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THE INFLUENCE OF PROBLEM-SOLVING ALGORITHMS ON STUDENTS' ATTITUDES TOWARDS MATHEMATICS. INVESTIGATIONS AT THE NINTH-GRADE LEVEL

DOCTORAL THESIS

(Abstract)

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Cluj-Napoca, 2026

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Introduction

Mathematics is a fundamental discipline for the development of logical thinking and problem-solving skills. Nevertheless, a substantial body of research has highlighted the existence of negative attitudes towards mathematics, frequently manifested through anxiety and a lack of motivation (Ashcraft & Krause, 2007). This issue is particularly significant at the ninth-grade level, a stage characterised by an increased degree of abstraction and complexity in mathematical content.

Within this context, problem-solving algorithms can provide valuable cognitive support by offering students a clear and structured framework for solving mathematical tasks while simultaneously strengthening their confidence in their own abilities, in accordance with Bandura's theory of self-efficacy (1997). At the same time, the literature cautions against an exclusively procedural use of algorithms, as such an approach may limit students' conceptual understanding of mathematics (Skemp, 1976).

Building upon the conception of attitudes towards mathematics as a multidimensional construct comprising cognitive, affective, and behavioural components (Di Martino & Zan, 2010), the present research investigates the influence of problem-solving algorithms on ninth-grade students' motivation, self-confidence, and engagement in mathematics learning.

The relevance of this study is further supported by the findings of international PISA assessments, which emphasise the importance of effective problem-solving strategies for both mathematical achievement and students' motivation to learn (OECD, 2019; OECD, 2023). The findings of this research are expected to contribute to the optimisation of instructional strategies and to the development of a positive and enduring relationship between students and mathematics.

CHAPTER I. PSYCHO-PEDAGOGICAL FOUNDATIONS OF MATHEMATICAL PROBLEM SOLVING

I.1. Problem Solving as a Complex Cognitive Activity

Mathematical problem solving represents a complex cognitive activity that requires the integrated mobilisation of conceptual and procedural knowledge, cognitive and metacognitive strategies, as well as motivational and affective resources. Beyond the mere application of algorithms, effective problem solving involves analysing the problem situation, selecting appropriate strategies, verifying solutions, and reflecting upon one's own problem-solving process (Gagné, 1975; Ausubel, 1968).

At the beginning of upper secondary education, the increasing level of abstraction in mathematical content requires students to develop advanced competencies in analysis, reasoning, argumentation, and knowledge transfer. Within this context, the use of problem-solving algorithms should be complemented by heuristic strategies and self-regulatory processes that enable students to adapt their approach to the specific characteristics of each mathematical problem.

I.1.1. Cognitive Processes Involved in Mathematical Problem Solving

Problem solving involves cognitive processes such as **analysis, synthesis, abstraction, generalisation, and knowledge transfer**, together with metacognitive processes of **planning, monitoring, and evaluating one's own problem-solving approach**. These mechanisms facilitate the selection of appropriate strategies and foster the development of flexible mathematical thinking (Gagné, 1975; Cerghit, 2006). At the ninth-grade level, they support students' transition from the reproductive application of algorithms to conscious, reasoned, and well-justified problem solvin.

I.1.2. The Role of Logical Reasoning and Mathematical Thinking in Structuring Problem-Solving Approache

At the ninth-grade level, students are expected to move beyond the mechanical application of algorithms and develop the ability to construct logical arguments in support of their solutions, in accordance with the general competencies prescribed by the national curriculum. Mathematical thinking involves abstraction, modelling, and the application of mathematical concepts across a variety of contexts, with an emphasis on understanding the relationships among concepts and adapting problem-solving strategies to the specific characteristics of each task (Cîrjan, 2007).

The development of logical reasoning and mathematical thinking fosters cognitive autonomy by encouraging students to reflect on their own strategies, verify the validity of their solutions, and regulate their learning processes (Bocoș, 2017). Consequently, the systematic integration of activities involving mathematical argumentation, modelling, and evaluation of the problem-solving process supports the development of mathematical competencies and promotes the formation of functional mathematical thinking appropriate for upper secondary education.

I.2. Algorithmic Thinking as a Psycho-Pedagogical Foundation of Mathematical Problem Solving

Algorithmic thinking represents a fundamental dimension of mathematics learning, providing a logical and rigorous framework for structuring the problem-solving process. It involves the application of ordered sequences of operations and rules that lead to the solution of a particular class of mathematical problems, thereby contributing to the development of procedural competence and enhancing the efficiency of cognitive activity. Within the ninth-grade mathematics curriculum, the subject-specific competencies emphasise the use of mathematical algorithms for identifying relationships, modelling mathematical situations, and constructing well-reasoned solutions.

I.2.1. Characteristics of Algorithmic Thinking

Algorithmic thinking is characterised by **rigour, clarity, coherence, and reproducibility**, facilitating the systematic organisation of information and the consistent application of mathematical procedures. Regular practice with algorithms promotes the development of **procedural fluency** while reducing the demands placed on **working memory**, thereby allowing cognitive resources to be allocated to the analysis and interpretation of problem situations (Kilpatrick et al., 2001; Rittle-Johnson & Schneider, 2015). At the same time, the conscious and purposeful use of algorithms enhances students' confidence in their own abilities and encourages them to engage successfully with mathematical tasks of increasing complexity.

I.2.2. Educational Value and Limitations of Algorithmic Thinking in Mathematics Learning

From a psycho-pedagogical perspective, algorithmic thinking contributes to the development of effective work habits, intellectual discipline, and the consolidation of mathematical competencies. However, the exclusive reliance on algorithmic procedures may result in mechanical problem solving and reduced cognitive flexibility when students encounter unfamiliar or non-routine situations. For this reason, the literature advocates integrating algorithmic approaches with heuristic strategies, as well as with activities that promote mathematical argumentation and reflective thinking. Such an integrated approach facilitates conceptual understanding and enhances the transfer of knowledge across a variety of mathematical contexts (Ausubel & Robinson, 1968; Gagné, 1975).

I.2.3. The Relationship Between Algorithms and Automatization

Automatization is the outcome of the systematic and conscious practice of algorithms, enabling the rapid and accurate execution of mathematical procedures. It reduces cognitive load, thereby creating favourable conditions for students to focus on the conceptual aspects of mathematical problem solving (Rittle-Johnson & Schneider, 2015). In mathematics instruction, however, automatization should be grounded in a thorough understanding of the underlying algorithms and their application across a variety of contexts, rather than being reduced to the development of mere mechanical routines. Under these conditions, problem-solving algorithms become effective cognitive tools that support both mathematical achievement and the development of a positive attitude towards mathematic.

I.3. Heuristic Thinking and Creativity in Problem Solving

Heuristic thinking involves the search for solutions through **flexible and exploratory strategies** grounded in **intuition, creativity, and reflective reasoning**. It plays a crucial role in solving **open-ended** or **highly complex mathematical problems**, where standard algorithmic procedures are either insufficient or unavailab.

I.3.1. Heuristic Strategies in Mathematical Problem Solving

Heuristic strategies include the **formulation and testing of hypotheses, analogy, graphical representation, the decomposition of complex problems into simpler sub-problems, and retrospective analysis of solutions**. These strategies facilitate the investigation of problem situations and the selection of effective solution approaches, thereby fostering **critical thinking** and the ability to construct well-reasoned mathematical arguments (Cîrjan, 2007). Their integration into instructional practice promotes students' active engagement in the learning process and supports the transfer of knowledge across a wide range of mathematical contexts.

I.3.2. The Role of Intuition and Discovery

Discovery learning draws upon students' intuition and prior experiences in the construction of mathematical knowledge. By exploring relationships among mathematical concepts and testing hypotheses, students develop a deeper conceptual understanding of mathematical content while strengthening their problem-solving abilities. From this perspective, the teacher's role is to create learning situations that encourage inquiry, exploration, and reflective thinking without replacing the student's own intellectual effort (Pólya, 1965).

I.3.3. Fostering Mathematical Creativity in Students

Mathematical creativity is cultivated through learning activities that encourage the exploration of multiple solution strategies, the justification of mathematical reasoning, and the formulation of new problems. The use of open-ended problems, discovery-based learning, and collaborative learning activities promotes the development of divergent thinking and enhances students' motivation to learn (Amabile, 1996). In this way, heuristic strategies complement algorithmic instruction by fostering the development of flexible mathematical competencies and promoting a positive attitude towards mathematics.

I.4. Balancing Algorithmic and Heuristic Approaches to Mathematical Problem Solving

In mathematics education, achieving an appropriate balance between **algorithmic** and heuristic approaches is essential for fostering efficient and creative mathematical thinking. Effective instruction requires the integration of algorithmic and heuristic thinking in accordance with the objectives of the lesson and the students' level of cognitive development.

The algorithmic approach ensures rigour, accuracy, and the acquisition of fundamental procedural skills through the systematic application of established rules and standard procedures. It is indispensable for solving well-defined mathematical problems and for consolidating students' foundational mathematical competencies.

However, an exclusive emphasis on algorithmic approaches may lead to cognitive rigidity, whereas the sole use of heuristic strategies, without adequate procedural support, may result in intellectual uncertainty and inefficient problem-solving. Within this context, the evaluation of the problem-solving process and the strategies employed becomes as important as the final solution itself, thereby preventing the inhibition of students' mathematical creativity (Amabile, 1997).

I.4.1. The Complementarity of Algorithmic and Heuristic Thinking

The selection of an appropriate problem-solving strategy depends on the nature of the mathematical task. Routine problems generally favour algorithmic approaches, whereas complex problems require the formulation of hypotheses, exploration, and the justification of solutions through the combined use of algorithmic and heuristic strategies. This balanced approach is also reflected in the mathematics curricula of several European countries, including France, Germany, and Finland, where mathematics programmes promote not only the application of algorithms but also the comparison of alternative methods, mathematical argumentation, and the generalisation of results (Eurydice, 2025; Eurydice, 2026).

Consequently, the effectiveness of mathematical problem solving at the beginning of upper secondary education depends on the flexible and complementary use of algorithmic and heuristic strategies. Together, these approaches contribute to the development of students' problem-solving competence, their ability to transfer knowledge across different contexts, and their cognitive autonomy (Cîrjan, 2007; Kuliutkin, 1974).

I.4.2. Adapting Instructional Approaches: Aligning Teaching Methods, Content, and Students' Developmental Characteristics

The new upper secondary mathematics curriculum places greater emphasis on the development of mathematical reasoning, problem-solving, modelling, and mathematical communication competencies, moving beyond an instructional approach centred exclusively on algorithmic procedures (Ministry of Education and Research, 2025). Within this context, instructional methods should be adapted to students' developmental level and to the nature of the mathematical content by integrating algorithmic and heuristic strategies (Pólya, 1965).

At the ninth-grade level, the increasing level of abstraction of mathematical content requires a progressive instructional approach in which algorithms provide a structured framework for organising knowledge, while activities based on discovery, exploration, and problem solving foster conceptual understanding and cognitive flexibility (Amabile, 1997; Pólya, 1980). Accordingly, the national curriculum recommends the use of problem situations and the justification of mathematical solutions, encouraging students to formulate hypotheses and compare alternative problem-solving strategies.

I.4.3. Examples of Instructional Situations

The balance between algorithmic and heuristic thinking is reflected in instructional situations designed to develop students' competencies in problem solving, mathematical argumentation, and mathematical modelling, in accordance with the national curriculum and European recommendations concerning mathematical literacy. Representative examples include solving the same problem using different methods, formulating mathematical problems based on mathematical relationships or graphical representations, and conducting retrospective analyses of solutions. Such activities encourage students to compare problem-solving strategies, justify their reasoning, and reflect upon their own cognitive processes.

Solving the Same Problem Using Multiple Methods

Solving a mathematical problem through **algorithmic, graphical, or heuristic approaches** enables students to compare alternative solution strategies, justify their reasoning, and develop cognitive flexibility. Students are encouraged to explain their solutions and establish meaningful connections among different mathematical representations.

Constructing Problems from Mathematical Relationships, Graphs, or Functional Contexts

Designing mathematical problems based on a mathematical relationship, a graphical representation, or a functional context promotes mathematical modelling, hypothesis formulation, and the transfer of knowledge to new situations. Such activities foster creativity, independent thinking, and autonomy in mathematical problem solving.

Retrospective Analysis of Solutions

In the study of **linear functions** at the ninth-grade level, students may determine the properties of a function either by applying standard algorithmic procedures (such as constructing a table of values and producing a graphical representation) or by analysing the coefficients of the function. Comparing these approaches, formulating new problems based on graphical representations, and conducting retrospective analyses of solutions highlight the complementary nature of algorithmic and heuristic strategies while fostering the development of autonomous mathematical thinking.

I.5. Motivational and Affective Factors in Mathematical Problem Solving

In line with contemporary approaches to **self-regulated learning**, reflection on one's own problem-solving process and the recognition of errors as valuable learning opportunities contribute to the development of students' autonomy and their ability to transfer knowledge across different contexts (European Commission, 2020). Furthermore, the **Council Recommendation on Key Competences for Lifelong Learning** emphasises the role of mathematics in fostering **critical and creative thinking**, as well as a positive attitude towards problem solving (Council of the European Union, 2018).

Consequently, the effectiveness of mathematical problem solving at the ninth-grade level depends on the dynamic interaction among the **cognitive, motivational, and affective dimensions** of learning. This perspective underscores the importance of promoting a **supportive learning environment** that facilitates the development of mathematical competencies while fostering students' positive attitudes towards mathematics.

I.5.1. Attitudes Towards Mathematics

Students' attitudes towards mathematics are strongly influenced by the way in which problem-solving activities are organised and guided. Instructional approaches that focus exclusively on the application of algorithms and the attainment of a single correct solution may foster a mechanical perception of mathematics and diminish students' interest in the subject (Cîrjan, 2007). In contrast, instructional strategies that encourage the exploration of multiple solution pathways, mathematical argumentation, and reflection on the problem-solving process promote cognitive engagement and the development of positive attitudes towards learning (Cerghit, 2006). From the same perspective, Pólya (1965) argues that the teacher should provide balanced guidance that supports students' thinking without replacing their intellectual effort, thereby fostering cognitive autonomy and personal responsibility for learning.

I.5.2. Intrinsic and Extrinsic Motivation in Students' Learning

Within educational psychology, motivation is regarded as a key determinant of students' engagement in mathematical problem solving. **Intrinsic motivation**, characterised by interest, curiosity, and the satisfaction derived from discovery, promotes perseverance, and encourages the use of higher-order cognitive strategies such as exploration, cognitive restructuring, and reflection on the problem-solving process (Amabile, 1997; Deci & Ryan, 2000).

Extrinsic motivation may take either controlled or internalised forms. The satisfaction of the fundamental psychological needs for **autonomy, competence, and relatedness** facilitates the internalisation of extrinsic motivation and supports the development of positive attitudes towards mathematics (Deci & Ryan, 2000; OECD, 2019). Consistent with European educational recommendations, mathematics instruction should promote intrinsic motivation and formative assessment focused on students' progress and the development of mathematical competencies (European Commission, 2018).

By creating a supportive learning environment and encouraging students to reflect on their problem-solving strategies, teachers foster the development of autonomy, strengthen students' sense of competence, and facilitate the transformation of extrinsic motivation into intrinsic motivation, in accordance with the principles of **Self-Determination Theory** and the objectives of contemporary education (Deci & Ryan, 2000).

I.5.3. Mathematics Anxiety and Its Impact on Performance

Instructional approaches that focus exclusively on outcomes and on the rigid application of algorithms may give rise to cognitive and emotional barriers, particularly when students are confronted with mathematical problems involving a high level of abstraction (Cîrjan, 2007). In contrast, the use of **formative feedback**, **scaffolded guidance**, and **interactive teaching methods** helps reduce mathematics anxiety by encouraging students to reflect on their own problem-solving processes and to view mistakes as valuable opportunities for learning within a cognitively supportive environment (Cerghit, 2006).

Reducing mathematics anxiety is closely associated with the development of students' self-confidence. Pólya (1965) emphasises that successful experiences achieved through personal effort and appropriate instructional guidance strengthen students' sense of competence and increase their willingness to engage with new mathematical problems, thereby contributing to the development of a positive attitude towards mathematics.

I.6. The Teacher's Role in Developing and Consolidating Mathematical Problem-Solving Competence

The development of mathematical problem-solving competence is the result of a purposeful instructional process in which the teacher acts as a **facilitator of learning**, organising problem situations and providing guidance that is appropriately adapted to students' developmental levels. Through the careful selection and structuring of learning tasks, the teacher enables students to identify mathematical relationships and construct problem-solving approaches grounded in conceptual understanding.

Throughout the instructional process, the teacher encourages students to explain their reasoning and employ a variety of problem-solving strategies. Pólya (1965) emphasises that instructional support should be carefully balanced so that the essential intellectual effort remains the responsibility of the learner. Furthermore, encouraging exploration, hypothesis formulation, and the comparison of alternative solution methods promotes the development of **cognitive flexibility** and enhances students' ability to **transfer knowledge** across different mathematical contexts (Cîrjan, 2007).

I.6.1. Guiding the Learning Process

At the ninth-grade level, guiding the learning process plays a pivotal role in supporting students' transition towards autonomous mathematical thinking, adapted to the increasing level of abstraction of the curriculum. The teacher facilitates students' cognitive development through guiding questions, scaffolded explanations, and formative feedback, providing instructional support that promotes autonomy without replacing the learner's intellectual effort (Bruner, 1970). In mathematics instruction, the balanced integration of algorithmic and heuristic strategies enhances students' capacity for analysis, mathematical reasoning, and self-regulation, while the gradual withdrawal of instructional support encourages responsibility for their own learning (Pólya, 1965). In accordance with European educational guidelines, instructional guidance should be closely aligned with formative assessment focused on both the learning process and students' progress (European Commission, 2018).

I.6.2. Feedback and Formative Assessment

In ninth-grade mathematics lessons, feedback and formative assessment should be integrated into the solution of authentic mathematical tasks through which students identify mathematical relationships, apply appropriate algorithms, and justify their solutions. Such learning activities foster the identification and processing of mathematical information, the application of mathematical concepts and procedures, mathematical communication, and the critical evaluation of one's own problem-solving process. Descriptive feedback and the analysis of problem-solving strategies support the development of learner autonomy, strengthen students' confidence in their mathematical reasoning, and enhance their ability to transfer knowledge to similar contexts, in accordance with the intended learning outcomes of the mathematics curriculum.

I.6.3. Creating a Learning Environment that Supports Mathematical Problem Solving

Learning through mathematical problem solving requires a learning environment that promotes cognitive engagement, exploration, and the willingness to take intellectual risks. At the ninth-grade level, such an environment is essential for helping students adapt to increasingly abstract mathematical content and for fostering autonomous learning. Pedagogical relationships grounded in trust, constructive feedback, and the acceptance of mistakes as a natural part of learning encourage active participation and reduce mathematics anxiety. Within this context, the teacher acts as a facilitator of learning, employing open-ended questions, mathematical argumentation, and alternative problem-solving strategies to stimulate divergent thinking. Formative assessment, with its emphasis on the learning process and students' progress, further strengthens intrinsic motivation and perseverance in mathematical problem solving.

CHAPTER II. MATHEMATICAL PROBLEMS BETWEEN ALGORITHMIC AND HEURISTIC APPROACHES

II.1. The Role of Mathematical Problems in Mathematics Learning

Mathematical problem solving constitutes a fundamental component of the learning process, serving both as a means of applying mathematical knowledge and as a framework for developing logical reasoning, mathematical modelling skills, and cognitive autonomy. Through its central role in teaching, learning, and assessment, the mathematical problem contributes significantly to the acquisition and development of the subject-specific competencies prescribed by the mathematics curriculum

II.1.1. The Contribution of Mathematical Problems to the Development of Mathematical Concepts

Mathematical problem solving constitutes a fundamental component of the **teaching–learning–assessment** process, serving both as a means of applying mathematical knowledge and as a framework for developing logical reasoning and cognitive autonomy. The evolution of school mathematics has consistently confirmed the central role of mathematical problems in structuring instructional activities, as they facilitate the integration and reorganisation of knowledge into coherent conceptual frameworks.

II.1.2. Problem Situations as a Mechanism for Cognitive Activation in Mathematical Problem Solving

Problem posing constitutes a fundamental instructional method in mathematics education, actively engaging students in the processes of inquiry and knowledge construction while fostering investigative thinking and intellectual autonomy (Nicola, 1996). Cerghit (2006) emphasises the role of the **problem situation** in generating **cognitive conflict**, which stimulates hypothesis formulation, the search for solutions, and the restructuring of existing knowledge.

II.1.3. Assessing Learning Through Mathematical Problem Solving

Problem-Based Learning (PBL) is a student-centred instructional approach in which the learning process is organised around the solution of open-ended problems, involving hypothesis formulation, the selection of appropriate strategies, and the evaluation of alternative solutions (Brio, 2023). In mathematics education, this approach enables the integrated development and assessment of **conceptual, procedural, and metacognitive competencies**, placing equal emphasis on both the problem-solving process and the final outcome.

II.1.4. The Interdisciplinary Dimension of Mathematics in Educational Contexts

Mathematical problem solving highlights the role of mathematics as a powerful tool for modelling and interpreting phenomena across a wide range of fields of knowledge. The application of mathematical concepts in interdisciplinary contexts facilitates their transfer to disciplines such as science, technology, and economics, thereby strengthening students' **knowledge transfer competencies** and enhancing the relevance and authenticity of mathematics learning

II.2. Algorithmization in Mathematics Education

Algorithmization is an instructional method aimed at rationalising the teaching and learning process, widely employed in mathematics education. Through this approach, learning is organised as a logical sequence of operations and decisions directed towards solving a particular category of mathematical problems. Unlike the heuristic approach, algorithmization provides a standardised problem-solving framework that facilitates efficient learning and the development of procedural skills (Landa, 1974).

II.3. Integrating Algorithmic and Heuristic Methods in Mathematics Teaching

The integration of algorithmic and heuristic methods represents a fundamental methodological principle in upper secondary mathematics education, contributing to the effectiveness of the teaching–learning–assessment process. Mathematical problem solving requires the systematic organisation of knowledge and the selection of appropriate strategies for identifying solutions, thereby highlighting the complementarity between **algorithmic rigour** and **heuristic flexibility** (Schoenfeld, 1985).

II.4. The Contribution of Mathematical Problem Solving to the Development of Mathematical Competence

Mathematical problem solving is a complex formative activity that integrates **cognitive, metacognitive, and affective-motivational** dimensions of learning. It contributes to the development of **mathematical competence**, defined as the ability to mobilise knowledge, procedures, and strategies effectively across a variety of mathematical contexts (Kilpatrick, Swafford, & Findell, 2001).

II.5. Contemporary Trends in Mathematics Teaching and Learning

Contemporary mathematics education is aligned with current educational frameworks that emphasise **competency-based learning**, **critical thinking**, and **problem solving in authentic contexts**. The Romanian National Curriculum and the **Pre-University Education Law No. 198/2023**, in accordance with the recommendations of the **European Commission (2018)**, highlight the essential role of mathematics in developing **STEM competencies**, **digital competencies**, and **transferable skills** required for lifelong learning and active participation in contemporary society.

II.5.1. Current Trends in Mathematics Teaching

Contemporary mathematics teaching is increasingly oriented towards the development of **competencies**, in accordance with the **Council Recommendation on Key Competences for Lifelong Learning** (Council of the European Union, 2018). **Mathematical competence** encompasses mathematical reasoning, problem solving, modelling, and the interpretation of quantitative information, extending beyond the mere application of algorithms. The findings of **PISA 2022** highlight the importance of applying mathematical knowledge in authentic contexts and fostering students' critical thinking skills (OECD, 2023).

II.5.2. The Educational and Policy Context of Mathematical Problem Solving

The **Council Recommendation on Key Competences for Lifelong Learning** (2018) defines **mathematical competence** as the ability to apply mathematical thinking to solve problems in real-world contexts through the integrated mobilisation of **knowledge, skills, and attitudes (KSA)**. Mathematical competence encompasses reasoning, modelling, argumentation, and the interpretation of results, and is recognised as a fundamental cognitive resource for the development of **STEM competencies** and for active participation in social and professional life (Council of the European Union, 2018).

II.5.3. Implications for Mathematics Teaching Practice

Recent curricular and legislative reforms have redefined the role of the mathematics teacher, who is increasingly viewed as a **designer of learning environments**, a **facilitator of mathematical reasoning**, and a **mediator between scientific knowledge and students' learning experiences**. Consequently, instructional design is increasingly competence-oriented, emphasising the use of **authentic mathematical problems**, **mathematical inquiry**, and **mathematical modelling**, rather than focusing exclusively on the transmission of subject content.

CHAPTER III. ATTITUDES TOWARDS MATHEMATICS IN MATHEMATICAL PROBLEM SOLVING AT THE NINTH-GRADE LEVEL

III.1. Characteristics of Ninth-Grade Students' Attitudes Towards Mathematics

In the relevant literature, **attitudes towards mathematics** are defined as a **multidimensional construct** encompassing **cognitive, affective, and behavioural components** (Di Martino & Zan, 2010). Among ninth-grade students, this construct assumes particular significance, as the transition from lower to upper secondary education is characterised by increasingly abstract mathematical content and higher cognitive demands.

A positive attitude towards mathematics promotes students' engagement in problem solving, perseverance, and academic achievement, whereas negative attitudes are associated with task avoidance, mathematics anxiety, and lower levels of academic performance (Di Martino & Zan, 2010; Neale, 1969). In accordance with the ninth-grade mathematics curriculum, mathematical problem solving constitutes the primary context for developing mathematical competencies, reasoning skills, and the ability to apply knowledge across a variety of situations.

An important factor influencing students' attitudes towards mathematics is **mathematics anxiety**, defined as a negative emotional reaction that interferes with the successful completion of mathematical tasks (Richardson & Suinn, 1972). Research has demonstrated that mathematics anxiety adversely affects **working memory** and academic performance (Ashcraft & Kirk, 2001). Consequently, contemporary curriculum frameworks advocate the creation of a supportive learning environment characterised by encouragement, constructive feedback, and formative assessment.

Within this context, analysing students' attitudes towards mathematics is essential for understanding the interaction between the **cognitive** and **affective** dimensions of learning. The implementation of **active learning strategies** and the establishment of a **supportive educational environment** contribute significantly to the development of mathematical competencies and to fostering positive attitudes towards mathematics as a school subject.

III.1.1. Characteristics of Early Adolescence

Early adolescence (ages 14-15), characteristic of ninth-grade students, is marked by the development of abstract thinking and formal reasoning, as well as by increased sensitivity to assessment and feedback (Piaget, 1972; Erikson, 2006). These developmental characteristics directly influence the ways in which students approach mathematics and mathematical problem solving.

At this stage, mathematical content becomes increasingly abstract, and success in learning depends not only on students' level of cognitive development but also on their motivation and confidence in their own abilities. Previous experiences of success or failure play a significant role in shaping students' attitudes towards mathematics (Di Martino & Zan, 2010).

Within the **pedagogical vocational track**, mathematics serves a dual purpose: the development of students' mathematical competencies and the formation of a pedagogical perspective on how these competencies will later be taught in preschool and primary education. Consequently, fostering a positive attitude towards mathematics is essential, as it may subsequently influence the professional practice of future teachers (Beilock et al., 2010).

Accordingly, mathematics instruction at the ninth-grade level should promote active learning strategies, formative assessment, and a supportive learning environment that reduces mathematics anxiety and encourages students' engagement in mathematical problem solving, in line with European educational recommendations (European Commission, 2018).

III.1.2. The Transition from Lower to Upper Secondary Education and Its Impact on Attitudes Towards Mathematics

The transition from lower to upper secondary education represents a critical stage in ninth-grade students' educational adjustment, accompanied by increased cognitive and emotional demands (Eccles et al., 1993). In mathematics, this transition is characterised by a higher level of abstraction, the use of more rigorous mathematical language, and a stronger emphasis on mathematical proof and problem solving, all of which may reduce students' confidence in their own abilities (Byrnes, 2001).

From a psycho-pedagogical perspective, this period is often associated with a temporary decline in motivation and an increase in school-related anxiety, particularly in mathematics. Positive learning experiences contribute to the development of favourable attitudes towards mathematics, whereas early failures may encourage students to avoid the subject.

Within the pedagogical vocational track, difficulties encountered in learning mathematics have additional implications, as they may influence future teachers' approaches to teaching the subject. Research indicates that negative attitudes towards mathematics held by prospective teachers can subsequently be transmitted to their future primary school pupils (Beilock et al., 2010).

Consequently, European educational policy documents recommend supporting students during this transition through curricular continuity, formative assessment, and a supportive learning environment (European Commission, 2018). The teacher's role is to facilitate students' adaptation to the academic demands of upper secondary education and to promote the development of positive attitudes towards mathematics.

Overall, the transition from lower to upper secondary education significantly influences students' attitudes towards mathematics by increasing both the level of abstraction and the cognitive demands of mathematical learning. Successful adaptation depends not only on students' competencies but also on the educational environment and the instructional strategies adopted by teachers.

Within the pedagogical vocational track, this transition assumes additional importance because students' relationship with mathematics may shape their future teaching practices. Consequently, formative interventions based on cognitive support, formative assessment, and the reduction of mathematics anxiety contribute to fostering positive attitudes towards mathematics and strengthening students' mathematical problem-solving competencies.

III.1.3. The Cognitive Component of Attitudes Towards Mathematics

The cognitive component of attitudes towards mathematics encompasses students' beliefs and perceptions regarding the difficulty of mathematics, its usefulness, and their own capacity to achieve success. A central element of this dimension is **mathematics self-efficacy**, defined as students' confidence in their ability to successfully perform mathematical tasks.

Furthermore, perceiving mathematics as a useful and personally relevant discipline enhances students' motivation and engagement in learning. Conversely, the belief that mathematics consists solely of the mechanical application of rules limits flexibility in problem solving and discourages the use of heuristic strategies.

Among ninth-grade students, these beliefs are shaped both by previous learning experiences acquired during lower secondary education and by the increased academic demands of upper secondary mathematics. Therefore, fostering positive beliefs regarding personal competence and the value of mathematics represents an essential prerequisite for active engagement in mathematical problem solving and the development of favourable attitudes towards the subject.

III.1.4. The Affective Component of Attitudes Towards Mathematics

The affective component of attitudes towards mathematics comprises the emotions and feelings associated with mathematics learning, directly influencing students' engagement in mathematical problem solving. Interest in and enjoyment of mathematics promote intrinsic motivation and perseverance, whereas mathematics anxiety impairs performance by reducing working memory capacity and concentration.

Among ninth-grade students, this dimension becomes particularly significant because the transition to upper secondary education is accompanied by increasingly abstract mathematical content and more demanding assessment practices. Consequently, experiences of success and failure exert a substantial influence on students' attitudes towards mathematics.

Bocoș (2013) highlights the importance of the educational climate in fostering students' motivation and positive attitudes towards learning. A learning environment characterised by support, constructive feedback, and recognition of individual progress contributes to reducing mathematics anxiety while strengthening students' self-confidence.

Accordingly, the affective dimension represents a key factor in developing positive attitudes towards mathematics and sustaining students' motivation to learn.

III.1.5. The Behavioural Component of Attitudes Towards Mathematics

The behavioural component of attitudes towards mathematics is reflected in the ways students participate in learning activities, demonstrating engagement, perseverance, or avoidance behaviours. Students with positive attitudes actively participate in mathematics lessons and persist in solving challenging problems, whereas negative attitudes are often expressed through task avoidance and a tendency to give up when confronted with difficulties.

Perseverance constitutes a key indicator of this behavioural dimension because successful mathematical problem solving requires sustained effort and the flexible application of diverse problem-solving strategies. In contrast, avoidance behaviours are frequently associated with mathematics anxiety and low levels of mathematics self-efficacy.

Bocoș (2013) emphasises the teacher's role in fostering students' engagement through learner-centred instructional strategies, collaborative learning activities, and constructive feedback. Consequently, the behavioural component reflects the manner in which students' beliefs and emotions are translated into observable actions, directly influencing their success in mathematical problem solving.

III.2. Factors Influencing Students' Attitudes Towards Mathematical Problem Solving

Students' attitudes towards mathematical problem solving significantly influence their cognitive engagement, perseverance, and academic achievement. Research indicates that students with positive attitudes demonstrate higher levels of motivation, self-regulation, and cognitive effectiveness, whereas negative attitudes are associated with task avoidance and school-related anxiety (Sinaga, Sitorus, & Situmeang, 2023; OECD et al., 2021).

Mathematical problem solving requires the analysis of problem situations, the selection of appropriate strategies, and reflection on the problem-solving process. Students' attitudes are shaped by their perceptions of their own mathematical competence as well as by previous experiences of success or failure.

The literature further emphasises that the development of mathematical problem-solving competence depends on the interaction among prior knowledge, instructional strategies, and students' motivation. Learner-centred and interactive instructional approaches encourage active participation and critical thinking, thereby fostering the development of positive attitudes towards learning (Cerghit, 2006).

From a motivational perspective, **Expectancy–Value Theory** explains students' engagement in learning through their expectations of success and the value they attribute to the learning task (Eccles & Wigfield, 2002). Furthermore, a learning environment characterised by support, constructive feedback, and assessment focused on students' progress contributes to the development of motivation and active engagement in mathematical problem solving (Deci & Ryan, 2000; Schunk et al., 2014).

III.2.1. Previous Learning Experiences

Previous learning experiences exert a significant influence on students' attitudes towards mathematical problem solving, contributing to the formation of both cognitive and affective representations of mathematics. Students' attitudes develop through the accumulation of experiences of success and failure, which shape the ways in which they approach challenging mathematical tasks (OECD et al., 2021; Zlate, 2009).

From a psychological perspective, positive learning experiences strengthen **mathematics self-efficacy** and **academic self-concept**, thereby fostering students' confidence and engagement in mathematical problem solving. Conversely, repeated difficulties and negative feedback may lead to task avoidance and diminished motivation (Bandura, 1997; Adeniyi, 2012).

Learner-centred instructional approaches based on exploration, collaboration, and reflection contribute to the creation of meaningful learning experiences and promote the development of positive attitudes towards mathematics (Kilpatrick et al., 2001; Schunk et al., 2014). Furthermore, **Expectancy–Value Theory** suggests that previous learning experiences influence both students' expectations of success and the value they assign to mathematical problem-solving activities (Eccles & Wigfield, 2002).

A learning environment characterised by support, constructive feedback, and the acceptance of mistakes as an integral part of learning fosters positive educational experiences and encourages the development of constructive attitudes towards mathematical problem solving (Deci & Ryan, 2000).

III.2.2. Curricular and Assessment Factors

The curriculum and assessment practices significantly influence students' attitudes towards mathematical problem solving because they shape learning experiences and students' perceptions of the relevance and difficulty of mathematics (OECD et al., 2021). A curriculum focused exclusively on procedures and repetitive exercises may encourage a mechanical approach to learning, whereas a **competency-based curriculum** that emphasises conceptual understanding and the application of knowledge in authentic contexts promotes cognitive engagement and the development of positive attitudes towards mathematics (Eccles & Wigfield, 2002).

Assessment also plays a pivotal role. **Summative assessment**, primarily focused on grading and ranking students, may increase mathematics anxiety and fear of failure, whereas **formative assessment**, based on constructive feedback and individual progress, strengthens students' confidence and motivation (Deci & Ryan, 2000).

The educational pathway also influences students' attitudes towards mathematics. Within the **general academic track**, greater emphasis is placed on abstract mathematical reasoning and performance-oriented assessment, which may increase academic pressure and influence students' emotional responses to mathematics.

III.2.3. Contextual Factors: The School and Family Environments

The **school** and **family environments** represent key contextual factors in shaping students' attitudes towards mathematical problem solving by influencing their learning experiences, motivation, and cognitive engagement (Bocoș, 2013; Zlate, 2009).

The school environment. The educational climate, the teacher–student relationship, and the instructional strategies adopted in the classroom significantly influence how students perceive and engage with mathematics.

The family environment. Family support shapes students' perceptions of effort, academic success, and failure, while also influencing their confidence, motivation, and attitudes towards learning mathematics.

Consequently, the combined influence of the school and family environments contributes substantially to the development of positive attitudes towards mathematical problem solving and to the establishment of a constructive relationship with mathematics learning.

Conceptual Model: School Environment – Family Environment – Attitudes – Academic Achievement

The proposed conceptual model explains students' academic achievement in mathematics through the indirect influence of the **school environment** and the **family environment**, mediated by students' attitudes towards mathematical problem solving. The school environment—including the educational climate, teacher–student relationships, instructional strategies, and assessment practices—and the family environment—including emotional support, parental expectations, and the encouragement of autonomy—contribute to the development of the **cognitive, affective, and behavioural components** of students' attitudes towards mathematics.

III.3. Mathematics Anxiety Among Ninth-Grade Students

Mathematics anxiety is a negative emotional response characterised by feelings of fear, tension, and avoidance in situations involving mathematics learning and assessment, adversely affecting students' cognitive processing and academic performance (Ashcraft, 2002).

At the ninth-grade level, mathematics anxiety may become more pronounced as a consequence of the transition to upper secondary education, the increasing level of abstraction of mathematical content, and more demanding assessment practices. The introduction of new concepts, such as **functions**, requires a higher level of abstract reasoning, which may intensify the difficulties experienced by students with previous experiences of academic failure.

From a psychological perspective, mathematics anxiety impairs **working memory** and the ability to concentrate, thereby reducing the efficiency of analysing and solving mathematical problems. Students experiencing high levels of mathematics anxiety tend to focus their attention on the fear of failure, leaving fewer cognitive resources available for successful problem solving (Ashcraft, 2002).

Reducing mathematics anxiety requires instructional interventions that emphasise **constructive feedback**, **formative assessment**, and the creation of a **psychologically supportive learning environment**. Such practices foster students' confidence in their own mathematical abilities and promote the development of positive attitudes towards mathematical problem solvin.

III.3.1. Major Causes of Mathematics Anxiety in the School Context

Mathematics anxiety among ninth-grade students is a **multifactorial phenomenon**, primarily influenced by assessment practices, the increasing complexity of mathematical content, and performance pressure. These factors directly affect students' attitudes towards mathematical problem solving and their engagement in learning.

Assessment may become a source of anxiety when it is perceived as punitive and focused exclusively on the final outcome. Fear of making mistakes and fear of failure often lead students to avoid participation and experience cognitive blocks during assessment situations.

The complexity of mathematical content, intensified by the high level of abstraction characteristic of the ninth-grade curriculum, may generate feelings of helplessness and encourage students to avoid mathematical tasks. Contextualising mathematical concepts, employing graphical representations, and differentiating learning tasks facilitate conceptual understanding while strengthening students' confidence in their mathematical abilities.

Performance pressure, reinforced by the expectations of teachers and parents as well as by comparisons with peers, intensifies students' fear of failure and reduces their motivation to learn. Emphasising individual progress, providing feedback focused on effort, and creating a psychologically supportive learning environment promote the development of intrinsic motivation and perseverance (Zlate, 2009).

Accordingly, mathematics anxiety can be reduced through pedagogical interventions centred on formative assessment, the contextualisation of mathematical content, and emotional support, thereby fostering the development of constructive attitudes towards mathematical problem solving.

III.3.2. Manifestations of Mathematics Anxiety in Mathematical Problem Solving

Mathematics anxiety directly influences students' attitudes towards mathematical problem solving and is associated with task avoidance, reduced perseverance, and diminished intrinsic motivation. It functions as an **affective variable** that mediates the relationship between educational experiences and academic achievement, constituting an important component of the affective dimension of attitudes towards mathematics (Zlate, 2009).

Within the **pedagogical vocational track**, mathematics anxiety is manifested primarily through fear of failure, low confidence in one's mathematical abilities, and the avoidance of mathematical tasks. Unlike students enrolled in the general academic track, whose anxiety is often associated with the increasing abstraction of mathematical content and performance pressure, students in the pedagogical vocational track are also influenced by their perceptions of the usefulness of mathematics and its relevance to their future teaching profession.

These affective manifestations are directly reflected in students' behaviour during mathematical problem solving, influencing how they approach tasks, select solution strategies, and persevere when faced with difficulties. For this reason, the following examples illustrate the specific manifestations of mathematics anxiety during problem-solving activities and highlight their implications for both academic achievement and students' attitudes towards mathematics.

Examples of Mathematics Anxiety During Mathematical Problem Solving

Example 1 – Functions. When solving a task such as determining the intervals over which a function is positive, some students may hesitate to begin the solution, repeatedly seek confirmation from the teacher, or abandon the task after making a minor mistake. Although the task itself is within their capabilities, mathematics anxiety reduces both engagement and perseverance.

Example 2 – Interpreting the Graph of a Function. In activities requiring students to explain the meaning of a function's graph, some may experience uncertainty when verbally articulating their mathematical reasoning. This manifestation of mathematics anxiety reduces self-confidence and active participation, even though it does not necessarily prevent successful task completion.

Example 3 – Pedagogical Contexts. In applied mathematical problems related to the pedagogical vocational track, students experiencing mathematics anxiety tend to underestimate their own competencies and perceive mathematics as an obstacle to their future teaching career, thereby reducing the value they attribute to the subject.

These examples demonstrate that, within the **pedagogical vocational track**, mathematics anxiety is expressed predominantly through **affective and motivational manifestations**, including avoidance behaviours, uncertainty, and reduced perseverance. In the present study, mathematics anxiety is conceptualised as an **affective subdimension of attitudes towards mathematical problem solving**, exerting an indirect influence on students' academic achievement.

III.4. The Relationship Between Mathematics Anxiety and Academic Achievement at the Ninth-Grade Level

The relationship between **mathematics anxiety** and **academic achievement** has been extensively investigated in the educational literature and is consistently described as an inverse relationship: higher levels of mathematics anxiety are associated with lower levels of achievement in mathematics. Mathematics anxiety interferes with the cognitive processes involved in mathematical problem solving, impairing students' ability to apply their knowledge and problem-solving strategies effectively (Ashcraft, 2002).

At the ninth-grade level, this relationship becomes particularly significant because students simultaneously face the transition to upper secondary education, increased academic demands, and the introduction of mathematical content characterised by a higher level of abstraction. Within this context, mathematics anxiety may lead to lower academic achievement not necessarily because of insufficient cognitive competence, but rather as a consequence of the **emotional and cognitive interference** experienced during assessment situations and mathematical problem-solving activities.

III.4.1. The Effects of Mathematics Anxiety on Reasoning and Mathematical Problem Solving

Mathematics anxiety adversely affects the cognitive processes involved in **mathematical reasoning** and **problem solving**, influencing both students' academic performance and the quality of their problem-solving processes. It consumes **working memory** resources, thereby reducing students' capacity to analyse mathematical information and apply effective problem-solving strategies (Ashcraft, 2002).

One of its most significant effects is the reduction of **cognitive flexibility**. Students experiencing mathematics anxiety tend to rely on memorised procedures without adequately analysing the problem situation, limiting their ability to transfer knowledge and adapt their problem-solving strategies to unfamiliar contexts (Zlate, 2009).

At the ninth-grade level, where mathematical content is characterised by a higher degree of abstraction, these effects become even more pronounced. Students may experience difficulties in interpreting mathematical symbols and constructing coherent mathematical arguments, not because of insufficient mathematical competence, but as a consequence of emotional stress and cognitive interference.

III.4.2. The Effects of Mathematics Anxiety on Academic Achievement and Students' Self-Efficacy

Mathematics anxiety has a detrimental impact on both **academic achievement** and **students' self-efficacy**, contributing to the development of a self-perpetuating cycle of learning difficulties. Emotional interference reduces the efficiency of the cognitive processes involved in mathematical problem solving, leading to lower levels of academic achievement even among students who possess adequate cognitive abilities (Ashcraft, 2002).

At the ninth-grade level, where mathematical concepts become increasingly abstract, mathematics anxiety is frequently manifested through repeated errors, incomplete solutions, and the avoidance of challenging mathematical tasks. Such experiences reinforce students' perceptions of mathematics as a difficult subject and reduce their engagement in learning activities.

From an affective perspective, mathematics anxiety undermines students' **self-efficacy beliefs** and confidence in their own mathematical abilities (Bandura, 1997). Consequently, students become more reluctant to participate in classroom activities, less willing to justify their mathematical reasoning, and increasingly dependent on support from teachers or peers.

Reducing these negative effects requires instructional strategies that emphasise **formative assessment**, recognise students' individual progress, and provide opportunities for successful learning experiences. Such practices strengthen students' self-confidence, enhance their mathematics self-efficacy, and ultimately improve their performance in mathematical problem solving.

III.5. The Role of Problem-Solving Strategies in Fostering Positive Attitudes Towards Mathematics

Problem-solving strategies play a fundamental role in fostering positive attitudes towards mathematics, as they provide students with clear cognitive frameworks for approaching mathematical tasks. The systematic use of strategies such as understanding the problem, planning the solution, implementing the chosen strategy, and verifying the solution reduces uncertainty and feelings of insecurity, thereby contributing to lower levels of mathematics anxiety and greater self-confidence.

At the ninth-grade level, where mathematical content becomes increasingly abstract, problem-solving strategies support mathematical reasoning and help students manage cognitive complexity more effectively. Students who possess well-developed problem-solving strategies perceive mathematical problems as more accessible, engage more actively in learning activities, and develop more positive attitudes towards mathematical problem solving (Pólya, 1965).

In conclusion, problem-solving strategies should be regarded not only as cognitive tools but also as affective resources that promote positive attitudes towards mathematics by reducing mathematics anxiety and strengthening students' sense of competence and confidence in their mathematical abilities.

III.5.1. Algorithmic Strategies as a Means of Enhancing Students' Confidence in Mathematical Problem Solving

Algorithmic strategies contribute significantly to the development of mathematical competencies at the ninth-grade level by providing students with clear and predictable procedures for solving mathematical problems. By structuring the problem-solving process, these strategies reduce cognitive uncertainty and strengthen students' sense of confidence, making them particularly valuable in supporting adaptation to the increased demands of upper secondary mathematics and in reducing mathematics anxiety.

However, the exclusive reliance on algorithmic procedures may encourage a mechanical approach to problem solving, limiting cognitive flexibility and the transfer of knowledge to unfamiliar situations. Therefore, the educational effectiveness of algorithmic strategies depends on their integration into instructional approaches that promote reflection, mathematical argumentation, and the flexible adaptation of procedures to novel problem situations, in accordance with Pólya's (1965) principles of conscious problem solving.

Accordingly, algorithmic strategies constitute an important foundation for fostering positive attitudes towards mathematics when they are employed flexibly and in combination with heuristic approaches.

Examples of the Use of Algorithmic Strategies at the Ninth-Grade Level

Example 1 – Sequences and Arithmetic Progressions

When determining a term of an arithmetic progression, students follow a structured sequence of steps: identifying the type of sequence, recording the given information, applying the general-term formula, and verifying the obtained result. This algorithm provides a secure procedural framework and contributes to strengthening students' confidence in mathematical problem solving.

Example 2 – Quadratic Equations

Solving a quadratic equation involves identifying the coefficients, calculating the discriminant, applying the quadratic formula, and verifying the solutions obtained. The clearly defined sequence of procedures reduces cognitive overload and facilitates students' understanding of the underlying mathematical process.

Example 3 – Metric Relations in a Right Triangle

When determining the length of a leg of a right triangle using the **Pythagorean Theorem**, students identify the known data, apply the appropriate mathematical relationship, and verify the obtained solution. This algorithm reinforces the rigour of mathematical reasoning while reducing uncertainty during geometry problem solving.

The systematic use of algorithmic strategies at the ninth-grade level provides students with structure and predictability in mathematical problem solving, thereby supporting the development of mathematical competencies, reducing mathematics anxiety, and fostering positive attitudes towards mathematics.

III.5.2. Heuristic Strategies as a Means of Enhancing Motivation and Positive Attitudes Towards Mathematics

Heuristic strategies encourage exploration, hypothesis formulation, and reflection on the problem-solving process, thereby fostering cognitive autonomy and strengthening students' confidence in their mathematical abilities. By directing students' attention towards the reasoning process rather than exclusively towards the final answer, these strategies reduce mathematics anxiety and promote active engagement in mathematical problem solving.

Instructional approaches such as systematic exploration, problem reformulation, and the use of analogies enable students to discover solutions through inquiry and adaptation, in accordance with the heuristic principles proposed by Pólya (1965). Success achieved through such exploratory processes reinforces students' **mathematics self-efficacy** and contributes to the development of positive attitudes towards mathematics.

Consequently, heuristic strategies enhance students' self-confidence by transforming mathematical problem solving into a process of exploration, learning, and intellectual achievement.

Examples of the Implementation of Heuristic Strategies in Relation to the General Competencies of the Ninth-Grade Mathematics Curriculum

The following examples illustrate how heuristic strategies can be integrated into the development of the **general competencies (GC1–GC6)** of the ninth-grade mathematics curriculum by promoting exploration, mathematical argumentation, and mathematical modelling across a variety of contexts. The use of **guided questioning**, **hypothesis formulation**, **visual representations**, and **reflection on the problem-solving process** supports conceptual understanding and encourages students' active engagement in learning mathematics.

III.6. Instructional Interventions for Reducing Mathematics Anxiety at the Ninth-Grade Level

Mathematics anxiety can be reduced through the use of **formative assessment**, the clear structuring of the problem-solving process, and the recognition of students' mathematical reasoning. These instructional interventions strengthen students' confidence and foster positive attitudes towards mathematical problem solving.

Reducing mathematics anxiety among ninth-grade students requires instructional interventions centred on **psychological safety**, the structured development of mathematical reasoning, and the recognition of individual progress. The combined use of formative assessment, clearly explained algorithmic strategies, and heuristic approaches helps reduce cognitive uncertainty while enhancing students' self-confidence. Such instructional practices create supportive learning environments in which students are encouraged to view mistakes as opportunities for learning, persevere when faced with challenging mathematical tasks, and gradually develop positive attitudes towards mathematics.

III.6.1. Instructional Strategies for Creating a Psychologically Supportive Learning Environment in Mathematics Classrooms

Creating a **psychologically supportive learning environment** is a fundamental prerequisite for reducing mathematics anxiety and fostering positive attitudes towards mathematical problem solving among ninth-grade students. Such an environment is characterised by the acceptance of mistakes as valuable learning opportunities, relationships based on mutual respect and support, and constructive feedback focused on the problem-solving process rather than solely on the final answer.

Within a psychologically supportive classroom, students are encouraged to express their ideas, experiment with alternative solution strategies, and persevere when confronted with difficulties without fear of criticism or punishment. In this way, the teacher promotes students' self-confidence, motivation, and mathematical reasoning, thereby encouraging active engagement in mathematical problem solving while reducing mathematics anxiety.

Drawing upon research findings in educational psychology and mathematics education, a number of observable indicators of a psychologically supportive learning environment can be identified and adapted to the developmental characteristics of ninth-grade students.

Observable Indicators of a Psychologically Supportive Learning Environment in Mathematics Classrooms

Relational indicators (teacher–student and student–student relationships) are reflected in both verbal and non-verbal behaviours, classroom interactions during whole-class instruction, and students' participation in pair and small-group activities.

Emotional indicators (students' emotional states) can be identified through students' active participation in learning tasks, body language, and their responses to teachers' questions and instructional prompts.

Instructional indicators (organisation of learning activities) include the structure of the lesson, the nature of the feedback provided, and the sequencing of instructional activities.

Assessment indicators are reflected in the types of assessment employed, the manner in which written and oral feedback is communicated, and students' responses to assessment outcomes.

Learning behaviour indicators include the amount of time students devote to completing learning tasks, their willingness to persist after encountering difficulties, and their ability to verbalise their mathematical reasoning during problem solving.

III.6.2. The Use of Interactive Learning to Reduce Mathematics Anxiety

Encouraging **active learning** represents an important instructional approach for fostering positive attitudes towards mathematics and reducing mathematics anxiety among ninth-grade students. By engaging learners in **problem posing**, inquiry, collaboration, and mathematical argumentation, the learning process becomes centred on knowledge construction and the development of mathematical reasoning (Bocoş, 2013).

Interactive instructional strategies encourage students to express their ideas, compare alternative solution strategies, and reflect on their own reasoning processes, thereby strengthening self-confidence and reducing the pressure often associated with assessment. Consequently, mathematics is perceived as more accessible and meaningful, while mathematical problem solving becomes an opportunity for exploration and learning rather than a source of anxiety.

The impact of these strategies varies according to the educational pathway. Within the **general academic track**, they primarily support the development of conceptual understanding and mathematical argumentation, whereas within the **pedagogical vocational track**, they play a predominantly motivational and affective role by strengthening students' confidence, engagement, and willingness to participate in mathematical learning. Accordingly, active learning represents an effective means of fostering a positive and enduring relationship with mathematics.

III.6.3. The Role of Collaborative Learning in Reducing Mathematics Anxiety

Collaborative learning constitutes an effective instructional strategy for promoting both the development of mathematical competencies and the reduction of mathematics anxiety. Through solving mathematical problems in pairs or small groups, students share ideas, compare alternative solution strategies, and collaboratively construct solutions within a learning environment characterised by mutual support and shared responsibility.

Collaboration reduces the pressure associated with individual performance and encourages students to regard mistakes as a natural and valuable part of the learning process. Mathematical dialogue and the justification of solutions contribute to conceptual understanding, strengthen students' self-confidence, and promote positive attitudes towards mathematical problem solving.

The educational impact of collaborative learning differs according to the educational pathway. Within the **general academic track**, collaborative learning primarily supports deeper conceptual understanding and the development of mathematical argumentation, whereas within the **pedagogical vocational track**, its principal contribution lies in reducing mathematics anxiety, strengthening students' sense of competence, and increasing motivation for learning mathematics.

Consequently, collaborative learning contributes not only to the development of students' **cognitive competencies** but also to their **social-emotional competencies**, thereby supporting the establishment of a positive and enduring relationship with mathematics.

III.7. Pedagogical Implications of the Relationship Between Attitudes Towards Mathematics, Mathematics Anxiety, and Performance in Mathematical Problem Solving

Optimising the academic achievement of ninth-grade students requires an integrated pedagogical approach that aligns the development of **mathematical competencies** with the **affective** and **motivational dimensions** of learning. Students' performance is influenced not only by the level of their mathematical knowledge but also by their attitudes towards mathematics, their self-confidence, and the quality of the problem-solving strategies they employ.

European educational policy documents advocate a **competency-based educational model** that emphasises active and collaborative learning, formative assessment, and the creation of a **psychologically supportive learning environment**, recognising these elements as essential for improving academic achievement and reducing mathematics anxiety (Council of the European Union, 2018; OECD, 2022). Within this framework, mathematics is viewed as a powerful tool for **problem solving** and **modelling real-world phenomena**, thereby enhancing both the relevance of mathematics and students' motivation to learn.

III.7.1. Pedagogical Implications for Designing Mathematics Teaching and Learning Activities

The design of mathematics learning activities should follow the logical progression of mathematical concepts and facilitate students' gradual transition from concrete situations to abstract concepts. The use of **inductive instructional strategies** supports the development of conceptual understanding and mathematical reasoning.

Instructional activities should extend beyond the transmission of algorithmic procedures by incorporating **problem situations**, **mathematical inquiry**, and **mathematical argumentation**, thereby encouraging the use of heuristic strategies and reflection on the problem-solving process. In this way, mathematics is perceived as a discipline of exploration and discovery rather than one of procedural routine.

Such an instructional approach contributes to the development of positive attitudes towards mathematics while reducing the anxiety associated with the pressure to obtain the correct answer rapidly.

III.7.2. Pedagogical Implications for Organising Active and Collaborative Learning

The organisation of learning activities through **active** and **collaborative learning** promotes the development of students' cognitive and social-emotional competencies while contributing to the reduction of mathematics anxiety and the strengthening of self-confidence. Learning activities conducted in pairs or small groups encourage **mathematical dialogue**, the comparison of alternative problem-solving strategies, and the justification of mathematical solutions, thereby facilitating conceptual understanding and the development of critical thinking.

Within this instructional context, mistakes are regarded as valuable learning opportunities, while collaboration fosters an atmosphere of mutual support and active participation. Consequently, mathematics is perceived as an accessible discipline centred on exploration and knowledge construction, promoting positive attitudes towards mathematical problem solving.

III.7.3. Pedagogical Implications for Assessment in Mathematics

Mathematics assessment should employ a variety of methods, including **short tests**, **systematic observation**, **guided classroom discussions**, and **project-based assessment**, with the primary purpose of continuously monitoring students' learning progress. Feedback should be timely, constructive, and focused on the problem-solving process, the strategies employed, and the quality of students' mathematical reasoning rather than solely on the final answer.

Contemporary pedagogical approaches advocate the use of **formative assessment**, **self-assessment**, and **reflection on the learning process**, as these practices contribute to the development of students' mathematics self-efficacy, learner autonomy, and confidence in their own mathematical abilities.

III.7.4. Pedagogical Implications for Creating a Learning Environment that Supports Mathematics Learning

The socio-emotional climate of the classroom significantly influences students' attitudes towards mathematics, their motivation to learn, and the level of mathematics anxiety they experience. A learning environment characterised by respect, support, and active participation fosters students' self-confidence and encourages engagement in mathematical problem solving.

The teacher plays a pivotal role in establishing such an environment by providing constructive feedback, recognising students' effort, and treating mistakes as valuable opportunities for learning. At the ninth-grade level, a **psychologically supportive learning environment** facilitates students' adaptation to the academic demands of upper secondary education while contributing to the prevention of mathematics anxiety.

Accordingly, promoting active learning, implementing formative assessment, and maintaining a positive educational climate constitute essential pedagogical principles for fostering positive attitudes towards mathematics and improving students' academic achievement.

III.7.5. Guidelines for Designing Mathematical Problem-Solving Activities

The work of the ninth-grade mathematics teacher should be directed towards the development of **subject-specific competencies** by balancing mathematical rigour with the accessibility of instructional content and adapting teaching practices to students' developmental characteristics. The design of learning activities should integrate both **algorithmic** and **heuristic** strategies, encouraging exploration, mathematical argumentation, and learner autonomy in mathematical problem solving.

Instructional planning should be based on the national mathematics curriculum and the results of **initial assessment**, while also taking into account the cognitive, motivational, and attitudinal characteristics of the student group. Learning activities should promote the development of **STEM competencies** through the identification and modelling of problem situations, the application of mathematical reasoning, the interpretation of results, the transfer of knowledge to new contexts, and effective mathematical communication.

In conclusion, fostering positive attitudes towards mathematics at the ninth-grade level depends upon the implementation of instructional strategies centred on conceptual understanding, problem posing, and reflective thinking, together with the creation of a stimulating learning environment that values students' effort, recognises individual progress, and promotes learning through exploration.

CHAPTER IV. A DESCRIPTIVE STUDY ON PROBLEM-SOLVING ALGORITHMS IN MATHEMATICS TEACHING

IV.1. Problem-Solving Algorithms in Mathematics Teaching

The literature consistently highlights the important role of **algorithmic strategies** in mathematics education, as they provide students with a structured framework for mathematical problem solving and facilitate the development of **procedural competence**. Owing to their rigorous and sequential nature, **problem-solving algorithms** contribute to the organisation of mathematical reasoning, the reduction of errors, and the strengthening of students' confidence in their problem-solving abilities (Pólya, 1965; Schoenfeld, 1985).

At the same time, research indicates that the effectiveness of algorithmic strategies depends largely on the manner in which they are integrated into the instructional process. An exclusively procedural approach may encourage mechanical learning while limiting the development of conceptual understanding and cognitive flexibility (Skemp, 1976; Hiebert & Grouws, 2007). Consequently, contemporary educational practice advocates the integration of problem-solving algorithms with heuristic strategies, mathematical argumentation, and reflective activities focused on the problem-solving process.

Beyond their cognitive function, problem-solving algorithms may also influence the affective and attitudinal dimensions of learning. A clearly structured problem-solving process can reduce uncertainty, strengthen students' sense of mathematics self-efficacy, and alleviate mathematics anxiety, thereby fostering more positive attitudes towards mathematics (Ashcraft & Krause, 2007; Hannula, 2012).

Based on these theoretical considerations, the present descriptive study aims to explore mathematics teachers' perspectives on the use of problem-solving algorithms in ninth-grade mathematics instruction. Specifically, the study seeks to identify how teachers perceive the contribution of these strategies to the development of mathematical competencies and to the enhancement of students' interest, motivation, self-confidence, and mathematics anxiety, thereby providing evidence for the optimisation of instructional practices and informing the practice-oriented research presented in the subsequent chapters.

IV.2. Research Aim

The aim of this study is to examine the pedagogical significance of using problem-solving algorithms in mathematical problem solving during the transition to upper secondary education by exploring mathematics teachers' perspectives and identifying their implications for optimising the teaching–learning process and supporting the affective and motivational development of students.

IV.3. Research Objectives

The general objective of the study is to investigate how mathematics teachers conceptualise and evaluate the systematic use of problem-solving algorithms at the ninth-grade level, as well as the pedagogical implications they attribute to these strategies with regard to students' affective-attitudinal development and learning trajectories.

The specific objectives operationalise the general objective by directing the investigation towards a detailed analysis of teachers' perceptions of the use of problem-solving algorithms and the pedagogical implications attributed to them in the teaching and learning of ninth-grade mathematics:

O1: To analyse teachers' perceptions of the role of problem-solving algorithms in fostering ninth-grade students' interest in and motivation for mathematics.

O2: To explore teachers' perceptions of the relationship between procedural algorithms and heuristic problem-solving strategies with respect to the development of students' self-confidence and their attitudes towards mathematics.

O3: To investigate teachers' interpretations of the relationship between the systematic use of problem-solving algorithms, students' academic achievement, and their overall attitudes towards mathematics.

O4: To identify directions for improving instructional practices through the convergence of qualitative data obtained from the focus-group interviews.

IV.4. Research Question

How do mathematics teachers perceive the role of problem-solving algorithms in influencing students' interest, motivation, self-confidence, and mathematics anxiety at the beginning of upper secondary education?

This overarching research question reflects the intention to explore the pedagogical meanings attributed to the algorithmisation of mathematical problem solving from the perspective of teachers' professional experience.

More specifically, the research question addresses the following dimensions:

Interest in mathematics, referring to the extent to which the systematic use of problem-solving algorithms is perceived as facilitating students' access to mathematical content and promoting cognitive engagement in learning activities;

Learning motivation, examined in relation to the role of algorithmic structures in reducing uncertainty and supporting students' perseverance in solving mathematical tasks;

Self-confidence, analysed in terms of the extent to which the application of problem-solving algorithms contributes to the development of mathematics self-efficacy and the consolidation of successful learning experiences;

Mathematics anxiety, explored from the perspective of the potentially dual role of algorithmisation, which may function both as a source of instructional support and as a potential contributor to cognitive rigidity and performance pressure.

IV.5. Research Hypotheses

The hypotheses are formulated as theoretically grounded expectations concerning teachers' perceptions, based on the existing literature, without implying causal or intervention-based relationships.

H1: Mathematics teachers perceive the systematic use of problem-solving algorithms in ninth-grade instruction as having a positive influence on students' interest in and motivation for mathematics.

H2: Mathematics teachers perceive meaningful differences between the effectiveness of procedural algorithms and heuristic problem-solving strategies with respect to the development of students' self-confidence and their perceptions of mathematics.

H3: Mathematics teachers perceive a positive relationship between students' academic achievement associated with the use of problem-solving algorithms and their overall attitudes towards mathematics.

H4: Mathematics teachers perceive the systematic use of problem-solving algorithms as having a dual effect on students' mathematics anxiety, depending on the manner in which these algorithms are integrated into instructional practice.

IV.6. Research Variables

Independent Variable: The Instructional Dimension of the Use of Problem-Solving Algorithms

The instructional dimension of the use of problem-solving algorithms is conceptualised as the **independent variable** and is operationalised through the analysis of teachers' representations and beliefs regarding algorithms, their instructional practices for integrating these algorithms into ninth-grade mathematics teaching, the ways in which they balance algorithmic approaches with mathematical reasoning and creativity, the contextual factors influencing the use of algorithms, and issues related to professional development and training needs in algorithm-based instruction.

Dependent Variable: Students' Affective-Attitudinal Dimension Towards Mathematics

Students' affective-attitudinal dimension towards mathematics is conceptualised as the **dependent variable** and is operationalised through four main indicators: students' interest in learning mathematics, their motivation to engage in mathematical problem-solving activities, their confidence in their own mathematical abilities, and the level of mathematics anxiety experienced in learning and assessment contexts.

IV.7. Participants

Sampling Criteria

The sample consisted of qualified mathematics teachers holding higher education degrees and possessing more than five years of professional teaching experience.

Participant Selection

Participant recruitment was conducted between **September and October 2023**. To ensure the desired focus-group size of **12 participants**, a total of **14 mathematics teachers** were invited, thereby providing a reserve in the event of participant withdrawal.

The final sample comprised **12 mathematics teachers** from **Târgu Mureș, Mureș County, Romania**, whose demographic and professional characteristics are presented in the table below.

IV.8. Research Methodology

IV.8.1. Focus Group Method

The focus group session lasted approximately **60-90 minutes** and was moderated by the principal researcher using a **semi-structured interview guide**. The discussion was audio- and video-recorded with the participants' informed consent, and confidentiality was ensured through the use of anonymous identification codes.

IV.8.2. Interview Guide

Introduction. The purpose of this discussion is to explore how mathematics teachers perceive and implement algorithmic strategies in mathematics teaching. Participation is voluntary, and there are no right or wrong answers. Participants are encouraged to express their views openly and to share their professional experiences and perspectives.

IV.8.3. Data Processing and Analysis

The focus group discussions were transcribed verbatim and subjected to **thematic content analysis**. The trustworthiness of the findings was enhanced through **methodological triangulation** and **peer debriefing**. Following transcription, the qualitative data were analysed using the procedures of **open coding**, **axial coding**, and **selective coding**, as described by Corbin and Strauss (2015).

Examples of initial codes included *"positive perception," "lack of resources," "professional development needs," "perceived effectiveness,"* and *"implementation challenges."*

The resulting coding framework and the themes identified through the content analysis provide a comprehensive overview of the principal analytical categories, facilitating a coherent interpretation of the qualitative data collected during the study.

IV.8.4. Research Procedure

The research procedure was designed in accordance with the principles of **qualitative research methodology**, employing the **focus group** as the primary method of data collection. This methodological approach was selected to facilitate an in-depth exploration of mathematics teachers' perceptions and professional experiences regarding the use of problem-solving algorithms in ninth-grade mathematics instruction.

IV.8.5. Organisation and Conduct of the Focus Group

The qualitative study was conducted using the **focus group method** on **16 September 2023** at the **"Mihai Eminescu" National Pedagogical College** in **Târgu Mureș, Romania**. At the beginning of the session, the moderator introduced the purpose of the research, the objectives of the study, and the procedures governing the discussion. Particular emphasis was placed on adherence to the principles of **research ethics**, including informed consent, data confidentiality, and the exclusive use of the collected data for scientific research purposes.

IV.8.5.1. Conduct of the Focus Group

The central phase of the focus group, lasting approximately **100 minutes**, was devoted to the systematic exploration of the research topic—the influence of the use of **problem-solving algorithms** in ninth-grade mathematics instruction. The discussion was guided by **open-ended questions** and **problem-based scenarios**, designed to encourage pedagogical reflection and the exchange of professional experiences among the participants.

IV.8.5.2. Concluding Phase

At the conclusion of the session, the moderator provided an interpretative synthesis of the principal themes that emerged from the discussion, relating them to the objectives of the doctoral research. Particular attention was given to identifying recurring ideas, areas of consensus, and differences in participants' perspectives, as well as to discussing their potential implications for the design of a **professional development programme** tailored to the instructional needs identified through the study.

IV.9. Study Findings

IV.9.1. Collection of Primary Qualitative Data: Research Procedure

Primary qualitative data were collected through the **focus group method**, involving **12 mathematics teachers** from **Mureș County, Romania**.

From both a quantitative and, more importantly, a qualitative perspective, the focus group interview successfully achieved its intended objectives. Participants' responses were consistent, well reasoned, and directly relevant to the research topic, providing a rich body of empirical data suitable for an in-depth qualitative analysis.

IV.9.2. Data Analysis and Interpretation: The Use of Content Analysis

The data obtained during the focus group were analysed using **qualitative content analysis**, with the aim of identifying the principal themes and meanings emerging from the participants' discourse.

The findings were synthesised in an **analytical framework** that enabled the systematic organisation of the qualitative data and facilitated comparisons across participants' responses, making it possible to identify both convergent and divergent viewpoints.

IV.9.3. Cross-Sectional and Within-Case Analysis of the Data

The focus group participants were mathematics teachers aged between **30 and 55 years**. The qualitative data were analysed both **within cases**, by examining the internal consistency of each participant's responses, and **across cases**, by comparing participants' perspectives on the same research topics.

The interview transcripts were analysed through **open coding**, **axial coding**, and **selective coding** (Corbin & Strauss, 2015), enabling the identification of the principal themes and analytical categories relevant to the objectives of the study. The findings are organised around **four overarching themes** and summarised in a **thematic synthesis matrix**, facilitating an integrated interpretation of teachers' perceptions and attitudes regarding the use of algorithmic strategies in mathematics teaching.

IV.9.3.1. Within-Case Analysis

Participants regarded **algorithmic strategies** as effective instructional tools for organising mathematical thinking and structuring the problem-solving process. They considered their effectiveness to depend on students' level of prior knowledge, systematic practice, and the adaptation of instructional approaches to individual learning needs. Furthermore, participants emphasised that algorithmic strategies contribute to the development of mathematical reasoning, enhance students' self-confidence, and reduce mathematics anxiety. They also recommended that these strategies be complemented by **digital learning resources** and implemented within a **supportive learning environment** characterised by clarity, sequential organisation, and instruction adapted to students' developmental levels.

IV.9.3.2. Cross-Case Analysis

The **cross-case analysis** involved comparing participants' responses to the same interview questions and research themes in order to identify common patterns, differences, and recurring trends across the dataset.

The analysis of responses to **Items 1–10** revealed a broad consensus among the participating teachers regarding the educational value of algorithmic strategies in organising mathematical thinking, developing procedural competencies, and improving students' academic achievement. Participants agreed that these strategies reduce cognitive uncertainty and facilitate learning, while emphasising that their effectiveness depends on their flexible application and integration with **heuristic**, **metacognitive**, and **collaborative learning strategies**. Furthermore, teachers recommended adapting algorithmic approaches to students' individual characteristics, incorporating digital technologies into mathematics instruction, and promoting a balanced pedagogical approach that fosters **critical thinking**, **creativity**, and the development of mathematical competencies.

IV.9.3.3. Data Analysis Using the Corbin and Strauss Grounded Theory Approach

The qualitative data were also analysed using the systematic **Grounded Theory** methodology proposed by **Corbin and Strauss (2015)**, following the stages of **open coding**, **axial coding**, and **selective coding**. This analytical strategy made it possible to identify relationships among the emerging categories and to develop an interpretative model explaining the role of **problem-solving algorithms** in mathematics teaching.

The findings indicate that teachers primarily perceive problem-solving algorithms as instructional tools for structuring mathematical thinking and organising the problem-solving process. According to the participants, these strategies contribute to the development of procedural competencies and strengthen students' confidence in their mathematical abilities. At the same time, teachers emphasised that the effectiveness of algorithmic strategies depends on their integration within a flexible instructional approach adapted to students' levels of prior knowledge and complemented by activities involving exploration, mathematical argumentation, and reflective thinking.

The resulting conceptual model comprises **four interrelated dimensions**: (1) the cognitive structuring function of problem-solving algorithms; (2) their influence on students' academic achievement and attitudes towards mathematics; (3) the contextual factors that determine the effectiveness of their instructional use; and (4) directions for the optimisation of mathematics teaching practices.

IV.10. Discussion and Conclusions: Pedagogical Implications

The findings of the focus group analysis reveal a nuanced understanding of the role of **algorithmic problem-solving strategies** in mathematics teaching, confirming the complexity of the relationship between the use of **problem-solving algorithms**, students' academic achievement, and their attitudes towards mathematics.

The thematic analysis identified four principal themes. First, algorithmic strategies are perceived as effective tools for structuring mathematical thinking and organising the problem-solving process (**Theme 1**). Second, they are considered to contribute to the enhancement of students' self-confidence and academic achievement (**Theme 2**). Third, their effectiveness is viewed as dependent upon the educational context and students' levels of prior knowledge (**Theme 3**). Finally, participants recommended the flexible use of algorithmic strategies in combination with heuristic approaches and educational technologies in order to optimise the teaching–learning process (**Theme 4**).

IV.11. Verification of the Research Hypotheses

The findings support the proposed research hypotheses, indicating that mathematics teachers perceive **problem-solving algorithms** as having a positive influence on students' motivation, self-confidence, and attitudes towards mathematics. The results also confirm the importance of maintaining an appropriate balance between **algorithmic** and **heuristic** strategies, adapted to the instructional context, in order to optimise learning outcomes and academic achievement.

Overall, the relationship between the research hypotheses and the empirical findings provides substantial support for the initial theoretical framework, confirming that teachers perceive problem-solving algorithms as making a positive contribution to both the **cognitive** and **affective-motivational dimensions** of mathematics learning.

IV.12. General Conclusions

The present study investigated the role of **problem-solving algorithms** in ninth-grade mathematics teaching from the perspective of mathematics teachers, with particular emphasis on their influence on students' attitudes towards mathematics.

According to the participants, problem-solving algorithms are most frequently employed when teaching topics such as **equations, functions, geometry, and trigonometry**, where they are valued for their clarity and instructional effectiveness. However, teachers also emphasised that an exclusively procedural approach may encourage mechanical learning while limiting students' cognitive flexibility and conceptual understanding.

IV.13. Pedagogical Implications

This study makes a number of significant contributions to both theory and educational practice by providing an updated perspective on how mathematics teachers perceive the role of **problem-solving algorithms** in relation to the **attitudinal dimension of mathematics learning** and the relationship between **algorithm-based instructional practices** and the affective climate of the mathematics classroom.

The pedagogical implications highlight the need to clarify the role of algorithmic strategies within **teacher education programmes**, to promote their balanced integration with heuristic approaches, to adapt instructional practices to students' individual characteristics, and to make effective use of digital educational resources. Furthermore, the findings support the implementation of **formative assessment** focused on students' progress as a means of promoting conceptual understanding and strengthening students' confidence in their mathematical abilities.

IV.14. Research Limitations and Directions for Future Research

IV.14.1. Research Limitations

The present study is **qualitative**, **descriptive**, and **exploratory** in nature and was conducted with a relatively small sample of mathematics teachers, which limits the generalisability of the findings. Furthermore, the analysis reflects exclusively the perspectives of teachers, without directly measuring students' attitudes towards mathematics or their academic achievement. Consequently, the findings should be interpreted within the specific educational context in which the study was conducted.

IV.14.2. Directions for Future Research

Future research could extend the present study by employing **quantitative** and **mixed-methods** research designs with larger and more diverse samples. Further investigations should also incorporate students' perspectives on their attitudes towards mathematics and mathematics anxiety, thereby providing a more comprehensive understanding of the relationships among instructional practices, affective factors, and academic achievement.

In addition, future studies are encouraged to compare the effectiveness of **algorithmic**, **heuristic**, and **metacognitive** problem-solving strategies, as well as to examine their respective contributions to the development of **mathematical competencies** and the integration of **algorithmic thinking** within **STEM education**.

CHAPTER V. RELATIONSHIPS AMONG PERCEPTIONS OF MATHEMATICS, ATTITUDES TOWARDS MATHEMATICS, MATHEMATICS ANXIETY, MATHEMATICS SELF-EFFICACY, AND ACADEMIC ACHIEVEMENT IN THE CONTEXT OF ALGORITHMIC INSTRUCTION

V.1. Introduction

Academic achievement in mathematics is influenced not only by students' cognitive abilities but also by psychological factors such as **perceptions of mathematics**, **attitudes towards mathematics**, **mathematics anxiety**, and **mathematics self-efficacy**. **Algorithmic instruction** has the potential to reduce cognitive uncertainty and strengthen students' confidence, thereby promoting engagement and improving academic performance. Investigating the relationships among these variables provides a theoretical and empirical basis for the development of educational interventions aimed at optimising the teaching-learning process and fostering the development of mathematical competencies.

The conceptual model proposed in this study considers **academic achievement in algorithmic mathematical tasks** as the central dependent variable and incorporates contextual variables, including **educational specialisation** and **type of educational programme**, which may influence both the levels of the psychological variables and the relationships among them (Ashcraft & Krause, 2007; Else-Quest et al., 2010; Frenzel et al., 2007).

Based on these theoretical foundations, the conceptual model proposes the following relationships:

Perceptions of mathematics → Attitudes towards mathematics (Eccles & Wigfield, 2002; Hannula, 2012);

Perceptions of mathematics → Academic achievement in algorithmic mathematical tasks (Schunk et al., 2014);

Attitudes towards mathematics → Academic achievement in algorithmic mathematical tasks (Ma & Kishor, 1997);

Mathematics anxiety → Academic achievement in algorithmic mathematical tasks (negative relationship) (Ashcraft & Kirk, 2001; Carey et al., 2017);

General self-efficacy → Academic achievement in algorithmic mathematical tasks (positive relationship) (Bandura, 1997; Schunk & DiBenedetto, 2020);

General self-efficacy × Mathematics anxiety → Academic achievement in algorithmic mathematical tasks (moderating effect; Bandura, 1997);

Educational specialisation and **type of educational programme** as grouping and moderating variables (Else-Quest et al., 2010; Frenzel et al., 2007).

V.2. Research Design

The present research is a **quantitative, non-experimental, cross-sectional, and correlational-explanatory study** investigating the relationships among **perceptions of mathematics**, **attitudes towards mathematics**, **mathematics anxiety**, **general self-efficacy**, and **academic achievement in algorithmic mathematical tasks**, while also examining the influence of **educational specialisation** and **type of educational programme**.

Regression analyses were employed to test the predictive relationships among the study variables. The explanatory nature of the research is supported by the use of regression models and integrated analytical frameworks that enable the examination of both direct and indirect relationships among the variables under investigation.

The study was conducted in accordance with the fundamental principles of research ethics, including **informed consent**, **participant anonymity**, **data confidentiality**, and the exclusive use of the collected data for scientific research purposes.

V.3. Research Aim

The aim of the present study is to contribute to a deeper understanding of the **psychoeducational mechanisms** involved in mathematics learning at the beginning of upper secondary education by investigating how the cognitive and affective variables associated with mathematics influence **academic achievement in algorithmic mathematical tasks**.

V.4. Research Objectives

V.4.1. General Research Objective

The general objective of this study is to examine the relationships among **perceptions of mathematics**, **attitudes towards mathematics**, **mathematics anxiety**, **general self-efficacy**, and **academic achievement in mathematics within the context of algorithmic instruction**, using a quantitative research approach with ninth-grade students. In the present study, **general confidence** is conceptualised as **general self-efficacy**.

V.4.2. Specific Research Objectives

To investigate the relationship between perceptions of mathematics and academic achievement in mathematics within the context of algorithmic instruction.

To examine the relationship between attitudes towards mathematics and academic achievement within the context of algorithmic instruction.

To determine the relationship between mathematics anxiety and academic achievement in mathematics within the context of algorithmic instruction.

To examine the relationship between general self-efficacy and academic achievement in mathematics within the context of algorithmic instruction.

To investigate the relationships among perceptions of mathematics, attitudes towards mathematics, mathematics anxiety, and general self-efficacy.

To determine the extent to which perceptions of mathematics, attitudes towards mathematical challenges, mathematics anxiety, and general self-efficacy predict academic achievement in mathematics within the context of algorithmic instruction.

V.5. Research Questions

To address the research objectives outlined in the previous section, the following research questions were formulated:

What is the relationship between **perceptions of mathematics** and **academic achievement in mathematics within the context of algorithmic instruction** (grades/test scores) among the students included in the study?

What is the relationship between **attitudes towards mathematics** and **academic achievement in mathematics within the context of algorithmic instruction**?

What is the relationship between **mathematics anxiety** and **academic achievement in mathematics within the context of algorithmic instruction**?

What is the relationship between **general self-efficacy** and **academic achievement in mathematics within the context of algorithmic instruction**?

To what extent are **perceptions of mathematics** associated with **attitudes towards mathematics**?

To what extent is **mathematics anxiety** associated with **general self-efficacy**?

To what extent do **perceptions of mathematics**, **attitudes towards mathematics**, **mathematics anxiety**, and **general self-efficacy** predict **academic achievement in mathematics within the context of algorithmic instruction**? *(Regression model)*

Is **algorithmic instruction** associated with the affective-cognitive variables (**perceptions of mathematics, attitudes towards mathematics, mathematics anxiety, and general self-efficacy**) as well as with **academic achievement in mathematics**?

Does **algorithmic instruction** explain additional variance in **academic achievement in mathematics** beyond that accounted for by the other psychological variables? *(Hierarchical regression analysis)*

Are there statistically significant differences in the variables under investigation (**perceptions of mathematics, attitudes towards mathematics, mathematics anxiety, general self-efficacy, and academic achievement**) according to demographic characteristics (e.g., **gender** and **grade level**, where such data are available)?

V.6. Research Hypotheses

V.6.1. General Hypothesis

H_0 (Null Hypothesis): There are no statistically significant relationships among **perceptions of mathematics**, **attitudes towards mathematics**, **mathematics anxiety**, **general self-efficacy**, and **academic achievement in mathematics within the context of algorithmic instruction**.

H_1 (Research Hypothesis): There are statistically significant relationships among **perceptions of mathematics**, **attitudes towards mathematics**, **mathematics anxiety**, **general self-efficacy**, and **academic achievement in mathematics within the context of algorithmic instruction**.

V.6.2. Specific Hypotheses

H1: There is a statistically significant positive correlation between **positive perceptions of mathematics** and **academic achievement in mathematics within the context of algorithmic instruction**.

H2: There is a statistically significant positive correlation between **positive attitudes towards mathematics** and **academic achievement in mathematics within the context of algorithmic instruction**.

H3: There is a statistically significant negative correlation between **mathematics anxiety** and **academic achievement in mathematics within the context of algorithmic instruction**.

H4: There is a statistically significant positive correlation between **general self-efficacy** and **academic achievement in mathematics within the context of algorithmic instruction**.

H5: There is a statistically significant negative correlation between **mathematics anxiety** and **general self-efficacy**.

H6: Perceptions of mathematics, **attitudes towards mathematics**, **mathematics anxiety**, and **general self-efficacy** significantly predict **academic achievement in mathematics within the context of algorithmic instruction**.

V.7. Research Variables and Their Operationalisation

The research model comprises four **independent variables—perceptions of mathematics**, **attitudes towards mathematics**, **mathematics anxiety**, and **general self-efficacy**—and one **dependent variable**, namely **academic achievement in algorithmic mathematical tasks**.

Perceptions of mathematics refer to students' evaluations of the usefulness, difficulty, and relevance of mathematics as a school subject, whereas **attitudes towards mathematics** reflect their cognitive, affective, and behavioural predispositions towards mathematical learning activities. **Mathematics anxiety** describes the level of tension and apprehension experienced when solving mathematical tasks, while **general self-efficacy** refers to students' confidence in their ability to cope successfully with academic demands.

These constructs were operationalised using validated **psychometric instruments** administered on **Likert-type scales**, in accordance with the original structure of each instrument and the recommendations reported in the relevant literature. **Academic achievement in algorithmic mathematical tasks** was assessed using objective indicators of students' mathematics performance. This methodological approach enabled the quantification of the study variables and the empirical testing of the conceptual model concerning the relationships between affective-cognitive factors and students' performance in algorithmic mathematical tasks.

V.8. Research Methodology

The present investigation employed a **descriptive, non-experimental research design** and was conducted during the **2024–2025 academic year**, spanning all five instructional modules of the Romanian school calendar. Data were collected in school settings under standardised administration conditions and in full compliance with the ethical principles governing educational research.

V.9. Participants

The sample consisted of **235 ninth-grade students** enrolled in **two upper secondary schools**.

With respect to the educational pathway, **four classes (121 students)** belonged to the **general academic track**, while **four classes (114 students)** were enrolled in the **vocational education track**.

Within the general academic track, the **Natural Sciences** specialisation included **58 students (24.7%)**, representing the second largest subgroup in the sample. This proportion reflects a substantial enrolment in science-oriented programmes, although it remains considerably lower than that of the **Pedagogical** specialisation.

The **Social Sciences** programmes comprised **63 students (26.8%)**, distributed relatively evenly between the two participating schools (**31** and **32 students**, respectively).

From an institutional perspective, the majority of participants (**146 students; 62.1%**) were enrolled at the **"Mihai Eminescu" National Pedagogical College**, whereas **89 students (37.9%)** attended the **"Alexandru Papiu Ilarian" National College**.

V.10. Research Instruments

The study employed **psychometric instruments** that were either developed or adapted to assess the variables included in the research model. The instruments utilised **four-point Likert-type scales**, consistent with their original design and with recommendations reported in the relevant psychometric and educational research literature.

V.10.1. The Modified Abbreviated Mathematics Anxiety Scale (mAMAS)

Mathematics anxiety was assessed using the **Modified Abbreviated Mathematics Anxiety Scale (mAMAS)**, a validated instrument consisting of **nine items** administered on a **four-point Likert-type scale**, with higher scores indicating higher levels of mathematics anxiety.

V.10.2. Perceptions of Mathematics and Attitudes Towards Mathematics Scale

Students' **perceptions of mathematics** and **attitudes towards mathematics** were assessed using researcher-developed scales constructed on the basis of the educational psychology literature and adapted to the developmental characteristics of ninth-grade students. The instrument employed a **Likert-type scale with an even number of response options** to minimise neutral responses. Negatively worded items were reverse-coded so that higher scores consistently reflected more positive perceptions of and attitudes towards mathematics.

Content validity was established through the development of items that were both relevant to the research constructs and appropriate for the target population. The instrument's **internal consistency reliability** was assessed using **Cronbach's alpha coefficient**, supporting its suitability for examining the relationships between students' perceptions of mathematics and the other variables included in the study.

V.10.3. General Self-Efficacy Scale

General self-efficacy was measured using a **short form of the General Self-Efficacy Scale**, which assesses students' beliefs in their ability to cope successfully with challenges and to achieve their academic goals.

V.10.4. Algorithmic Competence Test

Students' **academic achievement in algorithmic mathematical tasks** was assessed using an **Algorithmic Competence Test**, consisting of items designed to evaluate the application of **problem-solving algorithms** across several mathematical domains, including **functions**, **sequences and progressions**, **Viète's formulas**, **vectors in the plane**, and the **geometry of right triangles**.

V.11. Data Collection Procedure

Data were collected during regular mathematics lessons under **standardised administration conditions**. The questionnaires were administered online, while the **Algorithmic Competence Test** was administered subsequently during the same data collection session. To enable the matching of responses across all research instruments while preserving participants' anonymity, each student used a unique anonymous identification code, ensuring full compliance with the ethical principles governing educational research.

V.12. Data Analysis Strategy

The statistical analysis comprised **descriptive statistics**, the assessment of the **internal consistency reliability** of the research instruments, **correlation analysis**, **hierarchical multiple regression analysis**, and **between-group comparisons**. These analytical procedures were employed to describe the study variables and to examine the relationships among **perceptions of mathematics**, **attitudes towards mathematics**, **mathematics anxiety**, **general self-efficacy**, and **academic achievement in algorithmic mathematical tasks**.

V.13. Reliability Analysis of the Research Instruments

To evaluate the psychometric quality of the research instruments, their **internal consistency reliability** was assessed using both **Cronbach's alpha (α)** and **McDonald's omega (ω)** coefficients. The results indicated varying levels of reliability across the instruments, a consideration that was taken into account when interpreting the subsequent statistical analyses.

The scales measuring **perceptions of mathematics**, **attitudes towards mathematics**, **mathematics anxiety**, and **general self-efficacy** yielded **Cronbach's alpha** coefficients ranging from **0.52 to 0.64**, indicating moderate internal consistency, which is consistent with instruments adapted to the educational context under investigation. The corresponding **McDonald's omega** coefficients confirmed this pattern, providing additional evidence supporting the use of these scales for examining the relationships among the study variables.

To assess **mathematics self-efficacy specific to algorithmic learning**, the **Mathematics Self-Efficacy for Algorithmic Learning Scale (MSEALS)** was developed and validated. The instrument was specifically designed to evaluate students' confidence in solving algorithmic mathematical tasks. Reliability analysis demonstrated **excellent internal consistency** (**Cronbach's α = 0.958; ordinal Cronbach's α = 0.959**), indicating a high degree of item homogeneity and confirming the scale's ability to measure the intended construct reliably.

Overall, these findings support the adequacy of the research instruments and demonstrate that they provide a robust methodological foundation for investigating the relationships among **perceptions of mathematics**, **attitudes towards mathematics**, **mathematics anxiety**, **general self-efficacy**, and **academic achievement in algorithmic mathematical tasks**.

V.14. Descriptive Analysis of the Study Variables

The descriptive analysis aimed to characterise the variables under investigation and to identify the general patterns of students' responses. For each construct, **means**, **standard deviations**, and **minimum and maximum values** were calculated. Furthermore, analyses of item-level response distributions provided a detailed description of students' **perceptions of mathematics**, **attitudes towards mathematics**, **mathematics anxiety**, **general self-efficacy**, and **academic achievement in algorithmic mathematical tasks**.

Perceptions of Mathematics

Students' perceptions of mathematics were assessed using six items addressing the perceived **usefulness**, **difficulty**, and **developmental value** of the subject.

Regarding the usefulness of mathematics for understanding other school subjects, **57.0%** of the students perceived its usefulness as low, whereas **34.5%** considered it to be high. This finding suggests a limited awareness of the interdisciplinary nature of mathematics and highlights the need for more frequent integration of authentic and interdisciplinary applications into mathematics instruction.

With respect to perceived difficulty, **53.1%** of students rated mathematics as **fairly** or **very difficult**. This result indicates that many students already perceive mathematics as challenging during their first year of upper secondary education, supporting the implementation of instructional strategies that facilitate conceptual understanding and reduce uncertainty during mathematical problem solving.

Concerning the contribution of mathematics to the development of logical thinking, only **38.3%** of students considered this contribution to be substantial, whereas **61.7%** reported relatively low perceptions. These findings suggest that many students do not fully recognise the formative value of mathematics, which may negatively influence both their motivation and their engagement in learning.

Students' responses regarding the difficulty of understanding mathematical concepts further confirmed the perception of considerable cognitive complexity, particularly in relation to ninth-grade mathematical content. This finding highlights the importance of employing gradual instructional approaches and algorithmic strategies that facilitate the organisation of the problem-solving process.

Overall, the descriptive analysis indicates that students generally hold **moderately negative perceptions** regarding the usefulness and accessibility of mathematics, thereby justifying further investigation of the relationship between these perceptions and academic achievement in algorithmic mathematical tasks.

Attitudes Towards Mathematics

The analysis of the attitude scale revealed a **moderate level of interest and engagement** in mathematics learning activities. The distribution of responses indicated considerable individual differences in students' willingness to solve mathematical problems and their perseverance when confronted with challenging tasks.

The findings suggest that while some students demonstrate strong interest and confidence in mathematics, others adopt more reserved or avoidant attitudes. These differences confirm the multidimensional nature of **attitudes towards mathematics** and support further examination of their relationships with academic achievement and the other psychological variables investigated in this study.

Mathematics Anxiety

The descriptive analysis of **mathematics anxiety** revealed substantial variability in students' responses, indicating considerable individual differences in emotional reactions to mathematical tasks.

The response distributions obtained using the **Modified Abbreviated Mathematics Anxiety Scale (mAMAS)** showed that a substantial proportion of students experience feelings of tension during activities such as solving mathematical problems, completing written assessments, or responding to questions in front of the class. At the same time, other students reported relatively low levels of anxiety, confirming the heterogeneous nature of emotional responses to mathematics.

Overall, these findings support the hypothesis that mathematics anxiety represents an important factor in explaining academic achievement and justify its inclusion within the predictive model developed in this study.

General Self-Efficacy

Scores obtained on the **General Self-Efficacy Scale** indicated a **moderate level of confidence** in students' ability to cope successfully with mathematical tasks. Response distributions revealed considerable individual differences, ranging from students with relatively low confidence to those demonstrating high levels of self-efficacy.

These findings suggest that perceived personal competence constitutes an important determinant of students' engagement in learning and their achievement in algorithmic mathematical tasks, an issue examined further through correlational and predictive analyses.

Summary of the Descriptive Analysis

The descriptive analyses revealed sufficient variability across all study variables. The moderate levels of **perceptions of mathematics**, **attitudes towards mathematics**, and **general self-efficacy**, together with the substantial variability observed in **mathematics anxiety** and **academic achievement in algorithmic mathematical tasks**, justify the application of correlational and predictive statistical analyses and support the investigation of the relationships between affective-cognitive factors and mathematics achievement.

V.15. Correlational Analysis of the Relationships Among the Study Variables

The correlational analyses revealed a coherent pattern of relationships among the affective-cognitive variables, largely supporting the proposed conceptual model. The strongest associations were identified among **perceptions of mathematics**, **attitudes towards mathematics**, and **general self-efficacy**, whereas the direct relationships with **academic achievement in algorithmic mathematical tasks** were comparatively weaker.

A **moderate positive correlation** was found between **perceptions of mathematics** and **attitudes towards mathematics** ($\rho = 0.41$), indicating that students who perceive mathematics as useful and accessible generally display more positive attitudes towards the subject. Furthermore, perceptions of mathematics were positively associated with **general self-efficacy** ($\rho = 0.31$), suggesting that more favourable perceptions are accompanied by greater confidence in one's own abilities.

A further **weak-to-moderate positive association** was identified between **attitudes towards mathematics** and **general self-efficacy** ($\rho = 0.26$), indicating that students with more positive attitudes towards mathematics tend to report higher levels of perceived personal competence.

By contrast, **mathematics anxiety** exhibited **negative correlations** with **perceptions of mathematics** ($\rho = -0.15$), **attitudes towards mathematics** ($\rho = -0.19$), and **general self-efficacy** ($\rho = -0.24$). These findings confirm the inhibiting role of mathematics anxiety in shaping students' perceptions of mathematics, their engagement in learning, and their confidence in their own capabilities.

Overall, the correlational analyses indicate that **academic achievement in algorithmic mathematical tasks** is not explained by any single psychological variable in isolation but rather by the interaction among **perceptions of mathematics**, **attitudes towards mathematics**, **mathematics anxiety**, and **general self-efficacy**. These findings provide empirical support for the predictive analyses presented in the following section and reinforce the multidimensional nature of mathematical achievement.

V.16. Predictive and Explanatory Analysis of Academic Achievement in Algorithmic Mathematical Tasks

Within the explanatory model of **academic achievement in algorithmic mathematical tasks**, **mathematics self-efficacy specific to algorithmic learning (MSEALS)** is conceptualised as a **mediating variable** that facilitates the relationship between students' cognitive and attitudinal characteristics and their subsequent academic performance.

V.16.1. Hierarchical Multiple Regression Analysis

To test the explanatory model of **academic achievement in algorithmic mathematical tasks**, a **two-step hierarchical multiple regression analysis** was conducted.

Model 1 included the **cognitive and attitudinal variables**, namely **perceptions of mathematics** and **attitudes towards mathematics**.

Model 2 incorporated the **affective-motivational variables**, specifically **mathematics anxiety** and **mathematics self-efficacy for algorithmic learning (MSEALS)**.

The findings revealed a substantial increase in the proportion of variance explained in **academic achievement in algorithmic mathematical tasks** following the inclusion of the affective-motivational variables, particularly **mathematics self-efficacy for algorithmic learning (MSEALS)**. Whereas **perceptions of mathematics** and **attitudes towards mathematics** accounted for only a small proportion of the variance in academic achievement (**$R^2 = .013$**), the addition of **mathematics anxiety** and **MSEALS** significantly improved the explanatory power of the model (**$\Delta R^2 = .077$**).

These findings support the hypothesis that **task-specific mathematics self-efficacy** plays a crucial mediating role between students' cognitive characteristics and their academic achievement, providing a more robust explanation of performance than **general self-efficacy**, which was examined in the initial analytical model.

V.16.2. Mediation Analysis: The Role of Mathematics Anxiety and General Self-Efficacy

Relational Structure of the Mediation Model (Empirically Supported)

The analysis of the relationships among the study variables revealed **positive correlations** between **perceptions of mathematics** and **attitudes towards mathematics** ($\rho = 0.41$), **perceptions of mathematics** and **general self-efficacy** ($\rho = 0.31$), as well as between **attitudes towards mathematics** and **general self-efficacy** ($\rho = 0.26$). In contrast, **mathematics anxiety** was **negatively associated** with **general self-efficacy** ($\rho = -0.24$) and exerted an **indirect inhibitory influence** on students' academic achievement.

The findings indicate that **perceptions of mathematics** and **attitudes towards mathematics** do not directly influence **academic achievement in algorithmic mathematical tasks**. Instead, their effects are transmitted indirectly through **mathematics anxiety** and **self-efficacy**. Within this explanatory framework, **perceptions** and **attitudes** function as **foundational cognitive-affective determinants**, whereas **mathematics anxiety** and **self-efficacy** serve as **regulatory mechanisms** that influence students' academic achievement, which represents the ultimate outcome of these interacting affective-cognitive processes.

V.17. Group Comparisons by Educational Track and Academic Profile

To compare **mean scores** between the two **educational tracks**, an **independent-samples *t*-test** was employed. Differences in mean scores across **more than two academic profiles** were examined using a **one-way analysis of variance (one-way ANOVA)**. For all statistical analyses, the **level of statistical significance** was set at **$p < .05$**..

V.17.1. Differences According to Academic Profile

Differences among students enrolled in different **academic profiles** were examined using a **one-way analysis of variance (one-way ANOVA)** to assess the influence of academic profile on the affective-cognitive variables and **academic achievement in algorithmic mathematical tasks**.

The findings indicated that **perceptions of mathematics**, **attitudes towards mathematics**, **mathematics anxiety**, and **general self-efficacy** did not differ significantly across the academic profiles investigated (**$p > .05$**). These results suggest that students' perceptions of mathematics, their affective orientation towards the subject, and their evaluations of their own capabilities are relatively independent of their chosen academic profile.

In contrast, **academic achievement in algorithmic mathematical tasks** differed significantly across academic profiles (**$p < .05$**). The highest levels of achievement were observed among students enrolled in the **Science** profile, followed by those in the **Humanities** and **Vocational** profiles. This finding highlights the influence of curricular characteristics and differential exposure to mathematical learning activities on the development of algorithmic competence.

Overall, the analysis indicates that **academic profile** primarily influences students' mathematical achievement without producing significant differences in the affective-cognitive variables examined. These findings support the view that the development of **positive perceptions of mathematics**, **self-efficacy**, and **favourable attitudes towards mathematics** depends more strongly on the quality of learning experiences and instructional strategies than on students' academic specialisation.

V.17.2. Differences According to Educational Track

Differences between the **educational tracks** were examined using an **independent-samples *t*-test**.

The results indicated that there were **no statistically significant differences** between the educational tracks with respect to **perceptions of mathematics**, **attitudes towards mathematics**, **mathematics anxiety**, and **general self-efficacy** (**$p > .05$**). These findings suggest that the affective-cognitive variables investigated are relatively homogeneous across the educational tracks.

By contrast, the **independent-samples *t*-test** revealed **statistically significant differences** in **academic achievement in algorithmic mathematical tasks** (**$p < .05$**), favouring the educational track with a stronger emphasis on mathematics. This result confirms the important role of **curricular structure** and **instructional exposure to mathematics** in the development of algorithmic competence.

V.17.3. Integrative Interpretation

The comparative analyses indicate that **perceptions of mathematics**, **attitudes towards mathematics**, **mathematics anxiety**, and **general self-efficacy** do not differ significantly according to either **academic profile** or **educational track**, whereas **academic achievement in algorithmic mathematical tasks** is significantly influenced by these curricular factors.

The **one-way ANOVA** demonstrated that **academic profile** does not significantly differentiate the affective-cognitive variables but does produce significant differences in **academic achievement in algorithmic mathematical tasks**, confirming the influence of curricular structure on the acquisition of procedural mathematical competence.

Similarly, the **independent-samples *t*-test** showed that **educational track** does not significantly differentiate the affective-motivational variables but is associated with significant differences in **algorithmic mathematical achievement**, favouring the educational track with greater emphasis on mathematics instruction.

Taken together, these findings suggest that students' academic achievement reflects the interaction between the **educational context** and **affective-motivational mechanisms**, whereas the psychological variables examined primarily explain how students perceive, experience, and engage with mathematics.

V.18. Discussion of the Findings in Relation to the Conceptual Model

The findings provide empirical support for the proposed **conceptual model**, demonstrating that **positive perceptions of mathematics** and **favourable attitudes towards mathematics** promote students' engagement and perseverance, whereas **mathematics anxiety** negatively affects academic achievement. In contrast, **self-efficacy** facilitates learning and enhances students' ability to apply effective problem-solving strategies. The relationships observed among the study variables confirm the interdependence of the **cognitive**, **affective**, and **motivational** dimensions of mathematics learning, highlighting the importance of fostering an educational environment characterised by **constructive feedback**, **emotional support**, and the systematic development of students' confidence in their own mathematical abilities.

CHAPTER VI. PRACTICAL-APPLIED RESEARCH ENTITLED "CLASSROOM INVESTIGATIONS AT THE NINTH-GRADE LEVEL ON THE INFLUENCE OF PROBLEM-SOLVING ALGORITHMS ON STUDENTS' ATTITUDES TOWARDS MATHEMATICS"

VI.1. The Influence of the Systematic Use of Problem-Solving Algorithms on Students' Attitudes Towards Mathematics

Problem-solving algorithms are grounded in **constructivist** and **cognitive** perspectives, being regarded as instructional tools that facilitate the organisation of knowledge, reduce cognitive load, and foster students' self-efficacy. When integrated with **metacognitive strategies**, they support conceptual understanding and the development of positive attitudes towards mathematics. The theoretical framework underlying the present study assumes that the systematic use of problem-solving algorithms optimises learning and positively influences students' attitudes towards mathematics. This assumption was investigated through an exploratory questionnaire-based study involving ninth-grade students.

VI.2. Purpose of the Study

The purpose of the present research is to investigate the influence of the systematic use of **problem-solving algorithms** on the development and modification of **ninth-grade students' attitudes towards mathematics** by examining the relationships among **perceptions of mathematics**, **mathematics anxiety**, **self-confidence**, and **academic achievement**, while considering students' **academic profile** and **upper secondary educational track**.

The study adopts a predominantly **quantitative** approach with exploratory components, integrating a comparative analysis of data obtained through a **quasi-experimental pretest-posttest design**.

The objectives of the study are to:

- ✓ identify ninth-grade students' perceptions of **algorithmic mathematics learning**;
- ✓ investigate students' confidence in their mathematical abilities at the beginning of upper secondary education;
- ✓ explore levels of mathematics anxiety and the situations perceived as generating stress;

- ✓ evaluate the impact of the use of problem-solving algorithms on changes in students' attitudes towards mathematics;
- ✓ analyse differences according to students' academic profile and educational track.

These objectives enable the investigation of the affective and cognitive dimensions underlying students' relationships with mathematics and provide the empirical basis for the subsequent statistical analyses.

VI.3. Research Objectives

The study adopts a **mixed-methods design**, integrating an exploratory phase with a quasi-experimental phase. Accordingly, the research objectives are organised according to these complementary stages.

A. Exploratory Objectives

The exploratory phase aims to characterise the psycho-educational context of mathematics learning at the beginning of upper secondary education and to provide the foundation for the subsequent experimental intervention.

O1. To analyse the relationships among **perceptions of mathematics**, **attitudes towards mathematics**, **mathematics anxiety**, **self-efficacy**, and **academic achievement** among ninth-grade students.

O2. To identify the predictive role of **psychopedagogical variables** (perceptions of mathematics, mathematics anxiety, and self-efficacy) in explaining performance on **algorithmic mathematical tasks**.

O3. To compare the levels of the investigated variables according to **academic profile** (Science vs. Humanities) and **educational track** (general academic vs. vocational).

B. Experimental Objectives

The experimental phase aims to evaluate the impact of the systematic use of **problem-solving algorithms** on students' attitudes towards mathematics.

Its objectives are:

O4. To analyse the impact of the use of problem-solving algorithms on students' attitudes towards mathematics.

O5. To investigate changes in mathematics anxiety following the instructional intervention.

O6. To examine changes in students' self-efficacy and perceived mathematical competence following the intervention.

O7. To evaluate the relationship between the use of problem-solving algorithms and students' academic achievement in mathematics.

C. Applied Objective

O8. To formulate evidence-based instructional recommendations regarding the integration of **algorithmic strategies** into upper secondary mathematics teaching.

Achieving these objectives makes it possible to investigate both the cognitive and affective-motivational dimensions of students' relationships with mathematics and provides empirical evidence for optimising instructional practice.

VI.4. Research Questions

In accordance with the overall purpose, research objectives, and theoretical framework, the empirical investigation is guided by the following research questions:

RQ1. What is the relationship between the systematic use of **problem-solving algorithms** and ninth-grade students' attitudes towards mathematics?

RQ2. To what extent does the use of algorithmic strategies influence students' **mathematics anxiety** and **self-efficacy**?

RQ3. Are there significant differences between students enrolled in the **Science** profile and those in the **Humanities/Vocational** profiles with respect to the psychopedagogical variables investigated?

RQ4. To what extent do the psychopedagogical variables (**attitudes towards mathematics**, **mathematics anxiety**, and **self-efficacy**) predict students' academic achievement in mathematics?

RQ5. What attitudinal and emotional changes occur following the instructional intervention based on the systematic use of problem-solving algorithms?

VI.5. Research Hypotheses

General Research Hypothesis: *The systematic use of* ***algorithmic strategies*** *in teaching the* ***Common Core mathematics curriculum*** *to ninth-grade students is associated with* ***more positive attitudes towards mathematics****,* ***higher levels of self-efficacy****,* ***greater perceived usefulness of mathematics****,* ***lower levels of mathematics anxiety****, and* ***higher academic achievement on algorithmic mathematical tasks****, with these effects varying according to students'* ***academic profile*** *and* ***upper secondary educational track****.*

Specific Hypotheses:

H1. There are statistically significant differences between students in the **experimental group** and those in the **control group** regarding their attitudes towards mathematics following the implementation of the instructional intervention based on the use of problem-solving algorithms.

H2. There are statistically significant differences between students enrolled in the **Science** profile and those in the **Humanities/Vocational** profiles regarding their perceptions of mathematics and their attitudes towards the subject.

H3. There is a statistically significant positive relationship between prior mathematics achievement and students' perceptions of the usefulness of mathematics and their interest in the subject.

H4. There is a statistically significant negative relationship between mathematics anxiety and academic achievement in mathematics.

Null Hypotheses

The research hypotheses were tested against their corresponding **null hypotheses (H_0)**, following the principles of **inferential statistics** (Field, 2018). The null hypothesis assumes the absence of statistically significant relationships or differences between the variables under investigation.

Accordingly, the following null hypotheses were formulated:

H_{01}. There are no statistically significant differences between the experimental and control groups regarding attitudes towards mathematics following the instructional intervention.

H_{02}. There are no statistically significant differences between students enrolled in the Science profile and those in the Humanities/Vocational profiles regarding their perceptions of mathematics.

H_{03}. There is no statistically significant relationship between prior mathematics achievement and students' perceptions of the usefulness of mathematics.

H_{04}. There is no statistically significant relationship between mathematics anxiety and academic achievement in mathematics.

Rejection of the null hypotheses based on the statistical analyses provides empirical support for the corresponding research hypotheses.

Hypothesis Concerning the Boundary Conditions of Algorithmic Instruction

Rigid, exclusively procedural instruction may lead to **procedural dependence** and difficulties in transferring knowledge to novel situations (Hiebert & Grouws, 2007; Rittle-Johnson & Schneider, 2015).

In the absence of conceptual understanding, students may experience increased uncertainty when confronted with unfamiliar mathematical problems, thereby increasing levels of **mathematics anxiety** (Ashcraft, 2002).

Based on these findings, the present study incorporates a **boundary conditions hypothesis**, specifying the circumstances under which the instructional intervention may have limited or even negative effects.

H5 (Moderation Hypothesis). The positive effects of the use of **problem-solving algorithms** on students' attitudes towards mathematics are contingent upon their integration with **conceptual explanations** and **heuristic learning activities**. In the absence of such integration, rigid procedural instruction may result in procedural dependence, reduced transfer of learning, and higher levels of mathematics anxiety when students encounter unfamiliar mathematical problems.

VI.6. Research Variables

The **independent variable** of the study is the **systematic use of problem-solving algorithms**, implemented during mathematics instruction for the **experimental group**.

This variable is analysed comparatively between the **experimental group** (instruction based on problem-solving algorithms) and the **control group** (traditional mathematics instruction).

The **dependent variables** are as follows:

DV1. Attitudes Towards Mathematics. This variable reflects the affective and motivational dimensions of students' relationships with mathematics, including interest in the subject, enjoyment of mathematics lessons, and perceptions of the usefulness of mathematics.

DV2. Mathematics Anxiety. This variable refers to negative emotional reactions associated with mathematics learning and assessment, including fear, stress, and avoidance of participation.

DV3. Self-Efficacy. This variable represents students' perceptions of their own ability to solve mathematical tasks successfully and their sense of academic competence.

DV4. Academic Achievement in Mathematics. This variable comprises students' performance on **algorithmic mathematical tasks** together with their self-assessments of achievement in mathematics.

DV5. Perceived Usefulness of Mathematics. This variable reflects students' beliefs regarding the relevance and applicability of mathematics in academic and professional contexts.

Control (Grouping) Variable

For the comparative analyses, the following control variable was included: **Academic profile** (**Science**, **Humanities**, or **Vocational**).

VI.6.1. Operationalisation of the Research Variables

In educational research, the **operationalisation of variables** ensures coherence between the theoretical framework, the data collection instruments, and the statistical methods employed for data analysis (Cohen, Manion, & Morrison, 2007).

The study variables were operationalised through the items included in the questionnaire administered to ninth-grade students.

The **independent variable**, namely the **systematic use of problem-solving algorithms**, was operationalised using items assessing the **frequency of algorithm use**, **clarity of instructional explanations**, **perceived usefulness**, and the extent to which algorithmic strategies supported students in organising the steps required for problem solving. The resulting scores reflected students' perceived level of exposure to algorithmic instructional strategies.

The **dependent variables** were operationalised as follows.

Attitudes towards mathematics, conceptualised as a **multidimensional construct**, were assessed using Likert-type items measuring students' emotions, interest, engagement, and perceived usefulness of mathematics. The overall score was computed as the mean of the corresponding items (Ma & Kishor, 1997).

Mathematics anxiety was measured through items assessing fear of evaluation, stress experienced during mathematics lessons, and discomfort associated with solving mathematical problems in public. Higher scores indicated higher levels of mathematics anxiety (Ashcraft & Krause, 2007).

Mathematics self-efficacy was assessed using self-report items measuring students' perceived mathematical competence, confidence in solving challenging mathematical tasks, success in mathematics assessments, and perceived control over mathematical activities, in accordance with **Bandura's (1997) self-efficacy theory**.

Academic achievement was examined by combining students' self-reported and observed performance on **algorithmic mathematical tasks** with their self-evaluations of achievement. Specifically, academic achievement was operationalised through students' self-reported mathematics performance, previous mathematics grades, and perceived success in completing algorithmic mathematical tasks.

Scoring Procedure

All questionnaire items were rated on a **five-point Likert-type scale** (**1 = Strongly Disagree; 5 = Strongly Agree**). Scores for each construct were calculated as the **mean of the corresponding items**, and these composite scores were subsequently used in the statistical analyses examining the relationships among the study variables.

Outcome Variables Investigated

To avoid overly broad causal interpretations, the outcome variables investigated were classified into **two major categories**, widely recognised in the educational psychology and mathematics education literature: **cognitive outcomes** and **affective-motivational outcomes** (Kilpatrick, Swafford, & Findell, 2001).

This distinction reflects the view that **mathematical achievement** results from the interaction between **cognitive processes** and **affective-motivational factors** (Hannula, 2002; Pekrun, 2006).

1. Cognitive Outcomes

The **cognitive outcomes** were assessed through **mathematics achievement**, **procedural fluency**, and **transfer of learning**. These outcomes were measured using students' test scores, the accuracy and speed of problem solving, and their ability to apply **problem-solving algorithms** in novel mathematical situations. The systematic use of problem-solving algorithms is expected to enhance these cognitive outcomes by reducing **cognitive load**, promoting the development of **procedural fluency**, and fostering **conceptual understanding** (Kilpatrick et al., 2001; Sweller et al., 2011; Rittle-Johnson & Schneider, 2015; Hiebert & Grouws, 2007).

2. Affective-Motivational Outcomes

The study also examines the effects of the instructional intervention on **attitudes towards mathematics**, **mathematics anxiety**, and **mathematics self-efficacy**, psychological variables known to influence both learning and academic achievement (Pekrun, 2006; Hannula, 2002; Ashcraft, 2002; Bandura, 1997; Pajares & Miller, 1994). The effectiveness of the intervention is therefore evaluated with respect to both **cognitive** and **affective-motivational outcomes**, including the potential reduction of **mathematics anxiety** resulting from increased procedural clarity and structured problem-solving instruction (Ramirez et al., 2018).

VI.6.2. Operational Definitions

In the present study, the research variables were operationalised using the scores obtained from the assessment instruments administered during the **pre-intervention** and **post-intervention** phases. **Attitudes towards mathematics**, **mathematics anxiety**, **self-efficacy**, and **academic achievement in algorithmic mathematical tasks** were quantified using standardised indicators, thereby enabling comparisons between the **experimental group** and the **control group** and facilitating the evaluation of the effects of the instructional intervention.

The **independent variable**-the **systematic use of problem-solving algorithms**-was operationally defined as the implementation of **explicit**, **sequential**, and **reproducible algorithmic procedures** within the teaching–learning process, applied consistently throughout the experimental intervention. The effects of this intervention were examined by analysing the changes observed in the dependent variables.

Consistent with the study's **conceptual framework**, **heuristic strategies** were incorporated as a complementary component of the algorithmic instructional approach in order to promote **conceptual understanding**, **mathematical exploration**, and the **transfer of learning** to novel contexts. The operational distinction between **algorithmic** and **heuristic strategies** ensured both the conceptual clarity of the instructional intervention and the rigorous interpretation of the experimental findings.

VI.7. Research Strategy and Design

The study adopts a **mixed-methods** paradigm, integrating qualitative and quantitative approaches to achieve a comprehensive analysis of educational processes and to enable data triangulation, thereby enhancing the validity of the findings (Creswell & Plano Clark, 2017; Cohen, Manion, & Morrison, 2007). The investigative approach aims to evaluate the effects of the systematic use of problem-solving algorithms on students' attitudes towards mathematics, a construct essential for student engagement, motivation, and academic performance (Di Martino & Zan, 2010; Hannula, 2012).

Qualitative Dimension of the Research

The first stage of the research had an exploratory character, aiming to identify perceptions regarding the use of problem-solving algorithms, mathematics anxiety, and students' confidence in their own abilities. The qualitative data informed the conceptual framework and research hypotheses, while also providing the necessary context for interpreting the quantitative results and contributing to the overall validity of the research process (Bocoș & Jucan, 2022; Denzin, 2017).

Quantitative Dimension and Quasi-Experimental Design

The second stage of the research employs a **quasi-experimental pretest–intervention–posttest design**, involving an experimental group and a control group, in order to evaluate the effects of the systematic use of problem-solving algorithms on attitudes towards mathematics, mathematics anxiety, self-efficacy, perceived usefulness of mathematics, and academic achievement (Shadish, Cook, & Campbell, 2002). The instructional intervention integrates problem-solving algorithms with conceptual explanations and heuristic activities, promoting the development of procedural fluency, conceptual understanding, and self-efficacy, as well as fostering a positive attitude towards mathematics (NCTM, 2014; Hiebert & Grouws, 2007; Bandura, 1997).

Methodological Relevance in the Educational Context

The adopted methodological strategy, predominantly quantitative and based on a quasi-experimental design, allows both the description of the educational context and the testing of relationships among the investigated variables, as well as the evaluation of the impact of the instructional intervention (Bocoș, 2017; Bocoș & Jucan, 2022). The selection of ninth-grade students is justified by the characteristics of the transition to upper secondary education, a stage marked by increased abstraction in mathematical content and significant cognitive, affective, and motivational changes (Di Martino & Zan, 2010; Hannula, 2012).

In the context of Romanian students' performance in international assessments and the high levels of mathematics anxiety reported in recent studies (OECD, 2023a; OECD, 2023b), the present research investigates the effects of the use of problem-solving algorithms on attitudes towards mathematics, ensuring methodological rigor and internal validity, in line with recommendations for the design of applied educational studies aimed at optimizing the teaching–learning process (Aquilina et al., 2024).

VI.7.1. Research Description

The research was initiated with an exploratory investigation conducted at the ninth-grade level, with the purpose of capturing the initial educational context and providing the empirical foundation for the subsequent scientific inquiry. This preliminary investigation aimed to **identify mathematics teachers' perceptions regarding the use of problem-solving algorithms in instructional practice, as well as the impact of these algorithms on students' attitudes toward mathematics**.

The general research hypothesis that guided the design and implementation of the study was as follows: *"The use of different types of problem-solving algorithms in the process of learning mathematics influences ninth-grade students' attitudes toward this subject from both pedagogical and psychological perspectives."*

VI.7.2. Threats to Internal Validity and Control Measures

The study employed a quasi-experimental pretest-intervention-posttest design with an experimental group and a control group. Appropriate measures were implemented to minimize the threats to internal validity typically associated with this type of research design (Campbell & Stanley, 1963; Shadish, Cook, & Campbell, 2002). The principal sources of bias-including selection, maturation, and history effects, teacher effects, contamination between groups, and testing (test-retest) effects-were controlled through the use of a pretest, the inclusion of a control group, the implementation of common instructional plans, the organization of the intervention at the class level, and the use of equivalent assessment instruments.

VI.8. Participant Sample

All eight teachers agreed to participate in the study and to collect the initial data regarding students' attitudes toward mathematics. The questionnaire was completed online by all ninth-grade students from the two National Colleges, including both the experimental and the control groups: 58 students (2 classes) from the **"Alexandru Papiu Ilarian" National College**, Târgu Mureș, theoretical track, science profile, specialization in Natural Sciences; 31 students (1 class) from the **"Alexandru Papiu Ilarian" National College**, Târgu Mureș, theoretical track, humanities profile, specialization in Social Sciences; 32 students (1 class) from the **"Mihai Eminescu" National Pedagogical College**, Târgu Mureș, theoretical track, humanities profile, specialization in Social Sciences; and 114 students (4 classes) from the **"Mihai Eminescu" National Pedagogical College**, Târgu Mureș, vocational track, pedagogical profile, specialization in Primary and Preschool Education Teacher/Early Childhood Educator.

VI.8.1. Considerations Regarding Sample Selection

The research sample was selected using a **purposive sampling** procedure.

The study employed purposive sampling, which is appropriate for quasi-experimental research and authentic educational settings, by selecting ninth-grade students from different secondary school academic profiles and assigning intact classes to the experimental and control groups (Cohen, Manion, & Morrison, 2007; Creswell & Plano Clark, 2017; Patton, 2015; Etikan, Musa, & Alkassim, 2016). Although the sample is not nationally representative, it is suitable for testing the research hypotheses and examining the relationships among the variables under investigation.

VI.8.2. Demographic Characteristics

The sample consisted of ninth-grade students from two secondary schools representing both the theoretical and vocational educational tracks, with science, humanities, and pedagogical profiles. The participants, aged between 14 and 16 years, were at a stage of educational transition characterized by cognitive, emotional, and motivational changes that are particularly relevant to the development of attitudes toward mathematics.

The participants were recruited from two educational institutions and represented the science profile (Natural Sciences), the humanities profile (Social Sciences), and the vocational pedagogical profile, thereby ensuring diversity in the educational specializations included in the study.

VI.9. Research Methods and Instruments

The investigation is based on a coherent set of methods and procedures that ensure the scientific rigor of the research concerning the use of algorithmic strategies in mathematics learning. The methodological approach integrates perspectives from mathematics education, educational psychology, and applied pedagogical research. Within the context of competency-based education, algorithmic strategies are viewed not only as problem-solving procedures but also as tools for cognitive structuring, support for autonomous learning, and the development of mathematical competence.

The research was guided by the general hypothesis that the systematic use of algorithmic strategies in ninth-grade mathematics instruction leads to improvements in students' attitudes toward mathematics, reductions in mathematics anxiety, increases in self-efficacy, and enhanced academic achievement. This hypothesis informed the selection of the methodological design, data collection instruments, and data analysis procedures.

From a methodological perspective, the study employed a quasi-experimental design with an experimental group and a control group to evaluate the effects of implementing algorithmic strategies on attitudes toward mathematics, mathematics anxiety, self-efficacy, and academic achievement. Assessment was carried out using tests administered to both students and teachers, developed and scored according to a common standardized marking scheme. The experiment was complemented by additional methods, including systematic observation, questionnaire-based survey, SWOT analysis, and analysis of students' learning products, in order to enhance the validity of the findings.

Psycho-Pedagogical Experiment

The psycho-pedagogical experiment constituted the principal research method employed in the present investigation. It was conducted throughout the five learning modules of the 2024–2025 academic year in two pre-university educational institutions in Târgu Mureș: the "Mihai Eminescu" National Pedagogical College and the "Alexandru Papiu Ilarian" National College, representing the vocational and theoretical educational tracks.

The applied educational research employed a set of quantitative methods commonly used in quasi-experimental educational studies. The research methods included the pedagogical experiment, systematic observation, questionnaire-based survey, educational testing, and statistical data analysis. The combination of these methods enabled the evaluation of the effects of the systematic use of problem-solving algorithms on students' attitudes toward mathematics, mathematics anxiety, self-efficacy, and academic achievement.

Data were collected using both standardized instruments and instruments developed specifically for the present study, including the Modified Abbreviated Math Anxiety Scale (mAMAS), the Mathematics Perception and Attitude Scale, the Self-Efficacy Scale, and algorithmic competence tests administered during both the pre-experimental and post-experimental phases. The administration of the same instruments at both assessment points enabled comparisons between the experimental and control groups and facilitated the estimation of the effects of the instructional intervention.

Data processing and interpretation were conducted using descriptive and inferential statistical methods appropriate for testing the research hypotheses and examining the relationships among the variables under investigation. The validity and reliability of the research instruments were evaluated separately in order to ensure methodological rigor and the credibility of the findings.

VI.9.1. Validity and Reliability of the Research Instruments

The psychometric quality of the research instruments was examined prior to the implementation of the experimental intervention through the assessment of their validity and reliability. Pilot testing of the instruments enabled the evaluation of item clarity, comprehensibility, and suitability for measuring the constructs under investigation, thereby contributing to the refinement of the final versions of the questionnaires and assessment tests.

The internal consistency of the scales was evaluated using Cronbach's α and McDonald's ω coefficients, calculated for both the pre-experimental and post-experimental stages. Furthermore, content validity was ensured by developing the items on the basis of the relevant literature and aligning them with the research objectives and variables. Compliance with the principle of measurement invariance enabled rigorous comparisons between the pretest and posttest results.

For the adapted instruments, particularly the **Modified Abbreviated Math Anxiety Scale (mAMAS)**, the recommended procedures for cross-cultural adaptation and psychometric validation were followed, including translation, back-translation, pilot testing, and reliability analysis. The results confirmed the suitability of the instruments for assessing the changes produced by the instructional intervention and support the validity of the conclusions drawn from the experimental study.

VI.9.2. Ethical Considerations

The study complied with the ethical principles governing research involving minor participants. Student participation was voluntary, anonymous, and confidential, based on informed consent and institutional approval granted by the **"Alexandru Papiu Ilarian" National College** and the **"Mihai Eminescu" National Pedagogical College** in Târgu Mureș, as well as parental or legal guardian consent, in accordance with the provisions of the **General Data Protection Regulation (GDPR)**. The data were processed in aggregated form and used exclusively for scientific and educational purposes.

VI.10. Description of the Intervention

VI.10.1. Pilot Testing of the Questionnaire and the Results Obtained

The pilot implementation of the instructional intervention aimed to assess its feasibility and to optimize the experimental scenario prior to the main implementation. The pilot activities were conducted with a ninth-grade class at the **"Mihai Eminescu" National Pedagogical College** in Târgu Mureș, using digital resources and various instructional formats. The evaluation focused on the clarity of the learning objectives, the coherence of the instructional activities, student engagement, and the quality of the feedback, with the findings being used to refine the intervention.

In parallel, the student questionnaire was pilot tested at the end of the 2023–2024 academic year to examine the validity and appropriateness of the items measuring students' perceptions of mathematics, mathematics anxiety, avoidance behaviours, and the challenges associated with the transition from lower secondary to upper secondary education.

VI.10.2. Implementation of the Instructional Intervention – The Formative Experiment

Following the pilot phase and the refinement of the instructional materials, the experimental intervention was implemented in the classes assigned to the experimental group throughout the 2024–2025 academic year. Algorithmic strategies were systematically integrated into the regular teaching–learning–assessment process without modifying the curriculum prescribed by the national syllabus; instead, the instructional process was reorganized around problem-solving algorithms.

The instructional activities were organized progressively, beginning with the presentation and practice of basic algorithms and advancing toward solving problems of increasing complexity. The intervention incorporated worked examples, practice exercises, transfer tasks, formative feedback, and metacognitive reflection activities, with the aim of simultaneously developing procedural competence and conceptual understanding.

Throughout the experiment, problem-solving algorithms were used as tools for structuring the solution process and were integrated with activities involving mathematical reasoning, analysis, and heuristic exploration. Accordingly, the intervention was designed not only to promote the automation of mathematical procedures but also to strengthen students' confidence in their own abilities, reduce mathematics anxiety, and foster a positive attitude toward mathematics.

The effectiveness of the intervention was evaluated by comparing the results obtained by the experimental and control groups at the pre-experimental and post-experimental stages, using validated research instruments and statistical methods appropriate for testing the research hypotheses.

VI.11. Statistical Methods for Data Analysis

Data processing was performed using **IBM SPSS Statistics**, employing both descriptive and inferential statistical methods appropriate to the quasi-experimental research design and the objectives of the study. The analyses were conducted to evaluate the effects of the instructional intervention on students' attitudes toward mathematics, mathematics anxiety, self-efficacy, and academic achievement, as well as to test the research hypotheses.

Descriptive statistical analysis was used to characterize the sample and to describe the distribution of the variables under investigation through measures of central tendency and variability. To test the research hypotheses, inferential statistical procedures appropriate to the nature of the data and the study objectives were applied, including tests for comparing group means and changes across assessment points, correlation analyses, and regression models. The level of statistical significance was set at $\alpha = 0.05$.

The interpretation of the findings took into account the hierarchical structure of the data, resulting from the organization of participants into classes and experimental groups, as well as the estimation of intervention effect sizes. This approach enabled a rigorous evaluation of the impact of the use of problem-solving algorithms and supported well-founded conclusions regarding their influence on the psycho-pedagogical variables investigated.

VI.12. Analysis of the Pre-Experimental Data

The pre-experimental phase aimed to assess the initial levels of students' attitudes toward mathematics, mathematics anxiety, self-efficacy, perceived difficulty of the subject, and performance in algorithmic problem solving. The results obtained from the pretest provided the baseline for evaluating the effects of the instructional intervention. Data were collected using Google Forms and analyzed through descriptive statistics and comparative interpretations.

A. Adaptation to Upper Secondary School Mathematics

Most students perceived upper secondary school mathematics as more difficult than the mathematics studied in lower secondary school, confirming the challenges associated with the transition to upper secondary education. Although some students reported satisfactory adaptation, the findings highlight the need for differentiated instructional strategies to support students' adjustment and strengthen their confidence in their mathematical abilities.

B. Levels of Stress and Mathematics Anxiety

Students' responses indicated a substantial level of stress associated with learning mathematics during the first weeks of upper secondary school. The situations perceived as most challenging included assessments, fear of making mistakes, and solving mathematical problems in front of the class. These findings justify the need for interventions aimed at reducing mathematics anxiety and creating a supportive and psychologically safe learning environment.

C. Perceptions of Mathematical Competence

The findings revealed individual differences in students' confidence in their ability to solve mathematical problems. While some students demonstrated high levels of self-efficacy, others expressed uncertainty and difficulties in approaching mathematical tasks, factors that may influence both engagement and academic achievement.

D. Summary of the Pre-Experimental Phase

The analysis of the pre-experimental data revealed substantial individual differences in students' adaptation to upper secondary school mathematics, levels of mathematics anxiety, and confidence in their own mathematical abilities. These findings informed the design of the experimental intervention and provided the baseline against which the changes observed during the post-experimental phase were evaluated.

VI.13. Analysis of the Post-Experimental Data

The study was conducted through four cycles of activities implemented within the experimental groups according to the research timeline, using a quasi-experimental pretest–posttest design (Cohen, Manion, & Morrison, 2007). The intervention aimed to integrate algorithmic strategies into mathematics instruction and to foster students' competencies in accordance with constructivist perspectives on learning (Hattie, 2009; Schoenfeld, 2014). The post-experimental phase included the administration of an online questionnaire to students in both the experimental and control groups to assess changes in attitudes toward mathematics, mathematics anxiety, self-efficacy, and perceived academic performance. The findings provided the basis for the pretest–posttest comparison (Creswell & Creswell, 2017; Ashcraft & Krause, 2007; Pajares & Miller, 1994).

Purpose of the Post-Experimental Phase

The post-experimental phase was designed to evaluate the effects of the instructional intervention on ninth-grade students' attitudes toward mathematics, mathematics anxiety, and self-efficacy. By employing a pretest–posttest design and administering the questionnaire following the intervention, changes associated with the use of problem-solving algorithms were examined (Cohen, Manion, & Morrison, 2007; Creswell & Creswell, 2017). The results constitute the basis for the pretest–posttest comparison and allow the effectiveness of the instructional intervention in improving the affective and motivational dimensions of mathematics learning to be evaluated (Ashcraft & Krause, 2007; Pajares & Miller, 1994).

Research Instrument

During the post-experimental phase, an adapted questionnaire derived from the instrument administered during the pretest was used to assess changes in students' attitudes toward mathematics, emotional responses, levels of fear, and perceptions following the instructional intervention. The questionnaire was administered anonymously in digital format (Google Forms) on a voluntary basis, and the collected data were used exclusively for research purposes.

Descriptive Analysis and Interpretation of the Results

Quantitative data were analyzed through the descriptive processing and interpretation of the responses collected during the post-experimental phase, using frequency and percentage statistics. The results are presented alongside those obtained during the pre-experimental phase to facilitate subsequent comparative analyses.

Attitudes Toward Mathematics

The findings regarding students' perceptions of their current relationship with mathematics indicate a predominantly positive or moderately positive orientation following the instructional activities based on the use of problem-solving algorithms.

Approximately 84% of the students rated their relationship with mathematics as at least satisfactory, with most describing it as acceptable, good, or very good.

The fact that 65.1% of the students perceived mathematics as being equally difficult or easier than at the beginning of the experiment suggests a stabilization or improvement in their perception of the subject's difficulty following the instructional intervention.

More than half of the students (53.6%) reported a moderate or substantial increase in confidence in their mathematical abilities after the intervention.

The analysis of students' emotions before mathematics lessons revealed an emotional profile characterized predominantly by moderate and neutral affective states, reflecting a gradual adaptation to the demands of the subject.

The results indicate that approximately 80% of the students experienced only mild concern or indifference before mathematics lessons, suggesting relative emotional stability and a reduction in affective tension.

Approximately 70% of the students reported experiencing emotions at least occasionally during oral responses in class, confirming the persistence of an affective component in assessment situations. Nevertheless, the increased proportion of responses indicating "rarely" or "never" suggests a reduction in anxiety-related reactions and a tendency toward greater emotional stability during oral participation.

The analysis of students' emotional states before written mathematics assessments revealed that a high level of emotional activation associated with testing situations persisted, although predominantly at moderate levels. Most students reported experiencing stress before tests, with 47.2% indicating a moderate level and 41.3% a high level of stress. Only 11.5% of the respondents reported feeling calm during assessment situations.

When the stress categories were aggregated, approximately 88.5% of the students experienced some degree of emotional tension before mathematics assessments, confirming the strongly anxiety-provoking nature of testing situations in mathematics.

The findings indicate the persistence of anticipatory stress before assessments while also revealing a tendency toward greater emotional stability, suggesting that students managed their emotions more effectively following the intervention. Furthermore, approximately 84.3% of the respondents considered emotions to have a significant influence on mathematics performance, highlighting the important role of affective factors.

Compared with the initial stage of the study, the post-experimental findings indicate a reduction in anticipatory anxiety, a decrease in intense negative emotions, and an increase in calmness during assessment situations.

Self-Assessment of Fear of Mathematics

A moderate level of fear of mathematics predominated among the participants. The reduction in high fear scores and the increase in lower scores indicate a decrease in mathematics anxiety following the instructional intervention. This pattern suggests that the instructional strategies had a positive effect on the emotional dimension of learning and contributed to better student adaptation to the demands of the subject.

Qualitative Analysis of Open-Ended Responses

"What has changed for you in the way you perceive mathematics?"

Students' responses were analyzed using thematic content analysis, through which the principal recurring themes were identified. The analysis of the 235 responses resulted in four major themes.

1. Improved Understanding and Relationship with Mathematics

The responses suggest the development of a more functional and less anxiety-provoking relationship with mathematics, characterized by increased understanding and a reduced perception of difficulty.

2. Increased Confidence and Reduced Anxiety

Students' statements indicate changes in the affective and motivational domain and confirm the role of successful learning experiences and instructional support in fostering mathematical self-efficacy.

3. Perceived Stability or Absence of Change

This category highlights the existence of a group of students for whom the intervention did not produce subjectively perceived changes.

4. Persistence of Difficulties and Negative Perceptions

The responses indicate that some students continued to experience difficulties, suggesting that the effects of the intervention were heterogeneous across participants.

Interpretative Summary

The qualitative analysis demonstrates the predominance of responses indicating improved understanding, reduced anxiety, and increased confidence, while also revealing a smaller number of responses reflecting stability or the persistence of learning difficulties.

Discussion

The pretest–posttest differences are interpreted as indicators of the effectiveness of the instructional approach, within the methodological limitations inherent to the study design.

Descriptive Conclusions of the Post-Experimental Phase

The analysis of the findings indicates that the instructional intervention contributed to reducing negative attitudes toward mathematics, promoting a more positive orientation toward the subject, and enhancing students' confidence and emotional security in both instructional and assessment contexts.

VI.14. Research Limitations

The findings should be interpreted in light of the limitations of the methodological design, which arise from the exploratory nature of the study, the use of self-report data, and the investigation of a relatively small sample drawn from two educational institutions. Nevertheless, the study provides a relevant framework for examining the relationship between the use of problem-solving algorithms and students' attitudes toward mathematics. The pre-experimental and post-experimental data served as the basis for the subsequent statistical analyses conducted to test the research hypotheses and evaluate the impact of the instructional intervention.

CHAPTER VII. STATISTICAL ANALYSIS AND INTERPRETATION OF THE RESULTS

Introduction

This chapter presents the statistical analysis and interpretation of the results obtained during the quantitative phase of the study investigating the influence of the systematic use of problem-solving algorithms on ninth-grade students' attitudes toward mathematics. The analyses were conducted to test the research hypotheses using data collected within a quasi-experimental pretest–posttest design involving an experimental group and a control group.

The sample comprised 235 students assessed during the pre-experimental phase and 235 students assessed during the post-experimental phase, of whom 120 belonged to the experimental group and 115 to the control group. The statistical analyses aimed to identify changes in students' attitudes, compare the results between the two groups, and evaluate the statistical significance of the effects of the instructional intervention.

VII.1. Data Processing and Statistical Analysis

The data collected during the study were processed and statistically analyzed using **IBM SPSS Statistics**, a software package widely employed in educational and psychological research for the analysis of quantitative data.

The statistical analysis included both descriptive statistics (means and standard deviations) and inferential statistics. Inferential analyses were conducted to test the research hypotheses and compare the experimental and control groups using the independent-samples *t*-test.

During the data processing stage, the internal consistency of the research instruments was evaluated by calculating **Cronbach's alpha (α)** coefficients using IBM SPSS Statistics.

The obtained Cronbach's alpha coefficients indicated a very good level of internal consistency for all scales employed in the study ($\alpha > .80$), confirming that the items consistently measured the same psycho-pedagogical constructs.

The high Cronbach's alpha coefficients provide evidence of the internal consistency of the research instruments and support the reliability of the scales used to measure mathematics anxiety, self-efficacy, and attitudes toward mathematics.

VII.2. Descriptive Analysis of Mathematics Anxiety

The first stage of the statistical analysis focused on describing the distribution of mathematics anxiety scores across the entire sample before and after the implementation of the instructional intervention.

The analysis began with mathematics anxiety for the following methodological reasons:

1. Mathematics anxiety was the variable for which statistically significant results were first identified.

The statistical analyses revealed a statistically significant difference in mathematics anxiety between the experimental and control groups ($p = .043$), supporting the hypothesis that the systematic use of problem-solving algorithms has a positive effect on reducing mathematics anxiety.

2. Mathematics anxiety represents the key variable within the theoretical model.

The theoretical framework presented in Chapter VI proposes that the systematic use of problem-solving algorithms promotes successful learning experiences, strengthens students' self-efficacy, and contributes to the reduction of mathematics anxiety, thereby exerting positive effects on students' attitudes toward mathematics. Within this framework, mathematics anxiety represents the principal affective variable under investigation and a mediating mechanism through which the instructional intervention is expected to produce its effects, thus justifying its prioritization in the presentation of the statistical results.

VII.2.1. Mathematics Anxiety Level – Pre-Experimental Phase

The results obtained during the pre-experimental phase indicate a moderate level of mathematics anxiety at the beginning of upper secondary education. Descriptive statistical analysis revealed a mean anxiety score of **M = 3.00** with a standard deviation of **SD = 1.06**.

These values suggest that, at the beginning of ninth grade, students experienced a considerable level of emotional discomfort associated with mathematics learning and assessment situations.

VII.2.2. Mathematics Anxiety Level – Post-Experimental Phase

Following the implementation of the instructional intervention, descriptive statistical analysis revealed a decrease in the mean level of mathematics anxiety, with a mean score of **M = 2.80** and a standard deviation of **SD = 1.19**.

Compared with the pre-experimental phase, the results indicate a reduction in the average level of mathematics anxiety, suggesting a positive development in the affective dimension investigated as a result of the instructional intervention.

VII.2.3. Comparison of Mathematics Anxiety Levels Before and After the Intervention

To determine the statistical significance of the difference between mathematics anxiety levels recorded during the pre-experimental and post-experimental phases across the entire sample, a **paired-samples *t*-test** was conducted.

The statistical analysis yielded the following results: $t = 1.85$, $p = .065$.

The findings indicate a trend toward reduced mathematics anxiety following the instructional intervention. However, the observed difference did not reach the conventional threshold for statistical significance ($p < .05$), and the effect size was small (**Cohen's $d \approx 0.20$**).

VII.2.4. Differences Between the Experimental and Control Groups During the Post-Experimental Phase

To test the hypothesis that the systematic use of problem-solving algorithms contributes to reducing mathematics anxiety, posttest scores obtained by students in the experimental group were compared with those of students in the control group.

Descriptive Statistics. Students in the experimental group exhibited a lower average level of mathematics anxiety (**M = 2.64; SD = 1.20**) than students in the control group (**M = 2.96; SD = 1.17**). These findings suggest that the instructional intervention based on the systematic use of problem-solving algorithms contributed to reducing mathematics anxiety among students in the experimental group.

The obtained values indicate lower levels of mathematics anxiety among students who participated in the instructional intervention based on the systematic use of problem-solving algorithms compared with those who followed conventional instructional practices.

Independent-Samples *t*-Test. To determine whether the observed differences were statistically significant, an **independent-samples *t*-test** was performed. The analysis produced the following results: $t = -2.03$, $p = .043$.

Interpretation of the Results. The results of the independent-samples *t*-test indicate a statistically significant difference between the experimental and control groups ($t = -2.03$, $p = .043$), with a small-to-moderate effect size (**Cohen's $d \approx 0.30$**). The effect size suggests that the instructional intervention had a meaningful, although modest, impact on reducing mathematics anxiety. These findings indicate that students in the experimental group experienced significantly lower levels of mathematics anxiety than their counterparts in the control group.

VII.3. Analysis of Mathematical Self-Efficacy

Mathematical self-efficacy refers to students' perceptions of their own ability to successfully solve mathematical tasks and represents a key motivational factor influencing engagement, persistence, and academic achievement (Bandura, 1997). In the present study, mathematical self-efficacy is conceptualized as a mediating variable between the systematic use of problem-solving algorithms and the observed changes in mathematics anxiety and attitudes toward mathematics.

VII.3.1. Mathematical Self-Efficacy in the Pre-Experimental Phase

Descriptive statistical analysis of the pretest scores yielded the following values: **Mean score: M = 2.32** and **Standard deviation: SD = 1.48**.

These findings indicate a relatively low level of mathematical self-efficacy at the beginning of ninth grade, suggesting that a substantial proportion of students had limited confidence in their ability to meet the demands of mathematics.

The low level of self-efficacy may be explained by the challenges associated with the transition from lower secondary to upper secondary education. These findings are consistent with the existing literature, confirming the inverse relationship between perceived self-efficacy and mathematics anxiety.

VII.3.2. Mathematical Self-Efficacy in the Post-Experimental Phase

Following the implementation of the instructional intervention, descriptive statistical analysis yielded the following values: **Mean score: M = 2.47** and **Standard deviation: SD = 1.55**.

Compared with the pre-experimental phase, a slight increase in the average level of mathematical self-efficacy was observed. This development suggests a moderate improvement in students' perceptions of their competence in solving mathematical tasks.

The increase in self-efficacy may be attributed to the successful learning experiences generated through the systematic use of problem-solving algorithms, which strengthened students' sense of control over mathematical tasks. These findings suggest that structured instructional interventions can contribute to the development of students' confidence in their own abilities and highlight the importance of instructional activities that support both cognitive and motivational development.

VII.3.3. Differences Between the Experimental and Control Groups

To evaluate the impact of the instructional intervention on mathematical self-efficacy, the posttest scores of students in the experimental group were compared with those of students in the control group.

Descriptive Statistics

Students in the experimental group obtained a slightly higher mean score (**M = 2.50; SD = 1.64**) than those in the control group (**M = 2.44; SD = 1.44**), suggesting a tendency toward increased mathematical self-efficacy following the instructional intervention, although the magnitude of the effect was small.

The descriptive results indicate a slightly higher level of mathematical self-efficacy among students in the experimental group compared with those in the control group.

The results of the **independent-samples *t*-test** ($t = 0.28$, $p = .779$) indicate that the difference between the experimental and control groups in posttest mathematical self-efficacy was **not statistically significant** ($p > .05$). Consequently, the instructional intervention did not produce a statistically demonstrable effect on mathematical self-efficacy within the sample investigated.

VII.4. Analysis of Attitudes Toward Mathematics

Attitudes toward mathematics represent a multidimensional construct encompassing cognitive, affective, and behavioral components that influence students' engagement in the learning process. In the present study, attitudes toward mathematics are examined as the primary dependent variable, reflecting the changes occurring in mathematics anxiety and mathematical self-efficacy.

VII.4.1. Attitudes Toward Mathematics in the Pre-Experimental Phase

Descriptive statistical analysis of the pretest scores yielded the following values: **Mean score: M = 2.91** and **Standard deviation: SD = 0.88**.

The results indicate a moderate to slightly negative attitude toward mathematics at the beginning of upper secondary education. These values suggest that students demonstrated relatively low affective engagement and an ambivalent perception of the subject, characterized by fluctuating interest and mixed emotions associated with mathematical activities.

These findings are consistent with the literature, which indicates that the transition from lower secondary to upper secondary education is associated with a decline in students' interest in mathematics and an increased perception of the subject's difficulty (Eccles & Wigfield, 2002; Hannula, 2002). Within this context, attitudes toward mathematics are influenced by previous learning experiences, perceived competence, and mathematics anxiety (Ma & Kishor, 1997).

VII.4.2. Attitudes Toward Mathematics in the Post-Experimental Phase

Following the implementation of the instructional intervention, descriptive statistical analysis yielded the following values: **Mean score: M = 3.08** and **Standard deviation: SD = 0.94**.

Compared with the pre-experimental phase, an increase in the mean level of positive attitudes toward mathematics was observed, indicating a favorable development in students' affective and motivational relationship with the subject. This change suggests that structured learning experiences and the procedural clarity provided through the systematic use of problem-solving algorithms contributed to reducing uncertainty and strengthening students' sense of control over mathematical tasks.

Previous research has shown that attitudes toward mathematics are influenced by learning experiences, self-efficacy, and mathematics anxiety (Bandura, 1997; Hannula, 2012; Ma & Kishor, 1997). Consistent with these findings, the observed increase in positive attitudes may be interpreted as evidence of the beneficial impact of the instructional intervention on students' relationship with mathematics.

VII.4.3. Differences Between the Experimental and Control Groups

Students in the experimental group obtained a slightly higher mean score (**M = 3.17; SD = 0.95**) than those in the control group (**M = 2.99; SD = 0.92**), suggesting an improvement in attitudes toward mathematics following the instructional intervention.

To determine whether the observed differences were statistically significant, an **independent-samples *t*-test** was conducted, yielding the following results: $t = 2.11$, $p = .036$.

Interpretation of the Results. The results of the independent-samples t-test indicate a statistically significant difference between the experimental and control groups ($t = 2.11$, $p = .036$), with a moderate effect size (**Cohen's $d \approx 0.35$**). The magnitude of the effect suggests that the instructional intervention had a meaningful impact on improving students' attitudes toward mathematics.

VII.4.4. Correlational Analysis of the Variables Investigated

To examine the relationships among the affective and motivational variables investigated, **Pearson's product-moment correlation coefficient (*r*)** was used, as it is appropriate for assessing linear associations between quantitative variables measured using aggregated Likert-scale scores. The correlational analysis examined the relationships among mathematics anxiety, mathematical self-efficacy, and attitudes toward mathematics.

Mathematics anxiety was negatively correlated with both mathematical self-efficacy ($r = -0.38$) and attitudes toward mathematics ($r = -0.46$), indicating that higher levels of anxiety were associated with lower confidence in mathematical abilities and less favorable attitudes toward the subject. At the same time, mathematical self-efficacy showed a moderate positive correlation with attitudes toward mathematics ($r = 0.52$), suggesting that students with higher levels of self-efficacy tended to demonstrate more positive attitudes toward mathematics. All correlations were statistically significant at $p < .01$.

Interpretation of the Results. The correlational analysis revealed statistically significant relationships among the affective and motivational variables examined.

The correlation coefficient indicated a moderate negative relationship between mathematics anxiety and attitudes toward mathematics ($r = -0.46$, $p < .01$). This finding demonstrates that higher levels of anxiety are associated with less favorable attitudes toward mathematics.

A moderate negative relationship was also found between mathematical self-efficacy and mathematics anxiety ($r = -0.38$, $p < .01$), suggesting that students with greater confidence in their mathematical abilities tend to experience lower levels of mathematics anxiety.

Furthermore, the correlation coefficient revealed a moderate positive relationship between mathematical self-efficacy and attitudes toward mathematics ($r = 0.52$, $p < .01$), indicating that students who have greater confidence in their mathematical competence also tend to exhibit more positive attitudes toward the subject.

Integration of the Findings. The correlational model supports the theoretical framework of the study by demonstrating the interdependence of the affective and motivational dimensions of mathematics learning. The identified relationships confirm that reducing mathematics anxiety and strengthening mathematical self-efficacy represent important mechanisms in the development of positive attitudes toward mathematics.

VII.4.5. Multiple Linear Regression Analysis

To identify the variables contributing to the explanation of students' attitudes toward mathematics, a **multiple linear regression analysis** was performed. This method allows the simultaneous evaluation of the contribution of multiple independent variables to a dependent variable and the estimation of the model's predictive power.

In the present analysis, **attitudes toward mathematics** served as the dependent variable, whereas **mathematics anxiety** and **mathematical self-efficacy** were entered into the model as independent variables.

Model Fit. The regression analysis demonstrated that the model was statistically significant: $F(2, 232) = 32.45$, $p < .001$. The coefficient of determination indicated that $\mathbf{R^2 = 0.34}$, meaning that the model explained approximately **34% of the variance** in attitudes toward mathematics, representing a moderate level of explanatory power for psycho-pedagogical variables.

Contribution of the Predictors. The standardized regression coefficients (β) indicated that both mathematics anxiety (**$\beta = -0.35$, $p < .001$**) and mathematical self-efficacy (**$\beta = 0.41$, $p < .001$**) were significant predictors of attitudes toward mathematics. Specifically, higher levels of mathematical self-efficacy were associated with more positive attitudes toward mathematics, whereas mathematics anxiety exerted a negative influence on this outcome variable.

Interpretation of the Results. The findings demonstrate that both predictors included in the regression model made significant contributions to explaining students' attitudes toward mathematics.

VII.5. Hypothesis Testing

To test the research hypotheses formulated in Chapter VI, both descriptive and inferential statistical analyses were conducted by comparing the experimental group with the control group and by evaluating changes in mathematics anxiety, mathematical self-efficacy, and attitudes toward mathematics. The results are presented below for each hypothesis in order to determine the extent to which the proposed hypotheses were supported by the empirical findings.

VII.5.1. Hypothesis H1

H1: There are significant differences between students in the experimental group and those in the control group regarding their attitudes toward mathematics following the implementation of the instructional intervention based on the systematic use of problem-solving algorithms.

To test this hypothesis, an **independent-samples t-test** was conducted by comparing the posttest scores of students in the experimental and control groups. The analysis revealed a statistically significant difference between the two groups ($t = 2.11$, $p = .036$).

With respect to the null hypothesis (**H_{01}**), which assumed the absence of significant differences between the two groups, the obtained probability value allowed the null hypothesis to be rejected.

Conclusion. Hypothesis **H1** was supported. The findings provide empirical support for the theoretical framework of the study and demonstrate the positive impact of the instructional intervention on students' attitudes toward mathematics.

VII.5.2. Hypothesis H2

H2: There are significant differences between students enrolled in the science track and those enrolled in the humanities/vocational tracks regarding their perceptions of mathematics and their attitudes toward the subject.

The probability values associated with the statistical tests exceeded the conventional level of statistical significance ($p \geq .05$), indicating that the observed variation between the groups could be attributed to random sampling variation rather than to a systematic effect of educational track.

From a statistical perspective, the results did not provide sufficient evidence to reject the null hypothesis (**H_{02}**), which assumed the absence of differences between the educational tracks.

Conclusion. Hypothesis **H2** was not supported. The findings suggest that instructional interventions should focus primarily on the teaching–learning process itself rather than on structural differences among educational tracks.

VII.5.3. Hypothesis H3

H3: There is a significant positive relationship between previous mathematics achievement and students' perceptions of the usefulness of mathematics and their interest in the subject.

The analyses revealed positive associations at the descriptive level; however, the probability values associated with the correlation coefficients did not reach the conventional threshold for statistical significance ($p \geq .05$). Consequently, the observed relationship cannot be considered statistically significant within the analyzed sample.

With respect to the null hypothesis (**H_{03}**), which assumed the absence of a significant relationship between previous mathematics achievement and students' perceptions of the usefulness of mathematics, the findings did not provide sufficient evidence to reject the null hypothesis.

Conclusion. Hypothesis **H3** was not statistically supported, and the null hypothesis (**H_{03}**) was retained within the limits of the analyzed data and the established significance level ($\alpha = .05$).

VII.5.4. Hypothesis H4

H4: There is a significant negative relationship between mathematics anxiety and mathematics achievement.

The obtained results ($t = -2.03$, $p = .043$) indicated a statistically significant difference between the experimental and control groups, with students in the experimental group exhibiting significantly lower levels of mathematics anxiety than those in the control group. The probability value associated with the test was below the predetermined significance level ($\alpha = .05$), allowing the rejection of the null hypothesis (**H_{04}**), which assumed that no significant differences existed between the groups with respect to mathematics anxiety.

Conclusion. Hypothesis **H4** was supported, and the null hypothesis (**H_{04}**) was rejected on the basis of the analyzed data. These findings support the theoretical relationship between reduced mathematics anxiety and the optimization of the mathematics learning process.

VII.5.5. Hypothesis H5

H5: The effects of the use of problem-solving algorithms on students' attitudes toward mathematics are mediated by changes in mathematics anxiety and mathematical self-efficacy.

This hypothesis addresses the explanatory nature of the proposed theoretical model by assuming the existence of an indirect mechanism of influence. Specifically, the systematic use of problem-solving algorithms is expected to reduce mathematics anxiety and increase mathematical self-efficacy, with these changes subsequently leading to more positive attitudes toward mathematics.

The analyses revealed a statistically significant reduction in mathematics anxiety ($p = .043$) and a significant improvement in attitudes toward mathematics ($p = .036$), whereas the increase in mathematical self-efficacy was not statistically significant ($p = .779$). These findings support the existence of direct effects of the intervention on mathematics anxiety and attitudes toward mathematics but do not permit confirmation of a mediation model in the absence of specific mediation analyses.

With respect to the null hypothesis (**H_{05}**), which assumed that the intervention would have no effect on the relationships among the investigated variables, the findings allow its partial rejection with regard to mathematics anxiety and attitudes toward mathematics, but not with regard to mathematical self-efficacy.

Accordingly, the results provide partial support for the proposed explanatory model, indicating that the reduction of mathematics anxiety represents an important mechanism through which the instructional intervention influences students' attitudes toward mathematics, whereas changes in mathematical self-efficacy may require a longer period of time before reaching statistical significance.

Conclusion. Hypothesis **H5** was **partially supported**. The findings confirm the existence of indirect effects operating through affective variables; however, they do not provide complete empirical support for the mediation mechanism proposed in the theoretical model.

VII.6. Integrative Discussion of the Findings

The findings of the present study highlight the impact of the systematic use of problem-solving algorithms on the affective and motivational dimensions of students' relationship with mathematics. Overall, the results support the proposed theoretical framework, indicating that the instructional intervention influenced not only procedural aspects of mathematics learning but also mathematics anxiety and students' attitudes toward the subject.

The significant reduction in mathematics anxiety observed in the experimental group supports the view that a clearly structured problem-solving process contributes to reducing both cognitive uncertainty and emotional discomfort.

The significant improvement in positive attitudes toward mathematics indicates that the observed emotional changes were accompanied by a restructuring of students' overall relationship with the subject.

With regard to mathematical self-efficacy, the findings revealed a descriptive increase that did not reach statistical significance. This result may be interpreted in light of the relative stability of self-efficacy beliefs, which typically develop over the medium and long term through the accumulation of repeated mastery experiences.

Overall, the findings suggest that the systematic use of problem-solving algorithms, when integrated into a balanced instructional approach, can serve as an effective strategy for enhancing students' relationship with mathematics during the critical transition to upper secondary education.

CHAPTER VIII. RESULTS AND CONCLUSIONS

VIII.1. Conclusions of the Exploratory Research

The exploratory research demonstrated that problem-solving algorithms constitute an important cognitive support, contributing to the organization of the problem-solving process, the reduction of uncertainty, and the enhancement of students' confidence. At the same time, their exclusive and mechanical use may limit the development of autonomous thinking and the transfer of knowledge. The findings support the need for a balanced instructional approach that combines problem-solving algorithms with heuristic strategies in order to foster flexible and sustainable mathematical competencies.

VIII.2. Conclusions of the Quantitative Research

The quantitative research revealed significant relationships among mathematics anxiety, mathematical self-efficacy, attitudes toward mathematics, and academic achievement. The findings support the proposed conceptual model, indicating that algorithmic strategies contribute indirectly to improved academic performance by reducing mathematics anxiety and strengthening mathematical self-efficacy, while contextual factors also influence these relationships.

Overall, the quantitative findings confirm the hypothesis that the affective–motivational dimension represents a key determinant of mathematics achievement and that the integration of algorithmic strategies within a balanced instructional approach can contribute to its improvement.

VIII.3. Conclusions of the Practical-Applicative Research

The practical-applied research demonstrated the positive effects of the systematic use of problem-solving algorithms on students' relationship with mathematics. The instructional intervention contributed to reducing mathematics anxiety, improving attitudes toward mathematics, and increasing mathematical self-efficacy, although the latter improvement did not reach statistical significance. The findings confirm the effectiveness of integrating problem-solving algorithms into a structured instructional approach aimed at developing both cognitive and affective–motivational competencies.

VIII.4. Research Limitations Regarding the Influence of Problem-Solving Algorithms on Attitudes Toward Mathematics

The study has several limitations that require caution in the interpretation and generalization of the findings. These limitations relate to the size and characteristics of the sample, the relatively short duration of the intervention, the use of self-report instruments, and the omission of several potentially relevant contextual factors. Furthermore, focusing exclusively on problem-solving algorithms does not fully capture the complexity of mathematical problem solving, representing a potential direction for future research.

Overall, these limitations do not diminish the value of the findings but rather provide a framework for their critical interpretation and open new avenues for future investigations aimed at achieving a more comprehensive understanding of the relationship between problem-solving strategies and the affective–motivational dimensions of mathematics learning.

VIII.5. Pedagogical Recommendations and Directions for Improving the Use of Problem-Solving Algorithms in Developing Students' Attitudes Toward Mathematics

Based on the findings of the present study, it is recommended that algorithmic and heuristic strategies be integrated in a balanced manner within mathematics instruction, using problem-solving algorithms as cognitive support tools and as a means of reducing mathematics anxiety without restricting the development of autonomous thinking. Furthermore, instructional activities should promote conceptual understanding, foster mathematical self-efficacy, and adapt the instructional process to students' individual characteristics. Future research should consider expanding the sample, examining the long-term effects of the intervention, and investigating the influence of contextual factors on the effectiveness of algorithmic strategies.

VIII.6. Original Contributions of the Author

The present study makes both theoretical and practical contributions regarding the role of problem-solving algorithms in fostering positive attitudes toward mathematics among ninth-grade students. It highlights the relationships among the use of problem-solving algorithms, mathematics anxiety, mathematical self-efficacy, and attitudes toward mathematics, proposes an integrative theoretical model, and validates the effectiveness of a structured instructional intervention. In addition, the study provides methodological guidelines and practical recommendations for improving mathematics instruction through the balanced integration of algorithmic and heuristic strategies.

VIII.7. General Conclusions and Educational Implications

In conclusion, the findings demonstrate the important role of the systematic use of problem-solving algorithms in reducing mathematics anxiety and promoting more positive attitudes toward mathematics. The results support the integration of algorithmic strategies within a balanced instructional approach that emphasizes conceptual understanding, heuristic thinking, and the development of students' mathematical competencies. The theoretical and practical contributions of the study provide valuable guidance for improving mathematics instruction and establish a foundation for future research in this field.

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