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Computational Thinking in High School Mathematics

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Abstract

This literature review explores the integration of Computational Thinking (CT) and Artificial Intelligence (AI) in high school mathematics education. CT - which involves decomposition, pattern recognition, abstraction, and algorithm design - provides a structured framework for solving complex problems. ChatGPT and Gemini function as computational thinkers, capable of interpreting problems and using logic, abstraction, and pattern recognition to simulate human-like reasoning across domains. In contrast, advanced mathematical software such as Wolfram Alpha, GeoGebra, Symbolab, and Desmos are specialized tools designed to perform exact mathematical computations and visualizations, but they lack the ability to think or adapt contextually. While ChatGPT and Gemini help users understand and explore problems, math software precisely solves them based on defined inputs. Mathematical problem-solving remains a foundational element of both education and technological advancement. CT fosters logical reasoning and creativity, while AI enables efficient exploration of mathematical concepts through automation and intelligent systems. This integration not only supports deeper conceptual understanding but also helps educators tailor instruction to diverse learning needs. The review highlights three key themes: (1) AI integration improves students' performance in mathematics; (2) game-based learning (GBL) supported by AI increases engagement; and (3) CT development strengthens mathematical reasoning.

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Introduction

Brief Overview of Computational Thinking (CT) and Artificial Intelligence (AI)

Computational Thinking (CT) and Artificial Intelligence (AI) are closely connected, forming a powerful framework for problem-solving—especially in today's tech-driven world. Numerous educational researchers have incorporated AI into their studies, suggesting that the application of AI in education has the potential to improve the quality of educational administration, enhance instruction, and foster student learning outcomes (Chen, Lai, & Lin, 2020).

Integrating CT and AI with advanced mathematical software in solving mathematical problems accelerates the problem-solving process, increases accuracy, and enhances students' learning outcomes. Computational thinking is a powerful cognitive approach that integrates several key components. In this paper, we will analyze four significant elements:

- Decomposition – Breaking down a problem into smaller, manageable parts.
- Pattern Recognition – Identifying similarities or trends in data or problems.
- Abstraction – Focusing on important information while ignoring irrelevant details.
- Algorithms – Developing step-by-step procedures to solve problems.

On the other hand, AI is transforming how students, educators, and researchers approach and solve mathematical problems. It extends far beyond calculators and symbolic solvers -AI is now capable of interpreting, reasoning through, and even generating mathematical content. The integration of AI and computational thinking (CT) represents an emerging area of interest for educational researchers (Hsu et al., 2023; Huang & Qiao, 2022). AI assists mathematical tools to assist students with quick responses, detailed explanations, proof verification, and personalized support for diverse learning needs.

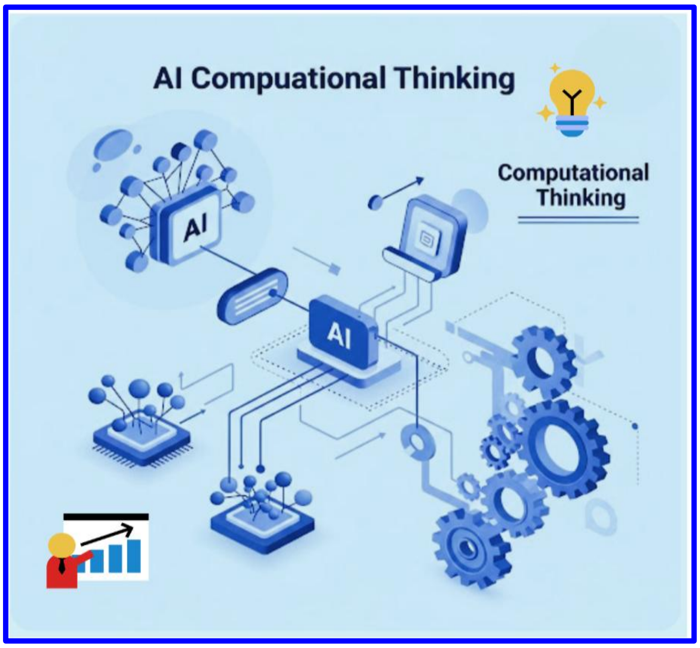

Figure 1. The Interrelation of Computational Thinking (CT) and Artificial Intelligence (AI) in Education

ChatGPT and Gemini function as computational thinkers, capable of interpreting problems, using logic, abstraction, and pattern recognition to simulate human-like reasoning across domains. In contrast, advanced math software like Wolfram Alpha, Geogebra, Symbolab, Desmos are specialized tools designed to perform exact mathematical computations and visualizations, but they lack the ability to think or adapt contextually. While ChatGPT and Gemini help users understand and explore problems, math software precisely solves them based on defined inputs.

Artificial Intelligence (AI) platforms assist teachers in creating efficient lesson plans and instructional materials. Notably, activities that integrate AI and Computational Thinking (CT) can be designed to accommodate learners with diverse levels of knowledge and skills. This integration is especially relevant in both interdisciplinary and subject-specific educational contexts (Weng et al., 2024). AI is also a powerful tool for developing mathematical content that aligns with the curriculum and meets the demands of 21st-century education.

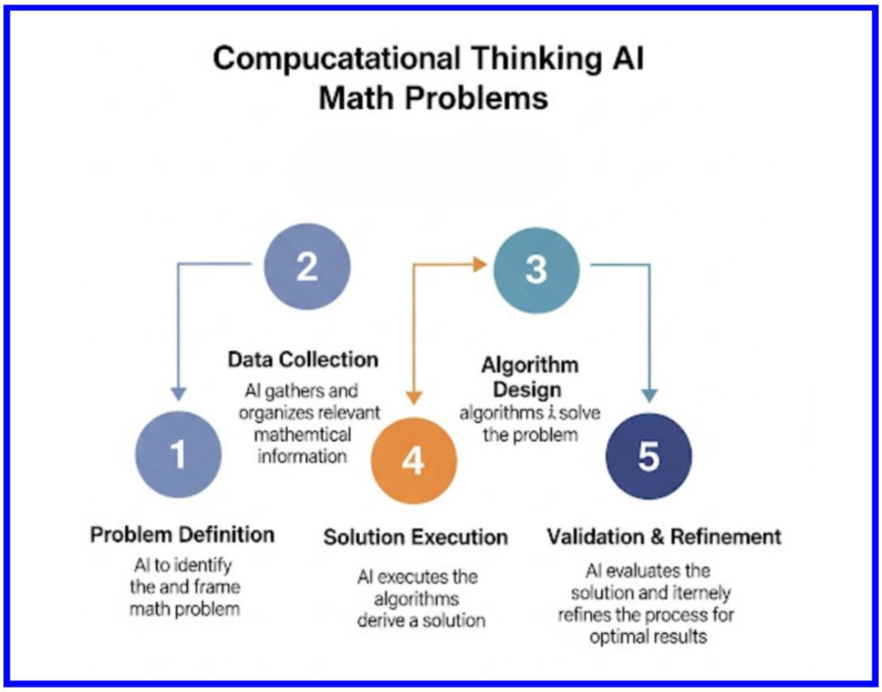

Figure 2. Step by Step Application of Computational Thinking (CT) Blending with Artificial Intelligence on Solving Mathematical Problems

Importance of Mathematical Problem - Solving in Education and Technology

Mathematical problem solving in education and technology plays a crucial role in both fields. In education, it fosters critical thinking, logical reasoning, and analytical skills. In technology, it forms the foundation of numerous advancements and applications. Studying mathematics through problem solving—making it more practical and relevant—enhances students' creativity, critical thinking, interaction, and autonomy (Clarke & Roche, 2018).

Technology also significantly impacts the quality of mathematical problem solving. The design of technological tools can greatly influence how students engage with them, which in turn may affect their mathematical understanding and problem-solving abilities (Lee & Hollebrands, 2006). Rocha (2020) emphasizes the importance of the knowledge students need to effectively use technology—specifically, the competence required to make appropriate and meaningful use of these tools. In addition, technology plays a significant factor in all mathematical activities. Applying technology in high school mathematics provides various pieces of information that can be easily implemented in mathematical projects (Pllana et al., 2024).

Mathematical sciences contribute greatly to the advancement of many other subjects, including technology. Advanced computer algorithms—such as those used for searching and sorting variables—are built on mathematical concepts like graph theory and recursion theory (FinTech Weekly, 2023). Linear algebra plays a critical role in the principles of machine learning and artificial intelligence. Many advanced technologies are primarily the result of ongoing innovation and research in mathematics (FinTech Weekly, 2023). Mathematics is a vital tool in both science and technology. In short, math is essential for scientific and technological progress, and its importance cannot be overstated (Mathnasium, 2023).

The advancement of mathematics accelerates the development of science and technology, and vice versa. The direction of progress between technology and mathematics is reciprocal. Beginning around the middle of the seventeenth century, scholars with mathematical education published treatises in which they applied the advanced mathematics of their time—particularly mathematical analysis—to technological problems (Klemm, 1976). Mathematicians have contributed significantly to technological advancement since ancient times, as exemplified by Archimedes. In the seventeenth century, several calculating machines using rotating wheels were introduced. Wilhelm Schickard (1592–1635) was likely the first inventor to propose such a machine, with Blaise Pascal (1623–1662) and Gottfried Wilhelm Leibniz (1646–1716) being the most famous (Lenzen, 2018).

On the other hand, the advancement of technology has also accelerated progress in mathematics. In addition to providing previously unthinkable computational capacities - in Ada Lovelace's broad sense of computation—technological innovations have inspired new ways of thinking about fundamental concepts in mathematics, such as proof, computation, and mathematical knowledge (Hansson, 2020). Moreover, the interaction between mathematics and technology is mutual: mathematics advances technology, and technology advances mathematics.

Purpose of the Review: Exploring How CT and AI Contribute to Mathematical Analysis

The purpose of this literature review is to explore how computational thinking (CT) and artificial intelligence (AI) contribute to mathematics education in high schools. There is a natural connection between computational thinking and mathematics, such as their shared logical structure and the ability to model mathematical relationships (Wing, 2008). Computational thinking and mathematical thinking are closely related; however, computational thinking emphasizes the use of technology to develop processes for solving mathematical problems.

A key element of computational thinking is the use of algorithms. An algorithm is a step-by-step process used to solve a specific problem (SplashLearn, n.d.). In mathematics, an algorithm is a method for solving problems—for example, the quadratic formula is an algorithm. The father of the algorithm is considered to be Al-Khwarizmi.

From a mathematical perspective, mathematical methods focus on analytical work to solve or prove statements. From a computational thinking perspective, a mathematical algorithm can be defined as a procedure used to solve a mathematical problem, particularly one that can be addressed using DSA (Data Structures and Algorithms) (GeeksforGeeks, 2024). In the field of DSA, algorithms are used to solve problems closely related to computer science.

AI is making a significant contribution to high school mathematics education through tools such as ChatGPT, Gemini, Magic School, and Alberta AI. Integrating these AI platforms with advanced mathematical software enhances both teaching and learning. In the Botana et al. (2024) case study, found that these tools complement one another: ChatGPT outlines reasoning steps, while GeoGebra verifies or refutes them both symbolically and numerically. Another often-overlooked form of educational AI is the use of online search engines, which—when combined with the vast amount of freely accessible online content—offer powerful learning support (Gadanidis, 2016). While many online resources provide free mathematical content for high school students, some advanced math software still requires payment. AI also encourages educators to explore mathematics instruction more deeply. Blending core computational skills with sensemaking and creative problem-solving demands not only a solid understanding of mathematical concepts but also strong Pedagogical Content Knowledge (PCK) and Mathematical Knowledge for Teaching (MKT) (NCTM, n.d.).

The purpose of the literature review in this paper is to highlight the relationship between computational thinking and AI in high school mathematics. Over the past two decades, a substantial body of literature has developed around the concept of computational thinking (CT), defined as “the thought processes involved in formulating problems and their solutions, so that the solutions are represented in a form that can be effectively carried out by an information-processing agent” (Wing, 2011, p. 20). Computational thinking enhances the process of doing high school mathematics; in addition, Magic School AI platform supports both teachers and students in becoming more effective in teaching and learning. According to Koehler and Sammon (2023), through the thoughtful integration of ChatGPT into instructional strategies, math teachers can foster a deeper appreciation of mathematics, cultivate mathematical proficiency, and prepare students for success both in mathematics and beyond.

Objective of the Paper

The objective of this paper is to review the literature and explore the relationship between computational thinking (CT) and artificial intelligence (AI) in high school mathematics education. Research suggests that integrating AI fosters improvements in student performance (Aljohani, 2019; Mutambara & Bayaga, 2020). The second theme examines the potential of game-based learning (GBL), which has been shown to enhance student engagement (Wu & Yang, 2022). The third theme focuses on CT in mathematics education, particularly the relationship between computational thinking and mathematical learning as proposed by Durksen et al. (2017), Román-

González et al. (2017), Wu and Yang (2022), and Ye et al. (2023). According to Bayaga (2024), both AI and CT positively impact mathematics education at the high school level.

These three themes collectively demonstrate that:

- The integration of AI in education positively influences students' performance in content-related skills.
- The implementation of GBL leads to increased student engagement.
- The development of CT skills has a positive effect on mathematics learning (Bayaga, 2024).

The overarching objective of the paper is to analyze how these two paradigms—AI and CT—influence teaching and learning in mathematics by reviewing various journal articles. Computational thinking is also driving the integration of AI into school curricula and broader global society (Wong et al., 2020). Valente and Marchetti highlight several ways in which CT and AI can be interconnected in education, essentially arguing that each can support the learning of the other. Together, they both significantly influence mathematics teaching and learning (Dohn et al., 2022).

Theoretical Background

Definition and Components of Computational Thinking and CT versus MT

Computational thinking is closely related to concepts of mathematical thinking. The four key computational thinking concepts—logic, algorithmic patterns, abstraction, and generalization—are approached using mathematical tools (Pllana, 2024). While mathematical thinking is traditionally emphasized in high school mathematics, integrating it with computational thinking is essential, as 21st-century education demands the application of technology to enhance student learning outcomes. Integrating computational thinking into mathematics is relatively straightforward because it closely aligns with mathematical thinking. As shown in Table 1, the comparative analysis indicates that computational and mathematical thinking are more similar than different.

Table 1. The Comparative Analysis of Computational Thinking (CT) vs Mathematical Thinking (MT), designed for Clarity and Relevance to High School Education

Comparative Analysis: Computational Thinking vs Mathematical Thinking		
Aspect	Computational Thinking (CT)	Mathematical Thinking (MT)
Definition	A problem-solving approach involving algorithms, abstraction, and automation	Logical reasoning and abstraction using mathematical structures
Primary Focus	Designing processes and systems to solve problems	Proving, modeling, and reasoning using mathematical logic
Core Skills	Decomposition Abstraction	Logical deduction Symbolic reasoning

Comparative Analysis: Computational Thinking vs Mathematical Thinking		
	Algorithm design Debugging	Generalization Proof
Tools Used	Code, pseudocode, flowcharts, simulations	Equations, formulas, graphs, proofs
Thinking Style	Procedural, iterative, solution-oriented	Deductive, abstract, structure-oriented
Problem Type	Step-by-step executable problems, often with multiple solutions	Conceptual or theoretical problems, often with one correct answer
Technology Involvement	Strong – relies on computers and software	Minimal – traditional paper-based (though technology can support)
Learning Outcome	Build functioning models, systems, and automations	Understand relationships, structures, and logical consistency
Application Areas	Computer Science, Robotics, AI, Data Science	Engineering, Physics, Economics, Pure Mathematics
Assessment Format	Projects, programming tasks, system designs	Tests, problem sets, mathematical proofs

Note: The table is generated by chatGPT

Decomposition

Decomposition means breaking a big or complicated problem into smaller, easier-to-handle parts. By solving each smaller part one at a time, it becomes easier to understand and fix the whole problem. For example, when we partition numbers and difficult calculations to help us solve tricky number problems (BiteSize, n. d.).

Pattern Recognition

Pattern recognition is about spotting similarities, trends, or repeated features in problems or data. When you recognize a pattern, you can use that knowledge to solve new problems more quickly. For example, this is crucial in sequences and series, as well as in real-world applications like predicting trends (LibreTexts, n. d.).

Abstraction

Abstraction means focusing only on the important information and leaving out the details that don't matter. This helps you think clearly and avoid distractions. An example may include a student being able to count linking cubes that represent some other set of objects like cars, dogs, or bikes (KylePearce3, 2017) .

Algorithms

An algorithm is a set of clear, step-by-step instructions for solving a problem or completing a task. Think of it like a recipe in cooking—each step must be followed in order to get the right result. Each instruction in an algorithm consists of commands and mathematical expressions (Pauli, n. d.). In computing and math, algorithms help you solve problems in a logical, repeatable way.

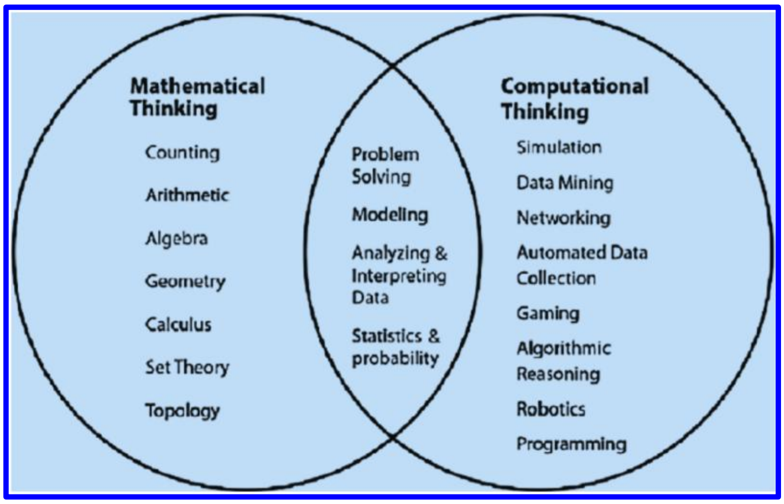

Figure 3. Intersection of Elements in Mathematical Thinking (MT) and Critical Thinking (CT) [The figure is modified from Kotsopoulos et al. (2019).]

Overview of AI Techniques Relevant to Mathematics

Usually there are a small number of proofs in high school mathematics compared to solving mathematical problems. AI assists teachers with problem solving and proof mathematical statements and simplifies proofs for high school students. Proof follows several steps in their processes. Stylianides (2007) described that proof is a mathematical argument, a connected sequence of assertions against a mathematical claim, with the following characteristics:

- It uses statements accepted by the classroom community (set of accepted statements) that are true and available without further justification.
- It employs forms of reasoning (modes of argumentation) that are valid and known to, or within the conceptual reach of, the classroom community.
- It is communicated with forms of expression (modes of argument representation) that are appropriate and known to, or within the conceptual reach of, the classroom community. (p. 291).

Teachers and students may use Magic School, Gemini, or ChatGPT to prove mathematical statements or create math projects. Many high school students use ChatGPT for classwork or homework. About 56% of teens who say they've heard a lot about it report using it for schoolwork (Sidoti et al., 2025). Magic School AI platforms assist math teachers with a variety of tools. Magic School AI is a suite of resources designed to help teachers develop lesson plans, design assignments, generate materials, create newsletters, and perform several other tasks

(University of Cincinnati CECH Library, n.d.).

Students, on the other hand, receive substantial support in math classes from advanced mathematical software such as Wolfram Alpha, Symbolab, Desmos, GeoGebra, and Mathway, often using these tools where AI platforms fall short. The combination of AI and advanced mathematical software accelerates mathematical processes and enhances students' learning outcomes.

The Role of Problem - Solving in Mathematics Education

Problem-solving skills in high school mathematics are essential, as they equip students with critical thinking, analytical thinking, and logical reasoning abilities. The aim of mathematical problem-solving is to deepen students' understanding of mathematical concepts, rather than simply memorizing facts and procedures (Sintema & Mosimege, 2023). These skills encourage students to strengthen their critical thinking by analyzing and evaluating mathematical solutions. They also become more open-minded as they identify patterns, processes, and methods for solving problems, and they develop into better decision-makers by exploring more effective strategies for finding solutions. As a result, students adopt a more pragmatic approach to mathematical problem-solving. The role of mathematical problem solving in shaping high school education contributes to students' deeper understanding and real-world application skills. There are many approaches to developing problem-solving skills. One of the most common methods used by students is trial and error, especially in real-world projects (Baez et al., 2024). Mathematical projects help students gain a deeper understanding of mathematical concepts while also developing their research skills. In math projects, students often search for original solutions. These solutions do not appear suddenly but emerge through a series of thought processes involving deep understanding (Munahefi et al., 2020). Problem solving in mathematics enhances students' understanding, which is a central goal of education. Real-world problems are usually complex and require deeper analysis to find effective solutions (Pllana, 2021). Solving problems in high school math projects requires students to apply higher-order thinking skills, often leading to unique solutions—much like those developed by researchers during their investigations. According to Cee (2025), math projects are crucial in preparing students for advanced studies in mathematics and related fields. Most importantly, solving mathematical problems in high school equips students with valuable tools for improving their SAT scores, succeeding academically in college, and building a brighter future.

Applications for Computational Thinking in Math Problem Solving

Decomposition, Abstraction, Pattern Recognition, and Algorithmic Thinking Aid Mathematics Learning

The paper centers on four key elements of computational thinking that are closely associated with high school mathematics education. Falk (2022) states, "Whether it is a problem in Calculus or determining divisors of a number, CT has empowered my students to be successfully armed with strategies and behaviors to solve challenging and complex problems." Decomposition involves breaking down complex mathematical problems into simpler parts; pattern recognition identifies recurring patterns or mathematical methods to solve or prove problems and statements; abstraction enables students to generalize from specific mathematical instances; and algorithms help streamline mathematical processes by organizing steps in a logical order. However, there is a common cliché that CT must be taught alongside technology and programming because of its practicality (Tsortanidou, 2021). Integrating computational thinking (CT) with technology in mathematics aligns with the 21st-century demands of contemporary high school education.

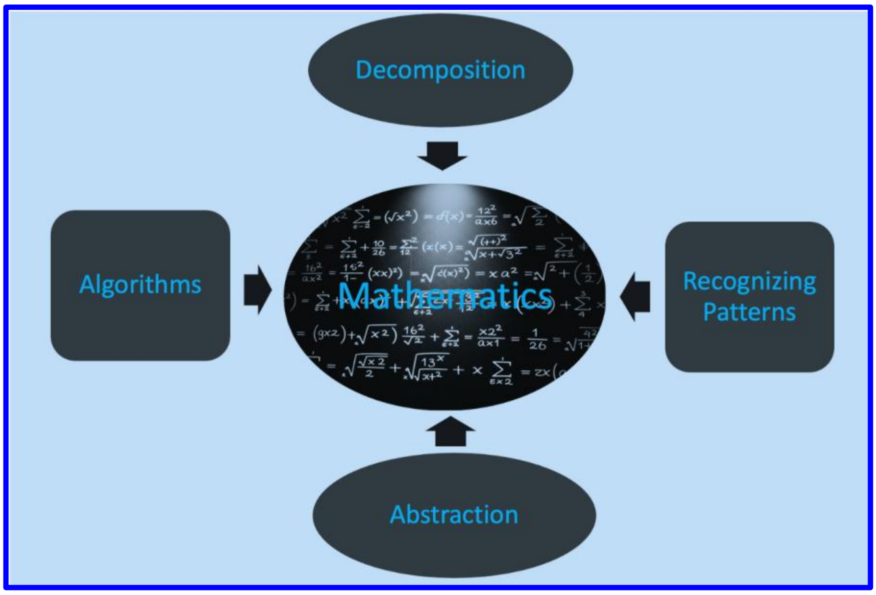

Figure 4. Application of Computational Thinking (CT) in High School Mathematics

Students apply decomposition when solving complex mathematical problems across various high school math subjects. For instance, problems in high school precalculus can be quite complicated; therefore, they often need to be broken down into smaller parts, much like solving puzzles. By mastering decomposition in precalculus, students are well-prepared for the challenges of calculus, where the chain rule, advanced integration techniques, and differential equations build upon these foundational skills (Lee, 2025).

Decomposition appears in many areas of mathematics. For example, in geometry, an important class of geometric decomposition techniques is based on the concept of expanding and shrinking a set (Structured Parallel Programming, 2012). High school students may need to find the area of complex polygons, whether intentionally or not, this requires applying the concept of decomposition. By breaking down or building up composite figures into known polygons, students begin to understand that the total area equals the sum of the areas of the component shapes (Math Teacher Coach, n.d.). Students can also apply decomposition effectively in other mathematical topics, tasks, and subjects.

Recognition patterns in math refer to the ability to identify and understand recurring structures, relationships, or regularities within mathematical concepts, problems, and solutions. Pattern recognition involves several key elements: identifying repetitions, recognizing structures, identifying mathematical properties, and making connections across similar concepts, techniques, or topics.

When pattern recognition training programs were implemented in middle and high school math classrooms, researchers found that even a few extra hours of supplemental practice led to significant improvements in students' math learning—for example, increasing test scores from around 35% to 65%—with these gains sustained even four months later (Kellman et al., 2010). Pattern recognition equips students with the skills needed to enhance their mathematical intuition and tackle advanced high school mathematics more effectively.

Many fundamental mathematical objects—especially more elementary ones, such as numbers and their operations—clearly model reality (Mitchelmore & White, 2004). Simply put, abstraction involves focusing on general information while disregarding specific details. For instance, equilateral triangles have six symmetries, and the composition of two symmetries results in another symmetry. Since the composition law is associative, these symmetries can form a group. The general concept of group theory extends beyond sets of symmetries to a wide range of structures, such as integers, rational numbers, real and complex numbers, vectors, matrices, and more (Ferrari, 2003). Abstraction often occurs when students model mathematical concepts from real-world scenarios.

The term *algorithm* has historical roots, originating from the Persian mathematician Al-Khwarizmi, whose work built upon earlier Indian mathematical concepts (Zimmer, 2022). Algorithms are essential in both mathematics and computer science and are used in everything from simple arithmetic to complex computations. In computer science, algorithms enable computers to follow instructions step by step to solve problems.

Mathematicians often repeat certain processes to arrive at results, which leads to a desire for more efficient methods. In this context, algorithms serve as shortcuts in mathematics. An algorithm in mathematics is a procedure—a description of a set of steps used to solve a mathematical computation. However, their use extends far beyond that today. Algorithms are applied across many branches of science—and even in everyday life. One of the most common examples is the step-by-step procedure used in long division (Russell, 2018). In short, an algorithm is a finite sequence of well-defined instructions used to solve a problem or complete a task.

Use of CT in Digital Learning Platforms Centered in Mathematics

Computational Thinking (CT) is a problem-solving approach that draws on principles of computer science and logical reasoning. CT was first defined by Papert in 1980, who argued that computers significantly influence students' thinking. He suggested that interactions with technology could contribute to the development of new types of mental processes (Papert, 1980). In a digital learning platform focused on mathematics, CT can significantly enhance students' understanding and engagement. Student engagement in mathematics through CT is driven by several factors, including personalization, real-world application, and skill transfer.

Personalization

Computational thinking through digital platforms enables personalized learning pathways based on students' performance and problem-solving behaviors. Adaptive content delivery adjusts teaching materials according to students' learning profiles (Peters et al., 2024). Digital platforms allow students to engage with content at an appropriate level of challenge. Data shows that personalized learning frameworks lead to significant increases in student engagement (+23%), retention (+22%), and problem-solving skills (+24%) compared to traditional approaches (Guevara-Reyes, 2025). Gamified environments also enhance student engagement by encouraging logical sequencing and problem-solving through coding-like experiences.

Real-World-Application

Projects involving data analysis or simulations help students view mathematics as a tool for solving practical problems. For example, a learner (the subject) interacts with a simulation (the tool) to understand how it can be used to explore real-world phenomena (the goal) (Hurt, 2023).

Skill-Transfer

CT skills overlap with those used in STEM fields, supporting students' long-term academic and career success. Applying CT through digital platforms in interdisciplinary subjects facilitates the transfer of skills across domains. By embracing the power of computer science, we can unlock new possibilities and drive positive change in the digital age (Johnston, 2023).

The application of CT through digital platforms in mathematics equips students with personalized learning opportunities that significantly enhance engagement. It increases students' motivation to tackle more challenging and advanced mathematical problems, including real-world examples. CT in digital learning environments also boosts retention and better prepares students for long-term success in education. Integrating CT into mathematical subjects improves logical flow in student thought processes.

CT's Impact on Student Understanding and Performance

Computational thinking (CT) impacts student understanding and performance by enhancing logical reasoning, conceptual understanding, engagement and motivation, transferable skills, assessment outcomes, and support for diverse learners. The PISA 2021 framework emphasizes that students should demonstrate computational thinking abilities when using mathematics to solve problems (Manohar & Viswanathappa, 2025). CT encourages students to decompose complex problems into smaller parts and solve them systematically. Solving mathematical problems step by step using CT helps build strategies that promote logical reasoning. This structured approach fosters clear reasoning and increases student motivation and engagement.

Table 2. Computational Thinking on Student Understanding and Performance

Impact Area	CT Contribution
Logical Reasoning	Step by Step reasoning - strategy building
Conceptual Understanding	Abstraction, modeling, algorithmic logic
Engagement and Motivation	Interactive design - real world application

Impact Area	CT Contribution
Transferable Skills	Logic, debugging - system thinking
Assessment Performance	Improved accuracy and reasoning
Support for Diverse Learners	Adaptive feedback - multimodal learning opportunities

Note: The table is generated by chatGPT

A primary motivation for introducing CT practices into mathematics classrooms is the rapidly changing nature of competencies of the discipline required for future work in society and the professional world (Hansen & Hadjerrouit, 2021). Engaging CT in high school mathematics prepares students for advanced mathematics, SAT exams for college entrance, and prepares for future work in professional areas. In an era of continuous technological evolution, individuals with strong computational thinking skills will find it easier to integrate into various industries, emerging as future leaders and innovators(Hsu & Chen, 2025). Following the process in chronological order improves accuracy and reasoning while they complete their assessment. In addition, CT supports diverse learners by adapting the educational mathematical level for every student by providing adequate feedback.

AI Platforms and Advanced Mathematical Software

AI and Mathematical Solvers

AI has the potential to fundamentally change many aspects of society, including education itself (Adiguzel et al., 2023). However, AI cannot replace teachers; it is a powerful tool that supports them. As a tool, AI plays a crucial role in assisting both educators and students across various aspects of education (Baez et al., 2025). Specifically, artificial intelligence enhances automated problem-solving in mathematics by applying algorithms that can understand, interpret, and solve mathematical problems. It is capable of identifying patterns, performing algebraic operations, and solving problems step by step. AI helps teachers and students deepen their understanding of mathematical concepts and solve problems more efficiently. AI can enhance student learning by providing personalized, real-time feedback and identifying individual learning styles (Atlas, 2023; Luckin, 2017).

Advanced mathematical solvers play a crucial role in shaping modern education. For instance, when high school students struggle to solve mathematical problems, they can benefit from tools like Symbolab. Symbolab is a math solver that provides step-by-step solutions to various types of problems. When students need to study functions and encounter difficulties, they can use Desmos, a graphing calculator. Desmos is a digital tool that, according to previous research, improves students' understanding and facilitates clear visualization (Chechan, 2023). It is known for its ease of use and features such as high-resolution zooming, which helps students better understand mathematical functions (Chorney, 2021). Both Symbolab and Desmos are free math tools that support students in learning mathematics, both in the classroom and during independent study.

When students face more complex problems, they may turn to more sophisticated math solvers such as GeoGebra, Photomath, and Wolfram Alpha—the computational knowledge engine. GeoGebra, an interactive mathematics software, exemplifies this shift by providing dynamic visualizations that support the comprehension of abstract concepts (Zainudin et al., 2025; Uwurukundo et al., 2020). Batiibwe (2024), in his study, demonstrated that GeoGebra, as subject-specific software, can serve as an effective tool in the teaching and learning of mathematics—particularly in geometry—where students in the experimental group showed significant improvements in conceptual understanding and achievement compared to those in the control group. High school students use GeoGebra across various math subjects—for example, in geometry (e.g., plane geometry and transformations), algebra (e.g., solving quadratic equations), and calculus (e.g., derivatives and areas under curves). It can even be used to prove theorems.

A few years ago, Stephen Wolfram announced exciting news about integrating ChatGPT with Wolfram Alpha to create a more advanced tool for delivering sophisticated results in science, mathematics, and technology. The collaboration between OpenAI and Wolfram illustrates how AI can become more trustworthy and capable by grounding its responses in computation and structured knowledge.

Explaining how the integration works, Wolfram (2023) stated: *"Under the hood, ChatGPT is formulating a query for Wolfram Alpha—then sending it to Wolfram Alpha for computation, and then 'deciding what to say' based on reading the results it got back."* In this partnership, ChatGPT plays the role of the thinker, while Wolfram Alpha acts as the tool that performs the computations. Together, they bridge understanding and execution—ChatGPT helps students think like mathematicians, and Wolfram Alpha helps them work like one.

Table 3. The Role of the AI as a Computational Thinker and Advanced Math Software as Executive Tools

Role	ChatGPT/Gemini (LLMs)	Advanced Math Software
Type	Computational Thinker	Computational Tools
Function	Emulates human reasoning, problem solving, explanation	Executes symbolic/numeric computations
Primary Strength	Flexible understanding, reasoning, teaching	Accurate and efficient computation
Limitations	May make errors in math logic or computation	May not understand real - world context or vague input
Use in Workflow	Ideation, modeling, explaining steps	Solving, verifying, graphing computing
Best For	Learning, exploration, interpreting problem	Fast, exact solutions, complex symbolic manipulation

Note: The table is generated by chatGPT

Integrating ChatGPT and Wolfram Alpha—accessible through ChatGPT Plus and often referred to as *Wolfram GPT* , (Yalalov, 2025)—provides a powerful combination of linguistic and computational intelligence. ChatGPT contributes natural language understanding and processing, while Wolfram Alpha offers computational reasoning and problem-solving capabilities. As a computational thinker, ChatGPT can assist high school students in math by explaining concepts and guiding them through solutions step by step, while Wolfram Alpha delivers accurate computations and answers.

Artificial Intelligence Enhances Game Based Learning (GBL)

Artificial intelligence (AI) aims to create machines that replicate human capabilities such as reasoning, awareness, decision-making, and problem-solving (Pfeiffer et al., 2021). AI significantly enhances game-based learning by personalizing content for students and promoting deeper engagement. It can make learning more enjoyable and accessible by offering tailored learning experiences, real-time feedback, interactive simulations, and gamified activities (Kumar et al., 2024). AI also enables educators to deliver interactive lessons through digital and virtual platforms, providing students with more diverse and dynamic resources than traditional methods allow (Wagan et al., 2023). Additionally, AI supports high school students in developing mathematical problem-solving skills through educational games. The use of AI in education is steadily increasing and is expected to grow further as augmented intelligence expands the potential for integrating AI into learning environments (Zhai et al., 2021). By making mathematics more engaging and interactive, AI is transforming math education in high schools and improving both teaching and learning outcomes.

Integration of CT and AI in Educational Contexts

CT and AI in Mathematics Instruction - Literature Review

There is limited literature on integrating artificial intelligence (AI) and computational thinking (CT) in mathematics education.

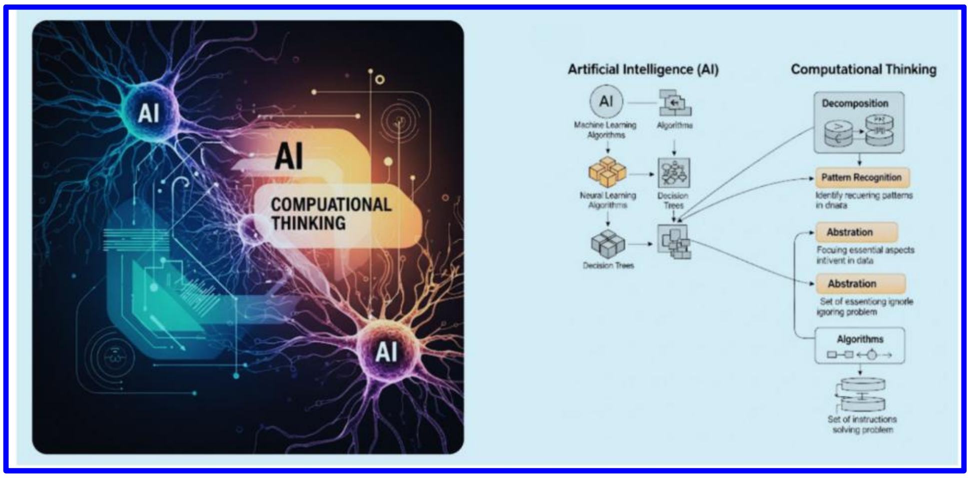

Figure 5. Natural Connections between Artificial Intelligence (AI) and Computational Thinking (CT) in Mathematics

Overall, investigations into the interrelationships and overlapping components between AI and CT in educational practices remain underdeveloped (Weng et al., 2024). However, computational thinking in mathematics or STEM is widely discussed in the literature, as there is a reciprocal relationship between computational thinking (CT) and mathematical thinking (MT). Two common learning pathways are identified: CT → MT → CT and MT → CT → MT (Wu & Yang, 2022).

Recently, AI-related articles have increasingly appeared in journals and digital literature. Moreover, AI is expanding the scope of literature to include digital multimedia content such as images, videos, and audio recordings (Buetow & Lovatt, 2024). Individually, both computational thinking (CT) and artificial intelligence (AI) are well represented in the literature.

CT and AI Integrated in Mathematics Unintentionally

High school students often apply computational thinking (CT) unintentionally when working on mathematics. Typically, they rely on critical thinking to solve problems. According to Noonoo (2019), computational thinking—a problem-solving process commonly used by computer scientists—is not much different from critical thinking and can be applied across various disciplines. Computational thinking is widely recognized as an essential skill set that involves applying mathematical concepts and computational methods to solve complex problems (Yeni et al., 2024).

When students engage with mathematical problems through projects or assignments, they often identify patterns that guide their problem-solving strategies. Moreover, many mathematical tasks require step-by-step reasoning, as well as the use of shortcuts to arrive at more efficient and accurate solutions. Increasingly, students are verifying their solutions or mathematical proofs using AI tools or advanced mathematical software. Through regular practice, they discover various combinations of tools to arrive at a single accurate solution.

Table 4. Performing Mathematical Tasks from the Perspective of High School Students

Task	CT or MT or Both
Writing a program to stimulate compound interest	CT + MT
Proving the Pythagorean Theorem	MT
Design an algorithm to sort numbers	CT
Analyzing statistical data from a science lab	CT + MT

Note: The table is generated by chatGPT

The more students engage in learning and doing mathematics, the more likely they are to develop the mathematical habits of mind that characterize productive mathematical thinkers - becoming experienced problem solvers who know what to do when they don't know what to do (Bryant, 2015). Intuitively, students are integrating CT and AI into their mathematical learning, even though research on this integration remains limited.

Teacher and Student Perspectives on Technology - Enhanced Mathematics Learning

Teachers and students benefit greatly from the use of technology. Mathematics teachers can present various figures, graphs, and tables through digital tools during their sessions. Technology enables students to engage more effectively during math instruction, and teachers can assign assessments and exercises digitally, often with directions to use advanced math solvers or educational YouTube videos for support. For instance, if a student wants to learn about complex fractions, the teacher might recommend watching specific Khan Academy videos (Pllana, 2022).

Additionally, students can study their preferred topics during their spare time, perhaps while enjoying their favorite snacks and drinks. Technology greatly enhances the learning experience in mathematics by making it more interactive. Students can collaborate with peers online and receive instant feedback. This transparency helps students feel more in control of their education, fostering independence and confidence as they see their efforts and progress reflected in real time (FACTS - A Nelnet Company, n.d.).

Table 5. Benefits and Challenges of Students and Teachers with respect to Technology

Perspective	Benefits	Challenges
Teacher	Visual Learning	Access inequality
	Personalized Pace	Tech learning curve
	Engagement	Distraction
Students	Interactive	Over-reliance
	Instant feedback	Tech frustrations
	Confidence boosts	Distractions

Note: The table is generated by ChatGPT

Despite the benefits of technology for educators and high school students, it also presents significant challenges. Not all students have equal access to technology due to their economic circumstances. Teachers must participate in professional development to better prepare for using technology effectively. Students can easily become distracted online - chatting, gaming, or Googling answers. In addition, cell phones are a major source of distraction for both students and teachers in the classroom. Many schools and districts in the United States have restricted student cell phone use during the school day because these devices have become a significant classroom disruption (Langreo, 2023). When teachers are giving instructions, some students do not pay adequate attention. During exams, students may attempt to use their phones to cheat, forcing teachers to shift their focus from instruction to monitoring, which distracts both them and their students.

Challenges and Gaps in Current Research

Lack of Standardized Frameworks to Integrate CT and AI in Curricula

Technology Integration Specialists work with teachers and students to support blended learning environments by strengthening technology skills and enhancing learning through improved integration of technology (Meriden Public Schools, n.d.). Technology is integrated into the majority of subjects in high schools. Computational thinking (CT) is a thought process rooted in computer science; therefore, it is a key component of educational technology.

The integration of computational thinking (CT) and artificial intelligence (AI) in mathematics is not yet widespread in high school curricula. However, there is extensive experience with technology integration in education, and the development of advanced technologies continues to expand the possibilities. Although CT does not have a universally agreed-upon definition internationally, it is closely related to mathematical thinking (MT). Both CT and MT, when applied to problem-solving, share similar characteristics—they are complex, abstract, and iterative in nature (Nordby et al., 2022). As integrating technology becomes increasingly essential for 21st-century high school education, CT can effectively complement and even substitute for MT, securing a valuable place in the curriculum.

The integration of AI in high school education is still in an experimental phase, yet it represents a significant contribution by educational researchers. Since AI systems can sometimes produce inaccurate or misleading results (also known as hallucinations), it is important that both teachers and students verify the outputs of AI-powered mathematical tools. Generative AI (GenAI) systems may occasionally provide inaccurate information, exhibit bias, or raise concerns about user privacy (Baidoo-Anu & Ansah, 2023). Protecting student privacy is especially critical and must not be compromised by the use of AI. Overall, the integration of AI into education is still in its early stages but holds promising potential for inclusion in school curricula.

Need for Empirical Evidence on Long Term Effectiveness

Using artificial intelligence (AI) in education is still very new. While it has a lot of potential, it also presents several challenges. To use AI effectively in schools, we need to study it carefully. Educators recognize that AI can sometimes produce output that is inappropriate or incorrect (U.S. Department of Education, 2023). This makes it important to conduct research on how AI affects teaching and learning, and whether it truly benefits students. It's also essential to consider issues such as fairness, ethical, accuracy, and safety. Without solid research, schools might adopt AI simply because it is popular - not because it is effective. That’s why teachers and researchers must work together to test AI tools and ensure they are both helpful and safe for students. This kind of research will help schools make informed decisions about how to use AI in education.

Equity and Access Issues Related to AI Tools in Education

Equity and access are major concerns in the application of AI in high school mathematics education. Some schools are financially better off than others and can afford to purchase AI tools such as Magic School, ChatGPT, Gemini, and Alberta AI for teachers. However, not all high schools have the resources to buy these apps, leading to significant inequality in the integration of AI into the educational experience. In recent years, the topic of educational digital inequality has increasingly attracted widespread attention from scholars (Wang et al., 2024). Additionally, AI platforms are often trained on data that may not equally represent all student populations, which can result in biased responses or assessments of students from diverse backgrounds. Language barriers, disabilities, and cultural differences may also impact how students interact with AI platforms. To ensure fairness, educators and policymakers must prioritize equal access to technology, address algorithmic bias, and design inclusive AI platforms that support all learners.

Conclusion and Future Directions

The roots of computational thinking go back to the 1930s with the development of computers and programming languages. Alan Turing was the first addressed the issue of artificial intelligence in his 1950 paper, "Computing machinery and intelligence," and proposed an experiment known as the "Turing Test" — an effort to create an intelligence design standard for the tech industry (Biography.com Editor, 2020). Alan Turing is considered the pioneer of computational thinking, as he laid the foundations of computer science. A few decades ago, computational thinking became widely recognized, particularly through the work of Jeannette Wing in 2006.

Integrating technology into the high school curriculum involves computational thinking, which shares many components with mathematical thinking. Computational thinking has gained a prominent place in computer science curricula and has found significant application in mathematics, as described in Table 3. It also serves as a gateway to artificial intelligence (AI) in high school education. While several individuals contributed to the early development of AI, John McCarthy is widely credited with founding the field. He coined the term "artificial intelligence" in 1956 at the Dartmouth Workshop, which is considered the birthplace of AI.

In recent years, platforms like ChatGPT have accelerated the demand for AI in high school education. The rapid development of new AI technologies is putting pressure on researchers and educators to integrate AI into curricula. However, because AI is a complex platform that poses challenges such as ensuring control and protecting student privacy, it is difficult to implement fully in school curricula at this time. Nonetheless, both computational thinking (CT) and AI can be effectively used in solving mathematical problems and can complement mathematical thinking. As AI becomes more integrated into high school curricula, the combined use of CT and integration of AI platforms with advanced mathematical software in mathematics will become an essential element of education.

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