D. (1989). Beliefs, attitudes, and emotions: New views of affect in Mathematics Education. In D. B. McLeod & D. M. Adams. (Eds.), *Affect and mathematical problem solving* (pp. 245–258). Springer.

Moreau, M. P., Mendick, H., & Epstein, D. (2009). What do GCSE students think of mathematicians? *Mathematics in School, 38*(5), 2–4.

Ortony, A., Clore, G. L., & Collins, A. (1996). *The cognitive structure of emotions*. Cambridge University Press.

Piatek-Jimenez, K. (2008). Images of mathematicians: a new perspective on the shortage of women in mathematical careers. *ZDM Mathematics Education, 40*, 633–646. https://doi.org/10.1007/s11858-008-0126-8

Piatek-Jimenez, K., Nouhan, M., & Williams, M. (2020). College students' images of mathematicians and mathematical careers. *Journal of Humanistic Mathematics, 10*(1), 66–100. https://doi.org/10.5642/jhummath.202001.06

Picker, S. H., & Berry, J. S. (2000). Investigating pupil's images of mathematicians. *Educational Studies in Mathematics, 43*(1), 65–94. https://doi.org/10.1023/A:1017523230758

Rock, D., & Shaw, J. M. (2000). Exploring children's thinking about mathematicians and their work. *Teaching Children Mathematics, 6*(9), 550–555. https://doi.org/10.5951/TCM.6.9.0550

Rothbauer, P. (2008). Triangulation. In L. M. Given (Ed.). *The SAGE Encyclopedia of Qualitative Research Methods* (Volume 1 & 2). SAGE.

Sam, L. C., & Ernest, P. (2000). A survey of public image of mathematics. *Research in Mathematics Education*, *2*(1), 193–206. https://doi.org/10.1080/14794800008520076

Sánchez, M., Rosas, A., & Molina, J. G. (2012). Mexican student's images of mathematicians. In S. J. Cho (Ed.). *Proceedings of the 12th International Congress on Mathematical Education.* (pp. 5838–5847). ICME. https://mariosanchezaguilar.files.wordpress.com/2012/10/aguilar_rosas_zavaleta_2012.pdf

Sánchez, M., Rosas, A., Molina, J. G., & Romo-Vázquez, A. (2016). Exploring high achieving students' images of mathematicians. *International Journal of Science and Mathematics Education, 14*, 527–548. https://doi.org/10.1007/s10763-014-9586-1

Stiles, D. A., Adkisson, J. L., Sebben, D., & Tamashiro, R. (2008). Pictures of hearts and daggers: Strong emotions are expressed in young adolescents' drawings of their attitudes towards mathematics. *World Cultures eJournal, 16*(2), 1–13. https://escholarship.org/uc/item/1sq263b7

Takeuchi, M. A., Towers, J., & Plosz, J. (2016). Early years students' relationships with mathematics. *Alberta Journal of Educational Research*, *62*(2), 168–183. https://doi.org/10.11575/ajer.v62i2.56197

Thomas, J. A., Pedersen, J. E., & Finson, K. (2001). Validating the Draw-A-Science-Teacher-Test Checklist (DASTT-C): Exploring Mental Models and Teacher Beliefs. *Journal of Science Teacher Education, 12*(3), 295–310. https://doi.org/10.1023/A:1014216328867

Thomas, M. D., Henley, T. B., & Snell, C. M. (2006). The draw a scientist test: A different population and a somewhat different story. *College Student Journal, 40*, 140–148.

Turgut, S., & Turgut, I. G. (2020). Me when I am learning mathematics: Reflections to elementary school student's drawings. *International Electronic Journal of Elementary Education, 13*(1), 139–154. https://www.iejee.com/index.php/IEJEE/article/view/1246

Yazlik, D. O., & Erdogan, A. (2016). Image of the high school students towards mathematicians. *Journal of Educational and Instructional Studies in the World, 6*(4), 1–14.

Yazlik, D. O., & Erdogan, A. (2018). Examining the image of prospective teachers towards mathematicians. *Universal Journal of Educational Research, 6*(1), 42–56. https://doi.org/10.13189/ujer.2018.060104