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Towards an Understanding of Mathematical Imaginaries in Contemporary Secondary Education

Hacia una comprensión de los imaginarios matemáticos en educación media contemporánea

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Abstract

The research explores the mathematical imaginaries in middle school students and their influence on learning and attitude towards mathematics. A theoretical framework is established to explore how beliefs and social practices shape the mathematical constructions of students, allowing the identification of the meanings and creations of reality configured around this discipline and its impact on the teaching and learning processes. The qualitative methodology, with an inductive approach, used semi-structured interviews with 20 students selected by convenience, considering variables such as gender, origin and academic performance to ensure diversity. The data were analyzed using grounded theory and systematic coding, allowing emerging categories to be identified that enriched the analysis. The results reveal positive perceptions, such as the practical usefulness of mathematics in daily life and the development of critical thinking, which foster a proactive attitude towards learning, while negative perceptions, such as anxiety, generate significant barriers. The creations reflect how students integrate mathematics into their daily and professional lives, highlighting both benefits and challenges. In conclusion, the inductive approach revealed a dual sketch of mathematical imaginaries: pressure and anxiety in the face of critical skills and empowerment, influenced by rigid methodologies and gender stereotypes, in contrast to cognitive flexibility and preparation for the future.

Keywords

Education, Learning, Secondary Education, Mathematics, Imaginaries, Induction.

Resumen

La investigación explora los imaginarios matemáticos en estudiantes de educación media y su influencia en el aprendizaje y en la actitud hacia las matemáticas. Se establece un marco teórico para explorar cómo las creencias y las prácticas sociales moldean las construcciones matemáticas de los estudiantes, permitiendo identificar las significaciones y creaciones de la realidad configuradas en torno a esta disciplina y su impacto en los procesos de enseñanza-aprendizaje. La metodología cualitativa, con enfoque inductivo, utilizó entrevistas semiestructuradas a 20 estudiantes seleccionados por conveniencia, considerando variables como género, procedencia y desempeño académico, para asegurar diversidad. Los datos fueron analizados utilizando la teoría fundamentada y codificación sistemática, permitiendo identificar categorías emergentes que enriquecieron el análisis. Los resultados revelan percepciones positivas, como la utilidad práctica de las matemáticas en la vida diaria y el desarrollo del pensamiento crítico, las cuales fomentan una actitud proactiva hacia el aprendizaje, mientras que percepciones negativas, como la ansiedad, generan barreras significativas. Las creaciones reflejan cómo los estudiantes integran las matemáticas en su vida diaria y profesional, destacando tanto los beneficios como los desafíos. En conclusión, el enfoque inductivo reveló un boceto dual de los imaginarios matemáticos: presión y ansiedad frente a habilidades críticas y empoderamiento, influenciados por metodologías rígidas y estereotipos de género, en contraste con la flexibilidad cognitiva y la preparación para el futuro.

Palabras clave

Educación, aprendizaje, enseñanza secundaria, matemática, imaginarios, inducción.

Introduction

From an educational perspective, the inductive approach promotes the co-construction of knowledge based on concrete experiences, facilitating the understanding of concepts in real contexts. According to Flick (2018), induction allows for a deep and nuanced understanding of educational

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experiences, highlighting the importance of taking into account both the subjective perspective and the specific context of students within educational processes.

The present study aims to explore how mathematical imaginaries influence the academic and personal trajectories of secondary school students. The main problem lies in how students' imaginaries influence their attitudes toward the discipline and their academic performance. The relationship between these creations and the learning of mathematics in secondary education is fundamental, as it directly affects students' perceptions of their ability to face mathematical challenges and develop competencies in this area. By framing the study epistemologically within social constructivism, as proposed by Vygotsky (1978), it is emphasized that learning is a socially mediated process in which knowledge is formed through constant interaction between people and their environment. This approach is essential for understanding how students develop meanings around mathematics, influencing their attitudes and motivations toward the discipline. In this sense, the central idea is that mathematical imaginaries play a fundamental role in shaping students' attitudes toward mathematics, affecting both their motivation and their academic and personal development. A qualitative methodology with semi-structured interviews and an inductive approach was used, which allowed identifying emerging patterns and meanings in the students' experiences.

This study is particularly relevant because secondary education is a crucial stage for consolidating knowledge, defining interests, and developing skills that will directly impact students' future decisions (Eccles & Roeser, 2009; Hernández *et al*., 2024). Mathematics plays a decisive role not only as a formative discipline but also as a tool for developing analytical skills and solving complex problems (NCTM, 2000).

Mathematics, as a formal discipline, is characterized by its abstract, logical, and axiomatic structure, based on modeling, demonstration, and analysis of quantitative problems (NCTM, 2000). These processes follow a predominantly deductive logic, moving from general principles to specific conclusions. However, mathematics teaching often uses an inductive approach, leading students from concrete cases to abstract concepts (Hjelte *et al*., 2020). This combination facilitates the connection between formal mathematics and its application in everyday situations, significantly impacting students' personal and professional skills, an aspect that is highlighted in contemporary approaches to inductive methodologies applied to mathematics education.

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It promotes the strengthening of cognitive skills, such as logical thinking and decision-making, complemented by the development of emotional skills, such as self-confidence. Understanding how meanings and creations of reality affect self-confidence, problem-solving, and the ability to face challenges is vital for the comprehensive development of students, as these skills are fundamental throughout life (Parada *et al*., 2024b). Mathematical imaginaries, understood as the meanings and creations of reality in that context, play a crucial role in shaping students' identity and attitudes toward mathematics (Parada *et al*., 2024a).

An individual's sociocognitive configuration, explored through an inductive approach in the educational context, shows how individual cognitive processes interact with social factors to shape students' perception and participation in their learning environment (Bandura, 1997; Saharrea, 2022). Imaginary meanings, as collective constructions, serve as interpretive frameworks for understanding shared reality (Castoriadis, 1997; Cegarra, 2012). Furthermore, according to Maslow (1943), satisfying basic needs is key for students to achieve self-actualization and fully develop their cognitive and sociocultural potential. Self-regulation and cognitive flexibility are essential in this process, allowing adaptation to academic challenges (Pintos, 1995).

Social imaginaries, according to Castoriadis (1997), are shared mental representations that a society creates to understand and structure its reality. In education, these imaginaries affect the way students perceive and relate to learning, fostering motivating attitudes or creating barriers. Understanding these imaginaries is crucial for developing pedagogical approaches that address both the academic needs and the cultural and psychological dimensions of learning. Integrating these imaginaries into educational analysis allows for contextualized and effective interventions, enriching the construction of knowledge and attitudes toward mathematics (Castoriadis, 1983; Silva, 2006).

Inductive exploration of mathematical imaginaries in secondary education reveals a complex interrelationship between individual perceptions and educational contexts. This research seeks to identify how students construct their meanings around mathematics and explore how these constructions influence their academic and personal trajectories. Through a hermeneutic perspective and an inductive approach, the aim is to find elements that have an impact on students' academic and personal development and that contribute to the promotion of the comprehensive and sustained development of mathematical skills.

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This document is organized into five sections: elements that outline a theoretical framework are presented, followed by the methodology used, then the results, the discussion, and finally the conclusions.

Inductive approach in mathematics education

The inductive method, essential in the social sciences, is based on observation, analysis, and systematization of data for the formulation of general theories (Cohen *et al*., 2018). In the field of education sciences, this approach allows for an understanding of educational dynamics and processes through the systematic collection of individual and collective experiences (Creswell & Poth, 2018). Induction fosters a deep understanding of how students construct knowledge and meaning, allowing for the creation of pedagogical strategies based on real evidence (Merriam & Tisdell, 2016). This method is particularly useful in the study of mathematics in secondary education, where students' imaginations and perceptions influence their learning and attitudes toward science, technology, engineering, and mathematics (STEM) disciplines (Boaler, 2022).

Efforts have been made in the literature to highlight the importance of creating learning environments that promote collaboration and dialogue, allowing students to reflect on their experiences and build knowledge collectively (Sawyer, 2014). In this context, inductive methodology not only facilitates the identification of patterns and trends in student perceptions, but also provides a solid basis for developing pedagogical interventions that respond to students' specific needs (Darling-Hammond *et al*., 2019).

In pedagogy, the relationship between induction, experience, and action is fundamental to the construction of meaningful knowledge (Dewey, 1938). The student's experience, understood as their direct and practical interaction in the learning environment, provides the raw material for the inductive process (Kolb, 1984). Through reflection on these experiences, educators can identify patterns and trends that inform teaching strategies to optimize learning (Schön, 2017; Romero, 2024). In mathematics, this triad allows us to address students' imaginaries, understanding how their personal and collective experiences shape their conceptions and attitudes toward the subject, thus influencing their future career choices in STEM areas (Sfard, 2008).

The implementation of the inductive method in secondary education allows educators to capture and analyze students' meanings and

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creations of reality around mathematics (Ernest, 2018). Understanding these elements of the imaginary is vital, as they directly influence their predisposition toward STEM careers (NCTM, 2013). Education based on induction, experience, and action not only improves mathematical learning but also enhances students' overall development, preparing them for academic and professional challenges (Bransford *et al*., 2000).

Hermeneutics of student experiences in mathematical learning

Bibliographic research, understood as the in-depth and systematic analysis of existing literature, is an essential pillar in the construction of rigorous academic studies. This journey has covered both classical theories and recent advances in education and mathematics, allowing us to map the epistemological landscape of the inductive method and intertwine perspectives that enrich our understanding of the phenomenon under study. From social constructivism to grounded theory, the importance of interpretation, critical reflection, and pedagogical adaptation is highlighted. Rather than compiling information, it is interpreted and synthesized, building a solid foundation that guides the exploration of mathematical imaginaries in secondary education and ensures conclusions grounded in a multidimensional theoretical framework.

Grounded theory, developed by Glaser and Strauss (1967), complements the pedagogical approach supported by induction, experimentation, and action through the systematization of everyday situations. This approach is particularly relevant in the study of mathematical imaginaries, as it integrates the investigative and educational dimensions to explore how students conceptualize and experience mathematics in their daily and academic lives (Charmaz, 2014).

The hermeneutics of mathematical experiences in secondary education focuses on interpreting the meanings and creations of reality configured by students around learning the discipline. This approach is crucial for understanding how students develop mathematical competencies and how these competencies influence their development (Tillería Aqueveque, 2023). The literature suggests that being mathematically competent involves not only mastering concepts and procedures, but also developing communication, reasoning, and problem-solving skills in mathematical contexts (Rico & Castro, 1995; Escudero *et al*., 2012). This hermeneutic study allows us to identify how students perceive and construct their

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mathematical reality, which can significantly influence their motivation and academic performance (Kaskens *et al*., 2020).

On the other hand, the hermeneutics of student experiences in the classroom allows us to identify the factors that facilitate or hinder learning. Positive attitudes toward mathematics and the perception of competence directly influence motivation, which favors academic performance (Gjicali & Lipnevich, 2021). In addition, an inductive approach to mathematics teaching promotes reflection on previous experiences and adaptive pedagogical action, which can significantly improve learning and attitudes toward the subject (Murphy & Ingram, 2023). This knowledge is essential for adjusting teaching methods to respond to the specific needs and contexts of secondary school students.

Methodology

This research takes a qualitative approach, using the inductive method to explore the meanings and creations of mathematical imaginaries in secondary school students. This approach allows for a deep understanding of the participants' experiences and perceptions, as it focuses on interpreting phenomena from the perspective of those involved (Taylor *et al*., 2016). The choice of the inductive method is based on the need to generate theories based on data obtained directly from students, rather than testing pre-existing hypotheses (Thomas, 2006). This methodology is suitable for exploratory studies that seek to discover new dimensions of the phenomenon under study (Corbin & Strauss, 1998).

A system of categories was established in which the unit of analysis or variable corresponds to «the meanings and creations of reality in the teaching and learning processes of mathematics configured by secondary school students» (Parada *et al*., 2024b). This system is structured as a theoretical construct that considers the categories «social construction of reality» (Berger & Luckmann, 1967), «learning environments» (Vygotsky, 1978), and «implications of mathematics in being» (Boaler, 2022). The construction of these categories is based on both relevant theoretical references and direct observation of educational practices. The theories made it possible to identify relevant epistemic approaches, while observations in school environments provided empirical evidence that refined the categories, ensuring their relevance in educational practice. Table 1 illustrates these categories and their interrelationships, providing a conceptual framework for analysis.

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Table 1
System of categories of mathematical imaginaries

Unit of observation	Category	Subcategory
The meanings and creations of reality in the teaching and learning processes of mathematics configured by secondary school students.	Social construction of reality	Worldview
		Collective subjectivities
		Social and academic evolution
	Learning environments	Physical context
		Social context
		Digital context
	Implications of mathematics on the self	Mathematical competence
		Life project
		Educational innovation
		Educational quality

A semi-structured interview script was designed with the support of the aforementioned category system, allowing the participants' experiences to be explored without losing sight of the research objectives (Kvale & Brinkmann, 2009). This instrument included open-ended questions to explore mathematical meanings and creations, as well as their perceptions and influences on the educational experience. The structure of the semi-structured interview balances the researcher's guidance with the interviewee's freedom, facilitating both in-depth exploration of specific aspects and natural and meaningful interaction (Patton, 2015).

As a theoretical expression turned into a qualitative collection tool, it was validated in content with the support of three experts with expertise in test theory, another in education sciences with a specialization in mathematics teaching, and a third in social imaginaries. Expert validation ensures that the instrument is appropriate and relevant to the research objectives.

The qualitative instrument was applied to twenty secondary school students, specifically in grades 10 and 11, belonging to Colegio Oriental Educational Institution No. 26 in San José de Cúcuta, North of Santander, Colombia. These grades were chosen because they represent a critical moment in secondary education, when students consolidate their understanding of mathematics and define their academic and professional interests, especially in STEM areas. In addition, as they are about to

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graduate, they have accumulated experiences that allow them to reflect deeply on the impact of mathematics on their school career.

The students were selected through convenience sampling, seeking to include both outstanding and non-outstanding students and to ensure representation of indigenous communities, people displaced by conflict, and gender balance. This technique allows information to be obtained to explore experiences and perspectives within their particular context.

The data collected were analyzed using grounded theory (Glaser & Strauss, 1967), a systematic approach that facilitates qualitative analysis to generate theories based on such data. In this work, grounded theory was activated to develop an emerging system of categories that captured the meanings and creations of students' mathematical imaginaries. This approach, aligned with the inductive method, allowed concepts and patterns to emerge organically from the participants' experiences, building the theoretical framework from the reality explored.

The process began with open coding, identifying key concepts related to the students' experiences. These concepts were preliminarily grouped into the initial categories: «Social construction of reality,» «Learning environments,» and «Implications of mathematics on being.» This early integration allowed the concepts to be aligned with the study objectives, exploring the relationships between individual experiences and their educational context. During selective coding, the categories were integrated into a cohesive theoretical framework that reflected both the emerging patterns and the central meanings identified in the data (Corbin & Strauss, 2015). The initial category system was enriched as new ideas emerged, ensuring that the final framework was closely aligned with the participants' actual experiences.

Analysis and results

The interviews were transcribed and analyzed with the support of the N-Vivo program (Jackson & Bazeley, 2019; QSR International, 2020), facilitating the coding process. This initial category system (Table 1) was used to structure the interviews and analyze the collected data, providing an initial theoretical framework that was modified and enriched during the analysis. Initially, open coding was used to identify and label key nodes or concepts in the data, allowing for an initial grouping of responses into relevant themes. Next, axial coding was applied, in which the relationships between these concepts were explored, grouping them into broader

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nodes or categories. Finally, in selective coding, the main categories were integrated and synthesized into a coherent theoretical structure. This process revealed an emerging system of categories based on students' meanings and creations about the processes of teaching and learning mathematics. Table 2 shows the emerging system of categories, which served as the basis for subsequent analysis.

Table 2
Emerging category system

Unit of observation	Category	Emerging subcategory	Subcategory
The meanings and creations of reality in the teaching and learning processes of mathematics shaped by secondary school students.	Social construction of reality	Cognitive and methodological aspects	Worldview
		Mathematical relevance and necessity	Collective subjectivities
		Educational challenges and opportunities	Social and academic evolution and academic
	Learning environments	Infrastructure and resources	Physical context
		Risks in the use of digital educational resources digital resources (RED)	Social context
		Adaptation and personal perceptions	Digital context
	Implications of mathematics on the self	Changes in mathematical competence	Mathematical competence
		Personal and professional impact	
		Financial decisions and practical usefulness	Life project
		Emotions and perceptions	Educational innovation
		General challenges and barriers	
		Barriers to learning	Educational quality

The development of the analysis allowed us to structure an explanatory theory about the meanings and creations of reality in the teaching-learning processes of mathematics configured by secondary school students, based on the initial category system. This analysis is based on the initial categories defined in the proposed system (Table 1). The explo-

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ration of the data allowed the emerging subcategories to reformulate and enrich the original subcategories. Each emerging subcategory in Table 2 reveals critical aspects of how students interact with mathematics, providing a solid basis for reflection on aspects that could establish elements for improvement in pedagogical approaches and the creation of effective and meaningful learning environments. The interconnection between categories, codes, and emerging subcategories enriched the analysis, providing a broad view of the social and academic reality, as detailed below for each category.

Social construction of reality

Students highlighted the integration of mathematics into their daily lives, recognizing its value beyond the immediate. Comments such as «it helps me think clearly» demonstrate its relevance to logical thinking. These perceptions emerged inductively as recurring patterns that align student experiences with the study's conclusions. Several students pointed out practical examples of the application of mathematics, such as solving problems related to budgeting or time. These experiences highlight its practical relevance and contribution to comprehensive education, consolidating mathematics in the sociocognitive environment (Parada *et al.*, 2024b). The sociocognitive approach shows that mathematical cognition is influenced by the social environment. Students see mathematics not only as a logical tool, but also as a useful resource for facing challenges, strengthening critical skills, and problem solving. This is reflected in positive attitudes toward the discipline and in their commitment to personal and academic improvement, providing a solid foundation for personalized teaching strategies.

Learning environments

Within this category, students highlighted how the physical context affects their educational experience. Several pointed out that excessive heat and noise make it difficult for them to concentrate and perform academically. One student commented, «On hot days, it is impossible to concentrate because there are no fans in the classroom,» while another said, «Sometimes it is hard to hear the teacher because of the noise outside or in the hallways.» These environmental conditions not only limit their ability to concentrate but also negatively impact their academic performance.

In terms of social context, the interviews revealed that positive interactions—collaboration among peers and support from teachers—

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contribute significantly to learning mathematics. One student said, «When we work as a team, I can understand difficult problems better,» highlighting the value of collaborative work. However, obstacles related to social dynamics also emerged, such as fear of ridicule: «Sometimes I don't ask questions because I think they'll make fun of me,» which shows how social dynamics affect motivation and learning.

In the digital context, students identified both challenges and opportunities in the use of RED. Some mentioned technical difficulties, such as unstable Internet connections: «It's frustrating when class is interrupted by connection problems,» while others valued the opportunities offered by online platforms: «Digital resources help me practice what I didn't understand in class.» These experiences show that, while digital resources enrich learning, they also present challenges in terms of access and proper use of technology.

Implications of mathematics on the self

Mathematical competence reveals how students perceive learning as a process that transforms their self-efficacy. One student commented: «I used to think I wasn't good at math, but now I can solve problems faster,» showing an improvement in his academic confidence. This development highlights mathematical skills not only as academic competencies, but as practices that foster motivation and the overcoming of academic challenges.

In terms of life plans, the interviews showed that mathematics influences personal and professional decisions. One participant said, «I want to study engineering because mathematics is key,» while another said, «Managing budgets helps me plan my financial future,» underscoring the relevance of this discipline both in achieving academic goals and in managing daily life.

On the other hand, educational innovation emerged as a relevant topic. Students highlighted that approaches such as gamification make mathematics more attractive: «Classes are more fun with games and applications,» said one of them. However, they also pointed out the need to diversify methodologies to improve educational quality. In addition, emotions such as frustration and satisfaction were shown to have a significant impact: «I get frustrated when I don't understand, but when I solve a problem, I feel like I can achieve anything,» confessed one student, highlighting the importance of addressing both emotions and barriers to learning.

The process of recognizing the meanings and creations of reality in the context of learning mathematics is based on a detailed analysis of

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the perceptions and experiences expressed by students during interviews. Emerging patterns show how they apply mathematics in their daily lives—when managing their time or handling budgets—and in their academic development, using logical thinking to approach other disciplines. One student stated: «Thanks to mathematics, I organize my time better and also understand science problems better.» The use of mathematics in these contexts strengthens skills such as self-efficacy and the ability to overcome challenges. These interpretations influence not only their immediate learning but also the construction of their life project, guiding personal and professional decisions. Positive perceptions boost their motivation and confidence, promoting academic performance and the resolution of challenges in everyday life. The following sections delve deeper into these experiences, revealing how they influence students' personal and professional development.

Meanings of reality

The meanings of reality identified provided a comprehensive understanding of how secondary school students interpret and value mathematics within their academic and personal contexts. These meanings encompass several dimensions, such as personal emotions and perceptions, the impact of the physical environment, teaching strategies, social interactions, and the practical applications of mathematics. Table 3 presents meanings such as the perception of mathematics in everyday life, the impact of environmental conditions on concentration, and the influence of social interactions on academic motivation.

These meanings reflect positive factors—such as the development of self-efficacy and motivation—and challenges related to the physical and emotional environment. This analysis provides a solid basis for understanding how students' interpretations of mathematics influence their learning process and personal development. Personal emotions and perceptions play a crucial role in how students relate to the subject, ranging from anxiety and rejection to interest and satisfaction, which directly influences their motivation and academic performance. On the other hand, the collective recognition of mathematics is significant, highlighting its importance in social and academic contexts, which enhances collaborative learning and contributes to the creation of social interaction environments for learning mathematics.

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Table 3
Meanings of reality identified in mathematics learning

Dimension	Meanings
Emotions and perceptions	Perspectives from personal emotions and perceptions
	Competence and self-efficacy as elements of learning
	Negative reactions to traditional methods
Physical environment	Negative influence of comfort and climatic conditions in the classroom
	Negative physical impact on concentration
	Personal perceptions of negative physical impact
	Negative impact on learning conditions
Teaching strategies	Positive influence of guidance and teaching methods
	Evaluation and complementation of the traditional method
	Criticism of the effectiveness of REDs in mathematics
Social interactions	Negative impact of social behavior and conduct
	Influence of social interactions
	Collective recognition and appreciation of mathematics
	Positive educational interactions and relationships
Practical application	Perception of mathematics in everyday life
	Personal and emotional development through mathematics
	Positive learning experiences
External and personal factors	Impact of personal and external factors
	Negative influence of environmental factors
	Influence on career and personal life decisions

Creations of reality

Creations of reality show how students construct and transform their environment through learning and applying mathematics. These creations reflect their ability to adapt mathematics to different contexts, highlighting its versatility in everyday life. Students who study mathematics develop a holistic and practical understanding of decision-making and problem-solving. In addition, learning mathematics can redefine

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career paths and open up new opportunities. Finally, mathematics contributes to personal and social development, fostering self-knowledge and essential social skills. Among the relevant creations of reality are: the adaptation and applicability of mathematics in different contexts; professional development and transformation through mathematical learning; and the exploration, recognition, and expansion of the social self through the integration of this discipline into everyday life.

At this stage of the study, a triangulation process was used to integrate qualitative and quantitative data in order to corroborate and enrich the findings (Denzin, 2017). The process was carried out by combining qualitative analysis based on grounded theory with quantitative measurements obtained from the *software*. The purpose was to ensure that the qualitative results identified in the interviews—such as the meanings about the perception of mathematics in everyday life and the challenges in the learning environment—were validated by their frequency of occurrence in the collected data.

The qualitative findings presented in Table 3 and the creations of reality—such as the adaptation of mathematics and professional transformation—reflect how students shape their perceptions. Figure 1 shows the frequency of occurrence of these meanings, highlighting patterns identified in the interviews. Triangulation allowed these findings to be validated with quantitative data, also detecting differences between perceptions and observed trends. Figure 1 also represents the occurrences identified through open coding and grounded theory. Key words were analyzed with N-Vivo to quantify their frequency, linking them to the dimensions described in Table 3. This process allowed us to consolidate the relevant meanings in the students' responses.

The analysis showed that emotional perceptions, environmental conditions, and practical applicability dominate the occurrences, all with frequencies below 10%. These results reveal that students attribute different meanings to mathematics, reflecting its impact according to the educational and personal context.

Once we recognize how students shape their meanings and constructions of reality in mathematics teaching and learning processes, it is useful to delve deeper into the analysis of the incidence and impact of these perceptions and constructions. Understanding how these meanings influence motivation and academic performance, and how these creations impact their daily and professional lives, provides a comprehensive view that guides the construction of mathematical imaginaries in secondary education. This, in turn, allows for the implementation of effective

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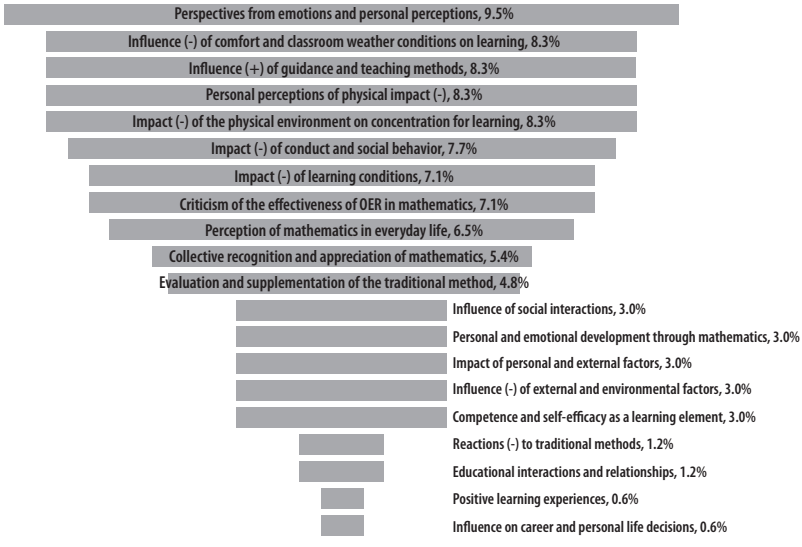
and personalized pedagogical strategies designed to foster the development of cognitive, emotional, and social skills relevant to mathematical learning and its application in everyday life.

Figure 1
Representation of occurrences of meanings in the interviews



Impact of meanings

Knowledge of the impact of the meanings of reality on the teaching and learning processes of mathematics reveals how students' perceptions impact their performance and motivation. During the interviews, students shared diverse experiences with mathematics, commenting that they felt «stress at the possibility of making mistakes» and «fear of being evaluated negatively,» which fostered insecurity and avoidance of studying this discipline. In contrast, students who perceive mathematics as a useful tool in everyday life highlighted its importance in decision-making, budget management, and problem-solving, which increased their interest and was reflected in better academic performance. Evaluations showed that these students achieved higher grades on tests and practical assignments, demonstrating both greater conceptual understanding and active engagement in collaborative activities.

Similarly, the collective appreciation of mathematics in their social environments reinforces positive attitudes toward the subject. Some

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participants noted that social recognition of the value of mathematics «motivated them to try harder,» promoting a collaborative environment in the classroom. Positive interactions with peers fostered confidence in facing challenges, facilitating an enriching educational experience. Thus, the shared perception of mathematics not only increased individual motivation but also promoted collaborative dynamics that enrich learning and strengthen student engagement.

Impact of creations

The impact of the reality creations generated by students reflects how they construct and transform their understanding of the world through learning and applying mathematics. These creations range from adapting mathematical concepts to everyday contexts to transforming their academic and professional perspectives (as discussed in the section «Creations of Reality»). This impact is manifested in students' ability to solve problems and make informed decisions, both in the classroom and in their daily lives. From an academic and professional standpoint, mathematics is positioned as a fundamental pillar in various areas of knowledge, including STEM-related disciplines. Students who identify this connection tend to see mathematics as a key tool for their personal and professional development, especially in careers that require analytical and problem-solving skills.

On the other hand, the creations of reality also reveal the challenges students face, such as academic pressure and the difficulty of connecting abstract concepts with practical situations. Overcoming these challenges through the use of RED and appropriate pedagogical support enriches their learning and fosters their self-confidence. Furthermore, this educational experience contributes to the development of social and emotional skills, thus strengthening their ability to work in teams and make decisions in complex contexts, both inside and outside the academic sphere.

A second phase of triangulation was applied in the research through additional analyses, such as branched mapping and cluster analysis. These analyses focused on keywords selected from the most frequent concepts in the interviews, linked to the meanings and creations of reality identified previously. Each term was associated with emerging themes, such as perceptions of the educational environment, the usefulness of mathematics in life, and academic challenges.

Before the final analyses, the keywords were refined to retain only the most relevant ones, eliminating redundancies and ambiguous terms

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that could introduce noise into the results. This refinement allowed the analysis to focus on the significant patterns derived from the interviews. The final set of keywords formed the cloud in Figure 2, which provides a clear graphical representation of the relevant occurrences of the identified meanings and impacts.

Figure 2
Words associated with the occurrences of meanings and the impact of creations

For its part, the branching map (Figure 3) illustrates how the words most frequently used by students in their responses are organized hierarchically, reflecting the interconnection between concepts. The upper nodes group general terms, such as «classmates» and «help,» while deeper levels reveal emotional nuances and specific situations, such as «stress,» «interactions,» and «frustration.» These relationships show how students perceive their social and academic environment, as well as the emotional challenges they face. For example, terms such as «rejection» and «fear» are linked to «frustration» and «confusion,» highlighting their emotional impact. Other groups, such as «everyday,» «explains,» and «didactic,» highlight the relevance of the practical use of mathematics and the importance of pedagogical strategies that promote its understanding. These associations offer valuable information for developing pedagogical approaches that respond to students' needs.

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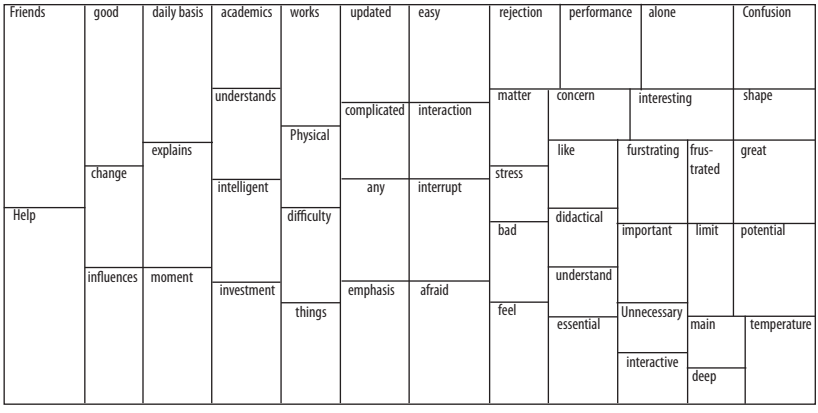
Figure 3
Branch map of words associated with the meanings and emotional impact of interactions in the academic environment



Next, in the cluster map (Figure 4), keywords are grouped according to their frequency and thematic relationship. The size of each bubble reflects how recurrent a term is, and its proximity shows significant associations in student responses. For example, terms such as «complicated,» «interesting,» and «easy» appear together, evidencing diverse perceptions about the difficulty and appeal of mathematics. This suggests that some students find the subject challenging but appealing, while others consider it accessible. These visual representations not only identify the most relevant terms and their connections, but also offer an accurate view of the predominant concerns expressed by participants, guiding the interpretation of results in an informed way (Miles *et al.*, 2018; Simmons, 2022).

Additionally, from the cluster analysis, the words «smart,» «understand,» and «good» are grouped at the top, suggesting an emphasis on the importance of understanding and intelligence in learning mathematics. The proximity between «investment» and «help» suggests that students perceive a direct relationship between the effort invested in their learning and the support received, which improves their performance. Terms such as «difficult,» «confusion,» and «stress» are also closely associated, indicating that these feelings are common in students' educational experience, reflecting the emotional and cognitive challenges they face in their learning process.

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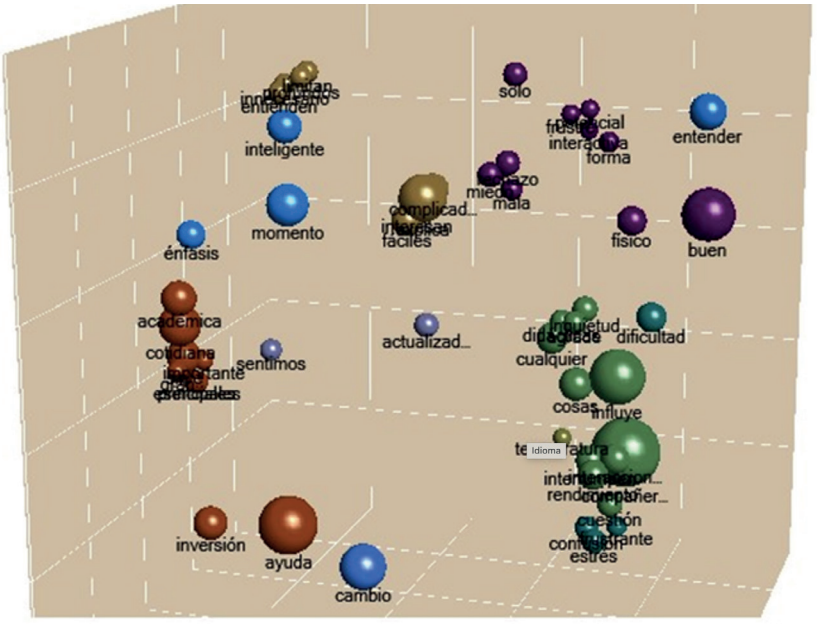
Figure 4
Cluster analysis of words associated with the incidence of meanings and the impact of reality creations



The keywords and their relationships in the branching map, cluster analysis, citations, and nodes established in N-Vivo, together with the support of the emerging category system, served as the basis for interpreting the incidences and implications of meanings and creations in mathematics education processes. This analysis organized the elements into hierarchical descriptors, linking them to the observed occurrences and their pedagogical implications. Each descriptor was based on thematic patterns and frequencies identified in the interviews, as well as on the structure of the emerging category system. Table 4 shows these descriptors, highlighting the key relationships between emerging meanings and creations, and their impact on academic performance and student motivation.

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Table 4
Global descriptors: incidence of meanings and implications of creations

Global descriptors	Incidence/implication
Anxiety and mental blocks during assessments due to complicated questions	Pressure and anxiety
Stress from being the only subject with difficulty	
Physical environment that causes anxiety due to discomfort and affects math performance	
Intense frustration by not understanding mathematics despite great effort	
Fear and rejection of mathematics due to frustrating experiences	
Perceived difficulty in understanding abstract and impractical mathematics	Disconnection from reality
Perception of irrelevance in studying deep mathematical topics	
Need for practical relevance of mathematics in everyday life	
Demotivation due to interruptions, affected by gender stereotypes	Influence of stereotypes
Self-limitation of career due to gender stereotypes and low self-confidence	
Reinforcement of critical skills due to daily use of mathematics	Critical and decision-making skills
Interactivity with mathematics improves critical and problem-solving skills	
Recognition of mathematics as key to enhancing practical skills	
Confusion and demotivation due to lack of up-to-date teaching methods	Rigid teaching methodologies
Difficulties in understanding due to a lack of methods adapted to new generations	
Indifference due to lack of planning of activities focused on different learning styles	
Limited understanding and rejection due to inflexible methods	
Overcoming frustration due to rigid teaching methods	

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Empowerment through mathematical understanding	Empowerment
Empowerment through the practical application of mathematics in everyday life	
Confidence and improved performance thanks to mathematical empowerment	
Empowerment through the usefulness and contextualization of mathematics	
Adaptability and effective problem solving thanks to the flexibility of mathematical thinking	Cognitive flexibility
Confidence and improved performance through mental adaptability	
Learning through participation, collaborative work, and understanding, not rigid memorization	
Engaging lessons and empathetic teachers stimulate mathematical learning	Preparation for the future
Innovative teaching practices influence future professional preparation	
Recognition of mathematics as essential in everyday life, work, and multiple areas of life	

The relationship between global descriptors and incidents/implications facilitates understanding of how each descriptor affects teaching-learning processes in mathematics. For example, anxiety and mental blocks during assessments due to complicated questions are descriptors that generate pressure on students. These types of incidents affect academic performance, creating a challenging educational environment for effective learning. Likewise, the stress of being the only subject with difficulty and the discomfort of the physical environment contribute to a high-pressure atmosphere, exacerbating students' anxiety.

Another important aspect is the disconnect from reality, in which the perceived difficulty in understanding abstract and impractical mathematics leads students to feel that this knowledge is not relevant to their daily lives. This can result in a lack of motivation and a rejection of the study of mathematics. The perception of irrelevance and the need for practical relevance are descriptors that affect the disconnect with educational reality, implying an urgency to adapt the curriculum to show the applicability of mathematics in everyday contexts.

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Gender stereotypes and low self-confidence limit and generate demotivation. These descriptors impact perceptions and aspirations, affecting self-efficacy and the development of critical skills. Active interaction with mathematics and recognition of its relevance in the development of practical skills are essential to counteract barriers and empower students.

Rigid teaching methods generate confusion and demotivation among students. Indifference due to the lack of activities adapted to different learning styles limits understanding and causes rejection. However, overcoming rigid methods can empower students by helping them understand mathematics through practical applications, improving their confidence and academic performance. Empowerment and cognitive flexibility are descriptors that have positive effects. The practical application of mathematics and its everyday usefulness reinforce confidence and improve performance. Adaptability and the ability to solve problems through mathematical thinking foster a flexible and resilient mindset. In addition, innovative pedagogies and the support of empathetic teachers prepare students to face the challenges of the future, recognizing the importance of mathematics in different areas of life.

The background information has been structured to identify positive and negative impacts on students' academic performance and personal development. The descriptors were organized into categories related to impacts and implications. The results were represented visually (Figure 5), showing the positive and negative elements that shape students' mathematical experience. This analysis revealed a complex interaction between these factors, highlighting both emotional and cognitive barriers and benefits in critical thinking and professional preparation.

Figure 5 shows that the mathematical configuration in secondary school students has a dual impact, characterized by positive and negative elements. Among the negative elements, pressure and anxiety are prominent. An excessive focus on competition and performance can generate high levels of anxiety and aversion to mathematics, especially when students encounter difficulties with concepts. This pressure not only affects academic performance but also students' mental health, creating a stressful environment that limits effective learning. Furthermore, mathematics is often perceived as too abstract and unrelated to practical applications, which diminishes its perceived value and leads to demotivation.

On the positive side, mathematics fosters critical and problem-solving skills that are useful in all areas of life. These skills enable students to approach complex problems logically and efficiently, improving their

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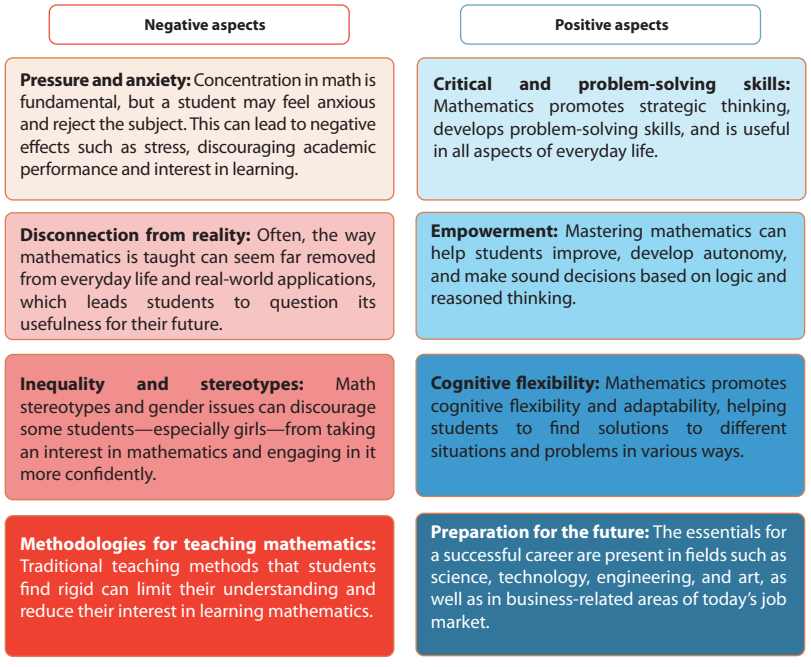
ability to make informed decisions. Empowerment is another key benefit of mastering mathematics. Students who succeed in understanding and applying mathematical concepts gain confidence in their abilities, providing them with tools to control their environment and making decisions based on logical reasoning. This empowerment contributes to better academic performance and a positive attitude toward learning.

Figure 5
Dual impact: positive and negative elements of the mathematics configuration in secondary education students



Cognitive flexibility emerged positively from the students' creations, revealing that mathematical learning enhances the ability to adapt and solve problems in various contexts. These skills are associated with preparation for future career opportunities by fostering the development of essential competencies to face the challenges of the 21st century.

Discussion

The findings of this research highlight how students' perceptions and experiences influence their mathematics learning process. The integration

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of an inductive approach allowed us to explore the diverse meanings and creations of reality that students develop around mathematics. The results indicate that positive perceptions, such as appreciating mathematics as useful in everyday life and beneficial for developing critical thinking, promote a proactive and collaborative attitude toward learning. However, barriers such as anxiety were also identified, which affect students' academic performance. This dualism in perceptions underscores the need for pedagogical approaches that enhance favorable attitudes and mitigate obstacles.

Compared to previous studies, the results of this research confirm the importance of an adaptive and supportive learning environment. Research such as that of Boaler (2022) and Sfard (2008) has pointed out that personal experiences and the social construction of meaning in mathematics are crucial for the development of competencies in STEM areas. This study complements these findings by showing how empowerment and cognitive flexibility emerge in students' creations, enriching their educational experience. The systematic coding process facilitated the detection of these emerging categories, providing an interpretive basis for the complex dynamics that affect academic and personal performance. The inductive approach allowed for the recognition of significant patterns that enrich the educational process in mathematics. The organization of the analysis using *software* leveraged a robust structure for interpreting and qualitative data, delving deeper into the impact of mathematics in the educational context (Bryda & Costa, 2023; Hansen *et al*., 2022; Taherdoost, 2022).

Although this study makes significant contributions, such as identifying meanings and creations around mathematics and using an inductive approach to capture students' subjective and contextual perspectives, it also acknowledges certain limitations. The sample, which is adequate for qualitative analysis, may not fully represent the diversity of experiences in other educational contexts. However, in qualitative research, a small sample is valid since the analysis emphasizes the quality of the data rather than the number of participants (Maxwell, 2013; Creswell & Poth, 2018). The triangulation applied strengthened the validity, compensating for sample limitations and allowing for a broad understanding of the phenomena investigated (Patton, 2015; Denzin, 2017).

Conclusions

This research, based on an inductive approach, has revealed the meanings and creations of reality that secondary school students construct around

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mathematics. Through open, axial, and selective coding, patterns reflecting individual and collective perceptions were identified. The inductive method proved fundamental in capturing the complexity of mathematical imaginaries, serving as a basis for designing adapted pedagogical approaches. Data triangulation, combining qualitative and quantitative analyses, strengthened the validity of the findings and allowed us to understand how educational experiences influence the formation of mathematical attitudes and competencies.

Inducing the intangible, such as mathematical imaginaries, involves valuing students' subjective and collective experiences. The results highlight the importance of learning environments that integrate cognitive, emotional, and social aspects. Strengthening positive perceptions, such as the practical usefulness of mathematics and the development of critical thinking, fosters a proactive attitude toward the subject. In turn, it is crucial to address negative perceptions, such as anxiety and disconnection from reality, to reduce their effects. This study provides a valuable sketch of mathematical imaginaries in secondary education, underscoring the need for pedagogical approaches that respond to the complexity of the student context and promote inclusive learning.

The duality in mathematical imaginaries reveals positive and negative experiences that shape perception and academic performance. Pressure and anxiety, linked to competition and a focus on performance, can generate aversion to mathematics, exacerbated by rigid methodologies, the disconnection between concepts and reality, and cultural stereotypes. However, positive imaginaries promote critical and problem-solving skills, empowering students to approach problems logically. Mathematical learning even develops cognitive flexibility, facilitating adaptation to diverse situations and preparing students for academic and professional challenges in a work environment that demands these skills.

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Declaration of Authorship - CRediT Taxonomy	
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Antonio José Bravo Valero	Conceptualization, data curation, formal analysis, research, methodology, *software*, validation, visualization, writing, original draft, writing, revision, and editing.
Juan Diego Hernández Albarracín	Conceptualization, research, methodology, writing, original draft, writing, revision, and editing.

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Declaration on the use of artificial intelligence
The authors María José Parada Carreño, Antonio José Bravo Valero, and Juan Diego Hernández Albarracín **DECLARE** that the preparation of the article entitled "Towards an understanding of mathematical imaginaries in contemporary secondary education" was supported by artificial intelligence (AI), through the use of ChatGPT 4.0 (standard non-thinking version) exclusively for the tasks of correcting writing and style in the final editing phase of the manuscript and to adjust the clarity of the responses to the reviewers, without any intervention in the theoretical or methodological content or in the results of the study.

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