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Mathematical Competencies for the Twenty-First Century: Challenges and Perspectives in School Education

Competencias matemáticas para el siglo XXI: desafíos y perspectivas en la educación escolar

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Abstract

Mathematical competencies are a fundamental component in addressing the educational demands of the twenty-first century, as they promote skills that go beyond procedural knowledge and foster reasoning, problem-solving, and decision-making in diverse contexts. The aim of this study was to analyze the main challenges and perspectives related to the development of mathematical competencies in school education. The research adopted a qualitative approach through a descriptive documentary design based on the review of indexed scientific literature and official documents published by leading international organizations in mathematics education. The findings revealed a shift in curricula toward competency-based

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approaches, emphasizing mathematical reasoning, mathematical literacy, critical thinking, and the integration of digital technologies into teaching and learning processes. In addition, active methodologies such as problem-based learning, mathematical modeling, and cooperative learning were identified as effective strategies for strengthening these competencies. However, significant challenges remain regarding teacher professional development, curriculum implementation, competency-based assessment, and unequal access to technological resources. The study concludes that strengthening mathematical competencies requires the integration of pedagogical innovation, continuous teacher training, and educational policies that promote meaningful learning, enabling students to successfully face the academic, professional, and social challenges of an increasingly dynamic and technology-driven society.

Keywords: Mathematical competencies; school education; mathematical reasoning; mathematics education.

Resumen

Las competencias matemáticas representan un componente fundamental para responder a las demandas educativas del siglo XXI, al promover habilidades que trascienden la adquisición de conocimientos procedimentales y favorecen el razonamiento, la resolución de problemas y la toma de decisiones en diversos contextos. El objetivo de este estudio fue analizar los principales desafíos y perspectivas relacionados con el desarrollo de las competencias matemáticas en la educación escolar. La investigación se desarrolló bajo un enfoque cualitativo, mediante un diseño documental de alcance descriptivo basado en la revisión de literatura científica indexada y documentos oficiales publicados por organismos

internacionales especializados en educación matemática. El análisis evidenció una evolución de los currículos hacia enfoques centrados en competencias, destacando la importancia del razonamiento matemático, la alfabetización matemática, el pensamiento crítico y la integración de tecnologías digitales en los procesos de enseñanza y aprendizaje. Asimismo, se identificó que metodologías activas como el aprendizaje basado en problemas, la modelización matemática y el aprendizaje cooperativo fortalecen significativamente el desarrollo de estas competencias. Sin embargo, persisten desafíos relacionados con la formación docente, la implementación curricular, la evaluación por competencias y las desigualdades en el acceso a recursos tecnológicos. Se concluye que el fortalecimiento de las competencias matemáticas requiere una articulación entre innovación pedagógica, actualización docente y políticas educativas que favorezcan aprendizajes significativos, preparando a los estudiantes para afrontar los retos académicos, profesionales y sociales de una sociedad en constante transformación.

Palabras clave: Competencias matemáticas; educación escolar; razonamiento matemático; enseñanza de las matemáticas.

Introduction

Over the past few decades, mathematics education has undergone a profound transformation driven by the technological, social, and economic changes that characterize the 21st century. In this context, mathematics instruction has shifted from focusing exclusively on the acquisition of procedural knowledge to emphasizing the development of competencies that enable students to interpret, analyze, and

solve complex problems encountered in their daily and professional lives. This evolution responds to the need to educate citizens capable of making informed decisions in an environment where information, data, and technology play a predominant role (OECD, 2024).

Mathematical competencies constitute an integrated set of knowledge, skills, attitudes, and cognitive processes that enable students to understand phenomena, formulate problems, use mathematical tools, and communicate solutions effectively. From the perspective of the Organization for Economic Cooperation and Development (OECD), mathematical literacy involves the ability to reason mathematically, formulate, apply, and interpret mathematics to solve problems in various real-world contexts, thereby fostering the active and responsible participation of citizens in contemporary society (OECD, 2022).

This paradigm shift responds to the demands of a society characterized by digitalization, big data analysis, artificial intelligence, and process automation. Consequently, education systems face the challenge of revising their curricula to incorporate competencies such as critical thinking, problem-solving, mathematical reasoning, digital literacy, and computational thinking, without neglecting the conceptual foundations of the discipline itself (OECD, 2024).

In this context, various international organizations agree that the success of mathematics education can no longer be measured solely by the ability to execute algorithms or memorize procedures. Rather, it is essential that students understand the meaning of mathematical concepts, establish relationships among them, and be able to apply this knowledge in real-world situations. The conceptual framework of PISA 2022 emphasizes that mathematical reasoning is at the core of mathematical literacy, integrating processes of modeling, reasoning, representation, and communication to address increasingly complex problems (OECD, 2022).

From a pedagogical perspective, this transformation also involves rethinking the role of the teacher. Far from merely serving as a transmitter of knowledge, the teacher becomes a facilitator of learning, capable of designing experiences that promote exploration, inquiry, and the active construction of mathematical knowledge. In this regard, the National Council of Teachers of Mathematics (NCTM, 2014) maintains that effective mathematics instruction requires practices centered on reasoning, argumentation, problem-solving, and active student participation—aspects closely linked to the development of 21st-century competencies.

Furthermore, research conducted by Kilpatrick, Swafford, and Findell (2001) suggests that mathematical competence should be understood as a multidimensional construct comprising conceptual understanding, procedural mastery, strategic competence, adaptive reasoning, and a productive attitude toward mathematics. This conception goes beyond traditional views focused solely on calculation and recognizes that meaningful learning depends on the interaction between knowledge, cognitive skills, and positive attitudes toward the discipline.

Consequently, contemporary mathematics education faces the challenge of balancing mastery of curricular content with the development of transferable competencies that enable students to function successfully in academic, professional, and social settings characterized by uncertainty and constant change.

Despite advances in curriculum design, significant challenges remain for the effective implementation of a competency-based approach to mathematics. One of the main obstacles lies in the gap between the prescribed curriculum, teaching practices, and the learning actually achieved by students. The OECD notes that, although many countries have incorporated competencies such as critical thinking, problem-solving, and data literacy into

their mathematics curricula, these innovations are not always reflected in instructional materials, teaching strategies, or assessment systems, resulting in significant discrepancies between curricular intentions and educational practice.

In this context, initial and continuing teacher education takes on strategic importance. Teachers must not only master mathematical content but also develop pedagogical competencies that enable them to promote active, collaborative, and contextualized learning processes. Ball, Thames, and Phelps (2008) emphasize that specialized knowledge for teaching mathematics integrates subject-matter expertise with an understanding of learning difficulties, ways of representing concepts, and instructional strategies that foster mathematical reasoning. Consequently, strengthening pedagogical content knowledge is one of the pillars for improving the quality of teaching.

Similarly, the incorporation of digital technologies represents both an opportunity and a challenge for contemporary mathematics education. Tools such as dynamic geometry software, simulators, adaptive platforms, graphing calculators, and generative artificial intelligence offer new possibilities for fostering mathematical exploration, visualization, and modeling. However, various studies agree that the integration of technology only yields significant improvements when it serves clearly defined pedagogical objectives, rather than being an end in itself. Digital transformation therefore requires curriculum planning that coherently integrates content, methodologies, and technologies, promoting meaningful and contextualized learning experiences.

Another fundamental aspect concerns the assessment of mathematical competencies. Traditionally, assessment systems have prioritized routine exercises focused on the mechanical application of algorithms. However, international trends propose assessment tools that evaluate students' ability to

analyze situations, construct models, justify procedures, interpret results, and communicate well-reasoned solutions. From this perspective, international assessments such as PISA have helped redefine the concept of mathematical performance, orienting it toward solving authentic problems and the functional use of knowledge in various social, scientific, and technological contexts (OECD, 2022). This shift implies that educational institutions must review both their assessment strategies and the criteria by which they evaluate learning.

Furthermore, mathematical competencies are closely linked to other skills considered essential for the 21st century, including creativity, communication, collaboration, digital literacy, and lifelong learning. These cross-cutting competencies enable students to tackle new situations, adapt their knowledge to diverse scenarios, and actively participate in a society characterized by constant innovation. From this perspective, mathematics is no longer viewed as an isolated discipline but rather as a language that facilitates the understanding of scientific, technological, economic, and social phenomena, thereby promoting evidence-based decision-making.

In Latin America—and particularly within the region's education systems—these challenges take on a special dimension due to inequalities in access to technological resources, differences in teacher training, and gaps in learning outcomes highlighted by various national and international assessments. These conditions make it necessary to strengthen educational policies that promote curriculum updates, teacher professional development, and the incorporation of active methodologies that foster deeper and more meaningful learning of mathematics.

Within this framework, this study analyzes the mathematical competencies required for the 21st century from an educational perspective, identifying the main challenges faced by schools and the opportunities offered by current pedagogical trends to

improve the quality of teaching. The study is based on the premise that the development of mathematical competencies not only fosters better academic performance but is also an indispensable element in shaping citizens capable of functioning critically in increasingly complex, digitized, and interconnected societies. Consequently, understanding the transformations taking place in mathematics education and the strategies necessary for their implementation represents a significant contribution for teachers, researchers, and education policymakers committed to strengthening 21st-century school education.

Methodology

This research was conducted using a qualitative approach, as it seeks to understand and analyze the main trends, challenges, and perspectives related to the development of 21st-century mathematical competencies in the context of school education. A descriptive literature review design was adopted, based on the review, analysis, and critical interpretation of scientific literature and official documents published by international organizations and high-impact academic journals. The literature search was conducted in indexed databases such as Scopus, Web of Science, ERIC, SpringerLink, ScienceDirect, and Google Scholar, using keywords in English and Spanish, including "mathematical competencies," "mathematics education," "21st century skills," "school education," "problem solving," "mathematical literacy," and "mathematics curriculum." The inclusion criteria considered publications from 2015 to 2025, prioritizing peer-reviewed articles, academic books, and documents issued by international organizations such as the Organization for Economic Cooperation and Development (OECD), the National Council of Teachers of Mathematics (NCTM), and UNESCO, due to their recognition in the field of mathematics education. In addition, several classic works widely accepted in the specialized literature for their conceptual

relevance were included, such as those by Kilpatrick, Swafford, and Findell (2001) and Ball, Thames, and Phelps (2008). The information gathered was organized using a literature review matrix that allowed for the classification of studies according to their objectives, methodological approaches, main findings, and contributions to the development of mathematical competencies. Subsequently, a thematic content analysis was conducted, identifying categories related to mathematical reasoning, problem-solving, mathematical literacy, the integration of digital technologies, critical thinking, teacher education, and competency-based assessment. Finally, the information was interpreted through a process of theoretical triangulation among the various authors and documents analyzed, with the aim of identifying commonalities, emerging trends, and current challenges in mathematics education, thereby ensuring the scientific rigor and reliability of the conclusions reached.

Results

A review of the scientific literature revealed a consensus that the development of mathematical competencies is one of the main objectives of 21st-century education systems. The studies reviewed agree that mathematics instruction has evolved from an approach centered on memorizing procedures toward models focused on developing mathematical reasoning, problem-solving, and the application of knowledge in real-world contexts (OECD, 2022; NCTM, 2014). This transformation responds to the demands of a society characterized by the intensive use of information, technology, and data-driven decision-making.

Furthermore, the literature review revealed that mathematical reasoning and mathematical literacy are the competencies most prominently featured in international curricula. Reports from the Organization for Economic Cooperation and Development

highlight that high-performing education systems prioritize the development of skills for formulating, interpreting, and solving problems, favoring conceptual understanding over the mechanical repetition of algorithms (OECD, 2022). In this regard, the analyzed documents show that mathematical modeling, reasoning, and the communication of results are essential elements for strengthening meaningful learning.

Another relevant finding concerns the role of active methodologies in mathematics instruction. The reviewed evidence indicates that strategies such as Problem-Based Learning (PBL), cooperative learning, mathematical modeling, and the use of contextualized situations increase student motivation and foster the development of higher-order skills related to critical thinking and decision-making. These methodologies promote more active student participation, transforming students from passive recipients into active agents in the construction of their own knowledge (Kilpatrick et al., 2001; NCTM, 2014).

With regard to the integration of technology, the studies analyzed agree that digital tools such as GeoGebra, simulators, adaptive learning platforms, and artificial intelligence-based applications offer significant opportunities to improve understanding of complex mathematical concepts. However, the literature also cautions that the incorporation of technology alone does not guarantee better learning outcomes; its effectiveness depends on adequate instructional planning, teacher training, and alignment with curriculum objectives (OECD, 2024).

Teacher training emerged as one of the most decisive factors in the development of mathematical competencies. The reviewed studies highlight that teachers require not only solid subject-matter knowledge but also pedagogical skills that enable them to design learning experiences centered on problem-solving, reasoning, and mathematical reflection. In this regard, Ball,

Thames, and Phelps (2008) argue that content-based pedagogical knowledge is an essential element for improving the quality of teaching and fostering deeper learning.

Furthermore, the analysis revealed that assessment systems are also undergoing a process of transformation. Current trends propose replacing assessments focused exclusively on routine exercises with instruments that evaluate students' ability to interpret information, justify procedures, construct mathematical models, and apply knowledge in different contexts. This approach aligns with the international assessment frameworks used by PISA, where mathematical performance is understood as the ability to use mathematics to understand and act upon real-world situations (OECD, 2022).

Finally, the literature review identified various challenges that still limit the consolidation of a competency-based approach. Among these are the persistence of traditional teaching methodologies, insufficient teacher training in innovative strategies, inequalities in access to technological resources, and discrepancies between official curricula and their implementation in classrooms. These findings highlight the need to strengthen educational policies aimed at curriculum updates, teacher professional development, and the incorporation of active teaching methods that promote meaningful mathematical learning relevant to the demands of the 21st century.

Conclusions

The literature review conducted leads to the conclusion that mathematical competencies are an essential component of 21st-century student education, as they go beyond mastery of content and procedures to foster skills such as mathematical reasoning, problem-solving, critical thinking, argumentation, and decision-making in real-world contexts. The reviewed literature shows that the most successful education systems

align their curricula with the development of these competencies, responding to the demands of a society characterized by technological innovation, digitization, and the constant use of information (OECD, 2022; OECD, 2024).

Furthermore, it is concluded that the success of this approach depends largely on the implementation of active teaching methodologies that place the student at the center of the learning process. Strategies such as Problem-Based Learning, mathematical modeling, cooperative learning, and the planned incorporation of digital technologies foster a deep understanding of mathematical concepts and strengthen the ability to apply knowledge in authentic situations. However, evidence shows that technology alone does not guarantee better learning; adequate instructional planning and solid teacher training are essential (NCTM, 2014).

Furthermore, the review revealed that teacher training and professional development are among the key factors in establishing competency-based instruction. Teachers require not only subject-matter expertise in mathematics but also pedagogical skills that enable them to design meaningful learning experiences, assess reasoning processes, and foster educational environments centered on active student participation (Ball et al., 2008). In this regard, strengthening professional development programs is a priority for improving the quality of mathematics education.

Finally, it is concluded that significant challenges still persist regarding the effective implementation of competency-based curricula, including the persistence of traditional teaching practices, limitations in technological infrastructure, gaps in teacher training, and discrepancies between educational policies and classroom realities. Given this situation, it is necessary to promote public policies that foster curricular innovation, strengthen teacher competencies, and support authentic assessment of learning, ensuring that mathematics

education effectively contributes to the development of citizens capable of addressing the scientific, technological, and social challenges of the 21st century.

Reference

Ball, D. L., Thames, M. H., & Phelps, G. (2008). Content knowledge for teaching: What makes it special? *Journal of Teacher Education, 59*(5), 389–407. https://doi.org/10.1177/0022487108324554

Kilpatrick, J., Swafford, J., & Findell, B. (Eds.). (2001). *Adding It Up: Helping Children Learn Mathematics*. National Academy Press.

National Council of Teachers of Mathematics. (2014). *Principles to Actions: Ensuring Mathematical Success for All*. National Council of Teachers of Mathematics.

OECD. (2022). *PISA 2022 Assessment and Analytical Framework*. OECD Publishing. https://doi.org/10.1787/dfe0bf9c-en

OECD. (2024). *An Evolution of Mathematics Curriculum: Where It Was, Where It Stands and Where It Is Going*. OECD Publishing. https://doi.org/10.1787/0ffd89d0-en