DOI: https://doi.org/10.57125/FED.2024.09.25.18

How to cite: Pllana, D., Baez, R., Sanchez, H., & Sandeep, N. (2024). Technology Inspires Mathematical Creativity in High School. *Futurity Education*, *4*(3). 309-333. https://doi.org/10.57125/FED.2024.09.25.18

Technology Inspires Mathematical Creativity in High School

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Received: April 27, 2024 | **Accepted:** July 17, 2024 | **Available online:** August 16, 2024

Abstract: Technology has a significant impact on the development of visual and mathematical creativity in high school. The purpose of this study was to observe how mathematical projects combining technology and creativity are implemented in a technology-oriented urban school in New Jersey. The study was conducted as a cross-sectional study using the observational method. The methodology section discusses examples of teacher projects such as modelling with circles, creating mathematical clocks, and exploring Theodore's spirals. The results section presents student projects, including watermelon clocks and drawing mathematical equations. Technology assisted teachers and students in finding patterns, creating mathematical equations, solving problems, and responding quickly to open-ended questions. This study extends the research field of creativity in high school by emphasising the complementarity of technology and mathematical creativity in the implementation of mathematical projects.

Keywords: Mathematical Creativity, Technology, Mathematical Projects, Modeling, Creative Clock, Spiral of Theodorus.

Introduction

The issue of technology in mathematical creativity in secondary school is extremely relevant in today's educational environment. Technology is rapidly integrating into the learning process, and its use can significantly increase the level of mathematical creativity among students. Modern technological tools allow creating interactive environments that encourage students to find innovative solutions to mathematical problems. This research will contribute to the development of new teaching methods that will help improve the quality of education and prepare students for the demands of the modern world.

In particular, a large number of scholars have been studying this problem. For example, Webb et al. (2021) find that integrating technology into mathematics education can lead to significant improvements in students' creative problem-solving skills. Cai et al. (2023) find that the use of technological tools in the classroom provides unique opportunities for students to explore mathematical concepts in a more engaging and interactive way. Raut and Pant's (2024) assertion that technology has the potential to transform traditional mathematics education by fostering a more creative and dynamic learning environment is a good place to start.

The paper centers on observing mathematical and visual creativity in digital mathematical projects at the technology-focused, urban high school in New Jersey. Technology enhances geometrical figures with detailed elements, enables quick analysis of mathematical problems, and inspires creativity. Thus it is important for us as educators to explore the relationship between technology and creativity, particularly in educational contexts (Mishra et al., 2012). The paper explores modeling, dealing with open - ended questions, and psosing tasks with circles and creative clocks; in addition, the paper deals with exploring the spiral of theodorus from the perspective of high school mathematics.

The beauty of the circles project asks students to start from the same image with 13 circles illustrated on the left side of Figure 1. Students create several google slides and the final project visually looks unique. The simple math project with circles is a great sample for mathematical creativity. Ideal solutions are often simple and straight to the point (or dot) (DMACGREGOR, 2021). Image on the right side is an example of the simple beautiful unique project.

The project drawing with mathematical equations asks students to draw a figure with mathematical equations. Mathematical equations telling you to do something, giving you information on how to respond, or come up with an answer (Cantor, 2020). This project shows the power of technology in inspiring mathematical and visual creativity.

Analyzing the relationship between technology and mathematical creativity, it is important to consider how technology inspires creativity in mathematics. The benefits for high school students of applying technology in education include the ability to draw figures to scale and obtain quick, accurate answers to mathematical problems. Technology has the potential to enhance creativity rather than inhibit it, especially when students are given the choice of what they create. Creativity can transform into innovation and make substantial contributions to any scientific field. However, this study is a case analysis conducted using qualitative methods, specifically observing mathematical projects at a technology-focused urban high school in New Jersey. A more comprehensive understanding of the relationship between technology and creativity could be achieved by applying mixed methods.

Research Problem

Today, the problem of using mathematics exists and has several gaps. Firstly, the insufficient use of technology in mathematics teaching Despite the fact that technology is increasingly used in teaching various subjects, its potential for developing mathematical creativity among high school students remains insufficiently explored. Secondly, there is a limited understanding of the impact of technology on mathematical creativity: existing research focuses mainly on the impact of technology on student achievement, but rarely examines how technology can foster creative approaches to solving mathematical problems.

This study was conducted to explore the gap in this area. The article presents options for using modern technologies that can contribute to the development of mathematical creativity in high school students. The article analyses the technological tools that are most effective in stimulating the use of a creative approach to solving mathematical problems, as well as the methods of their implementation in the educational process. This will allow creating more effective educational programmes that will not only improve students' academic performance, but also contribute to the development of their creativity in mathematics.

Research Aim and Research Questions

The aim of the research focuses on the influence of digital technology on high school mathematical creativity. Creativity, as highlighted by Sawyer and Henriksen (2024), is fundamental to human life and is a complex process that lacks a singular instrument for measurement. The research aims to address the question: Does technology inspire mathematical creativity? Due to the expansive nature of this question, the researchers intend to analyze it from a narrower perspective suitable for a concise research paper.

Literature Review

The paper focuses on two key factors: literature review and the observation of mathematical projects in relation to technology and mathematical creativity. The literature review demonstrates the connection between technology and mathematical creativity, providing foundational support for the research throughout the paper. Mathematical creativity, a concept evolving alongside digital technology, is imbued with innovative ideas, emphasizing the creative direction of mathematics education and reflecting the transformation of mathematics education in the digital age (Guo, 2023).

Measuring creativity lacks a precise instrument, but a general approach capable of recognizing creativity involves identifying novel elements in the mathematical process or final product. Some scholars summarize mathematical creativity through a two-factor model: a product-based evaluation model and a process-based evaluation model (Guo, 2023; Muzaini et al., 2023). Identifying unique elements within mathematical projects and recognizing new elements in the final work provides an opportunity to assess creativity.

In literature, mathematical creativity is hard to define concisely, but it has a huge scope. Research has revealed that students' mathematical creativity can be demonstrated by solving problems in diverse ways, such as different representations of mathematical concepts, varying use of properties (definitions or theorems) of mathematical objects within the field of mathematics, and diverse characteristics of mathematical objects (Saefudin et al., 2023). Identifying new elements in students' work, such as mathematical problems, concepts, geometrical figures, new patterns, etc., is associated with mathematical creativity.

Technology offers information to everyone. While knowledge depends on a person's individual obligations and interests, information is a more tangible and factual entity accessible to everyone. Given that emerging technologies are increasingly used to support creativity, a thorough review of the relationship between creativity and emerging technologies would be valuable for future studies on creativity and technology use (Li et al., 2022). Applying technology in high school mathematics provides various pieces of information that can be easily implemented in mathematical projects. Students' work reflects creativity through these projects, as demonstrated by observations of mathematical projects at a technology-focused urban high school in New Jersey.

Creativity is a significant aspect of education. According to Bloom’s taxonomy, creativity represents the highest level of thinking (Subanji & Nusantara, 2022). Therefore, it is essential to explore creativity from various perspectives. This study analyzes mathematical creativity and, to some extent, visual creativity, viewed through the lens of digital technology empowered by artificial intelligence.

In the thick lines, the research study blended the information from the literature review and observing mathematical projects at the technology-focused, urban high school in New Jersey. Based on these two relevant factors, to the best of our abilities, we found out there is a positive correlation between digital technology and mathematical creativity.

In general, technology inspires mathematical creativity in high school mathematics. All mathematical projects at the technology-focused, urban high school in New Jersey elaborated in this paper use digital technology (geometric or graphic Desmos) and apply mathematical creativity. The concern on mathematical creativity is the ability to generate ideas from given information (Idris & Nor, 2010). Digital technology through Desmos enabled mathematical modeling, modifying figures, generating new figures, identifying patterns, and offering a variety of mathematical ideas.

Observing mathematical projects on paper from the perspective of digital technology and mathematical creativity reveals the uniqueness and high quality of the work. These projects focus on the beauty of circles. Technology can generate numerous beautiful images starting from just a few basic steps. The beauty and utility of a circle demonstrate that often the simplest things, which are frequently overlooked, can be the most useful (Math and Multimedia, 2013).

Another captivating shape resembling a snail's shell is the Theodorus spiral, also known as the "Einstein Spiral," "π Spiral," and "Square Root Spiral," which can be constructed by anyone familiar with the

Pythagorean Theorem (Barlow, 2018). However, technology allows for creating the spiral with scale and detail that facilitate deeper analysis by students.

Working with technology to explore circles, create clock designs, and investigate the Theodorus spiral motivates teachers and students alike toward mathematical creativity. By integrating creativity into mathematical challenges, students are inspired to view math as an art of possibilities. Students engage in creating the creative watermelon clock and drawing creative cartoon characters using mathematical equations, which require a specific procedure. The entire project process involves several steps; consequently, students need to apply multiple mathematical strategies until they complete the work (Pllana, 2021). The combination of mathematical strategies with digital technology inspires mathematical and visual creativity profoundly.

Method and Materials

This study is a cross-sectional study that used the observation method to analyse the impact of technology on high school students' mathematical creativity. The observations were conducted from January 2024 to March 2024 in eight schools. The study used observation methods and surveys of high school students. The main goal was to identify how technology affects the development of mathematical creativity among students. Observations were conducted in classrooms where various technological tools were actively used, such as interactive whiteboards, computer programs for modelling mathematical problems, and online resources for self-study.

In addition, the article discusses examples of mathematical projects completed by teachers as models for students. This section presents several mathematical projects on the beauty of circles, creative clocks and Theodore's spiral. The teachers' mathematical projects provide strong evidence that technology inspires mathematical creativity through detailed shapes, varied patterns, and effective problem solving.

The observations were conducted over a three-month period from January 2024 to March 2024. The study was conducted in an urban school in New Jersey, where technological innovations are actively implemented in the educational process. The following algorithm was used to identify the results of the study:

1. The impact of interactive technologies on student motivation (interactive technologies significantly increase students' interest in learning mathematics. The use of interactive whiteboards and computer programmes creates a more engaging learning environment, which has a positive impact on student motivation).

2. Developing critical thinking through technology (the use of technology helps students develop critical thinking. In particular, computer programs for modelling problems contribute to a deeper understanding of mathematical concepts and stimulate creativity in solving them).

3. Improving learning outcomes through online resources (online resources for self-study allow students to work at their own pace and focus on those aspects that require additional attention. This increases the effectiveness of the learning process and contributes to better learning).

4. Development of cooperation and communication skills (the use of technology promotes cooperation between students. Group projects using interactive tools help students learn to work together, exchange ideas and solve complex problems together).

Overall, the study showed that technology plays an important role in the development of mathematical creativity among high school students. Interactive tools, computer programmes and online resources not only increase students' motivation, but also promote critical thinking, improve learning outcomes and foster collaboration.

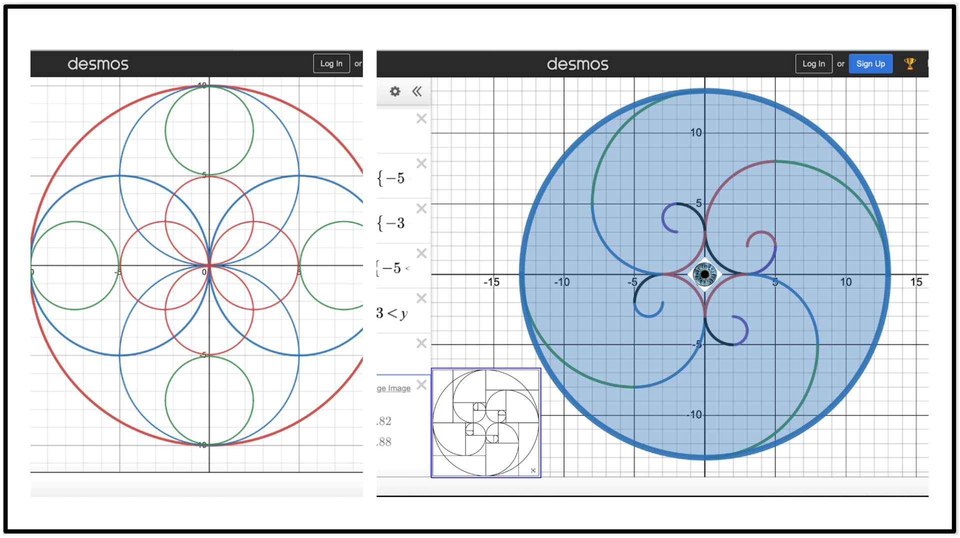
For further research, it is recommended to study in more detail the specific technological tools that have the greatest impact on different aspects of mathematical creativity.

Results

Technology elevates mathematical creativity in high school math by enabling precise drawing of mathematical figures to scale, maintaining symmetry, and visualizing geometric interpretations. This study focuses on high school math projects exploring the intersection of technology and mathematical creativity in education. Mathematical projects serve diverse purposes and cover various content; however, this paper specifically examines several examples. These include teachers' and students' projects involving symmetry, creative clock designs, and the Spiral of Theodorus. Teachers' digital math projects foster creativity through group work among students. When used appropriately, both content-specific and content-neutral technology can be effective in the math classroom (Picha, 2018). Project content may involve mathematical modeling, problem-solving, and often addresses open-ended questions. All mathematical projects necessitate the use of digital tools. In summary, digital technologies and online platforms for creativity provide new avenues for expression and foster alternative knowledge communities that facilitate feedback, sharing, and collaboration (Henriksen et al., 2021). Figure 1 in the left serves as a starting point through creativity with technology to reach a different destination as is presented in Figure 2.

Figure 1

Circles on the Right and Left Sides Present the Symmetry and Aesthetic Sensitivity Generated With Graphing Desmos (Empowered With AI)- Digital Technology



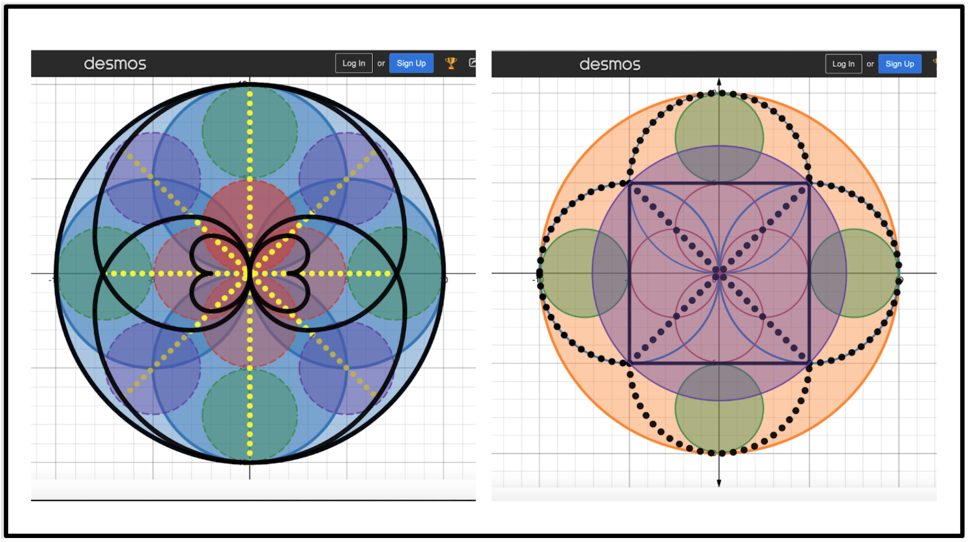
Source: Math project for students at the technology-focused, Urban High School in New Jersey.

Technology enables geometric figures to express their aesthetic sensibility through detailed elements depicted at actual scale. Figure 1 on the left side demonstrates the symmetry of the circles concerning the x-axis, y-axis, and origin. This project involves an open ended question that asks students to generate a new model started from the left geometrical figure presented in Figure 1. The math teacher instructed students to begin the project with this figure and create a minimum of five different slides leading to a new final project. The preparatory stage of mathematical creativity consists of various approaches used by the mathematician to lay the groundwork (Sriraman, 2004). In this case, creativity manifests through open-ended questions, as each group must reach conclusions without knowledge of the final slide destination. Despite starting with the same figure, each student group developed a unique creative figure. Evidence of this can be seen in Figures 1 and 2, where the left and right sides present entirely distinct models despite their shared origin. Technology enhances students' ability to refine their creativity, allowing each group to produce a unique project.

In Figure 1, the Fibonacci sequence generates a figure with an eye in the middle of a circle, which is then modified by incorporating a smaller figure from a previous iteration into the corner. Simply changing the image of the eye to a diamond or another shape creates a new figure. Austin Kleon emphasizes that creativity belongs to everyone (Spencer, 2021), stating, 'Creativity is taking what's in front of you and everybody else and making something new out of it.' Observing and analyzing Figures 1 and 2 demonstrates creativity through technological modeling, taking what is commonplace and generating entirely new and unique figures. Additionally, digital technology creates each circle in Figure 1, which showcases beauty to the human eye through Fibonacci sequences and symmetry.

Figure 2

Geometrical Figures on the Left and Right Sides are Modeled From the Left Side Geometrical Figure Presented in Figure 1



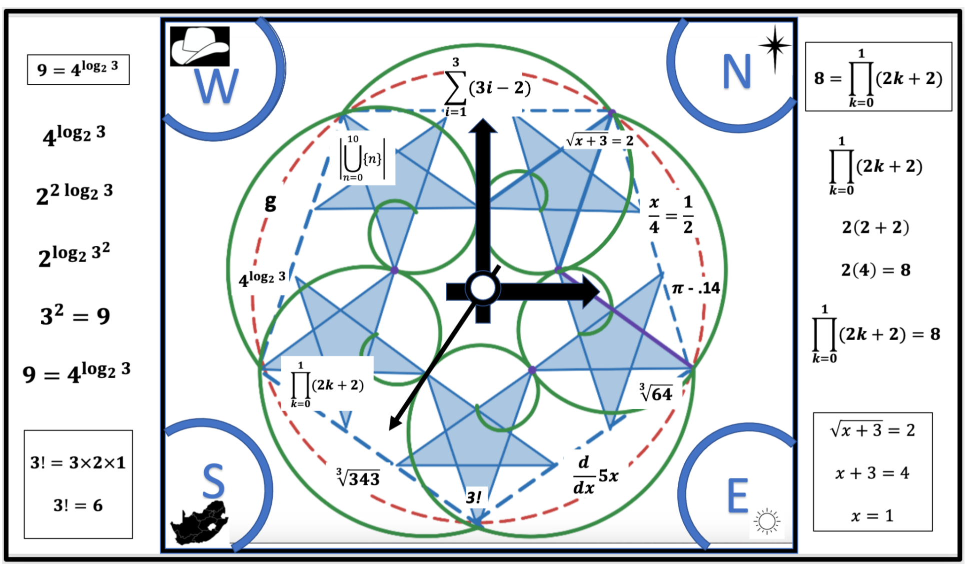
Source: Math project for students at the technology-focused, Urban High School in New Jersey.

Technological advancements enable creativity to reach new heights. The evolution of technology has significantly simplified the process of connecting creative minds and ideas, thereby propelling innovation (Mackenzie, 2020). Similar to the examples illustrated in the preceding figures, technology facilitates the creation of geometric shapes and graphs at scale, allows for the modification of various models with different or similar patterns, preserves symmetry and beauty in figures, and generally fosters mathematical creativity. Creativity and technology can coexist harmoniously, debunking any notion of mutual exclusivity (Mackenzie, 2020). Digital technology, powered by artificial intelligence, can predict new patterns, modify various models, and accurately determine the most aesthetically pleasing geometrical figure, as demonstrated by the challenging comparison between the two figures (right and left) in Figure 2.

Another project that explores modeling incorporating elements of symmetry, particularly with respect to origin, is the creative clock illustrated in Figure 3. The geometrical figure in Figure 3 features a regular pentagon, stars, and curves based on Fibonacci sequences. In a regular pentagon, all interior angles are equal, and all sides are of equal length (Cuemath, n.d.). The figure generated using geometric Desmos, powered by artificial intelligence, includes symmetric Fibonacci curves around a regular pentagon with origin symmetry. Radial symmetry is more complex as it exhibits symmetry in multiple directions (Baez, et al., 2024b); in this case, it is presented in five directions. Radial symmetry is observed in stars, circles, many flowers, certain fruits, and vegetables. Overall, symmetry embodies elements of aesthetic sensitivity that naturally attract creative ideas.

Figure 3

The Creative Clock Signed Numbers With Mathematical Expressions That Signified Numbers in the Order From 1 to 12 Generated Through Geometric Desmos – Powered by AI



Source: Math project for students at the technology-focused, Urban High School in New Jersey.

The creative clock illustrated in Figure 3 is marked with mathematical expressions representing integers from 1 to 12. Clock numbers 9, 6, 8, and 1 on both sides of the figure illustrate the equality with the corresponding mathematical expressions. In mathematics, an expression is a sentence that includes at least two numbers or variables and at least one mathematical operation. For example, when the expression $\sqrt[3]{343}$ is simplified, it equals the integer 7; simplifying the expression $\pi - .14$ approximates the numerical value 3. Similarly, simplifying the expression $\sum_{i=1}^{3} \square\, (3i-2)$, which represents a series, equals the numerical value 12. Likewise, each mathematical expression assigned in the creative clock corresponds to a numerical value on the clock.

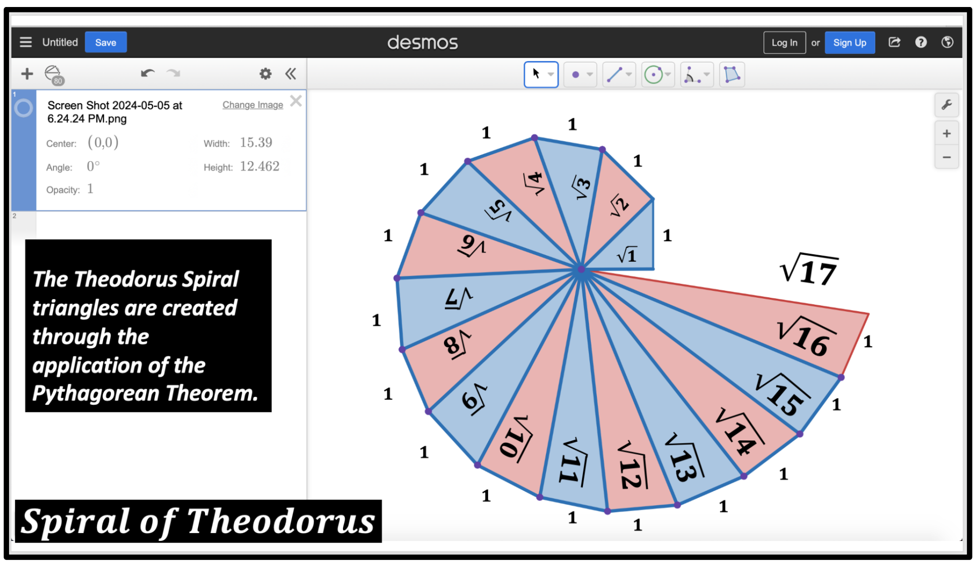
The creative clock, generated with digital technology, is not only beautiful with its symmetric radial curves but also contains four figures inscribed in the corners bordered with semicircles. These figures or images serve to convey information quickly. Humans can process an image in the blink of an eye — literally

(Alpuim & Ehrenberg, 2023). The four images symbolize the presence of the timer across the globe: West, North, East, and South. The West is symbolized by a cowboy hat representing the Western world. The North is symbolized by the North Star, representing the northern hemisphere. The East is symbolized by the Sun, signifying sunrise. The South is represented by a country on a map, symbolizing South Africa. Taking the first letter of each cardinal direction (NWSE) and rearranging them yields 'NEWS'. The 'NEWS' of this project in Figure 3 signifies a new mathematical and creative clock — a unique timepiece.

Project content could involve technology, mathematical modeling, problem-solving, identifying patterns, and often addresses open-ended questions. Observing mathematical projects generated with digital technology (geometric desmos) in Figure 4 reveals the ability of technology to construct the figure (theodorus spiral) with high accuracy, and students might analyze from multiple angles. Theodorus of Cyrene constructed continuous right triangles and got a beautiful spiral. He used that spiral to prove that all non-square integers from 3-17 are irrational (Kaya, n. d.). All triangles can be constructed by using the starting point isosceles triangle and continuing with the right triangle using pythagorean theorem.

Figure 4

The Theodorus Spiral Created by Using Digital Technology – Geometric Desmos Powered by Artificial Intelligence



Source: Math project for students at the technology-focused, Urban High School in New Jersey.

The Theodorus Spiral project utilizes digital technology, and each triangle can be analytically obtained using the Pythagorean theorem. The term 'hypotenuse' originates from the Greek words meaning 'to stretch,' referring to the longest side (Hall, 2021). Usually, sequence is denoted with $(a_n)^{\infty}{}_{n=0} = (a_1, a_2, a_3, \dots)$ and frequently starts with the index n is equal with zero. The equation $c_n = \left(\sqrt{a_n}\right)^{17}{}_{n=1}$ describes sequences of the hypotenuses in the Theodorus Spiral, where an a_n is an element of natural numbers. The equation in the given form $c_n = \sqrt{\left(\sqrt{a_n}\right)^{2}{}_{n} + 1}$ describes the Pythagorean theorem for the triangles in the Theodorus Spiral. . If we continue to plot the spiral there are more questions which need more sophisticated mathematics to be answered. Further exploration of the spiral raises more questions that demand sophisticated mathematics for resolution (Kociemba, n.d.). The application of technology and mathematical creativity in the Theodorus Spiral enables the solution of various mathematical problems.

Observing the high school mathematical project (Spiral of Theodorus) enables students to complete mathematical projects by involving the relationship between technology and mathematical creativity. The best way to describe this relationship is the definition of Alexander Rauser, a CEO of prototype - a digital strategy agency. Rauser claims, creativity comes from observing the world, interpreting it, and bringing new concepts and ideas, while technology has become a new lens through which to see the world differently and access information (Mackenzie, 2020). In addition to facilitating the creative process, technology is also playing an increasingly important role in shaping the way we think about and understand creativity (Dombrowski, 2022). Technology enables the spiral of theodorus showing different perspectives or various forms which gives teachers and students to explore and find new creative solutions.

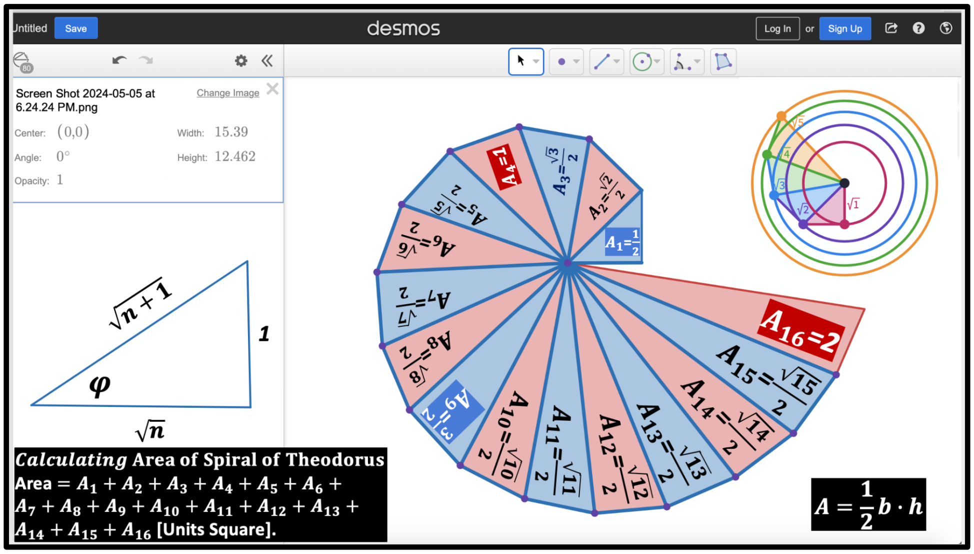
Exploring various elements, areas, angles, and the changes in each radius or hypotenuse from the previous triangle in the Theodorus spiral project. In Figure 5, the original spiral concludes with a triangle having a hypotenuse of the square root of 17. However, you can extend these triangles indefinitely (Polypad, n.d.). On the left side of the figure, a right triangle denotes the angle, two legs, and the hypotenuse. In the upper right corner of the figure, the hypotenuses serve as the radii of circles. On the right side of the figure, each right triangle's area is displayed. Since there are 17 hypotenuses, one would logically expect 17 triangles and the calculation of 17 triangle areas. The figure generated by Geometric Desmos (digital technology) powered by artificial intelligence clearly shows 16 triangles. Therefore, calculating the total area of the Theodorus spiral involves computing the surface area of these 16 right triangles.

Analyzing the triangle on the right side of Figure 5, the relationship between the angles and sides in the right triangle yields $tan\varphi = \left(\frac{1}{\sqrt{n}}\right)$, which implies $\varphi = arctan\left(\frac{1}{\sqrt{n}}\right)$. Since the spiral of Theodorus consists of 16 triangles, calculating the total angle of all triangles describes the series $\varphi = \sum_{n=1}^{16} arctan\left(\frac{1}{\sqrt{n}}\right)$.

The difference between a hypotenuse and the previous one is described by the equation $r_n = \sqrt{n+1} - \sqrt{n}$. This equation also describes the difference in radius of the upper right image in Figure 5. Calculating the total area of the Spiral of Theodorus can be described by the equation $A_T = A_1 + A_2 + \ldots + A_{16}$ or $A = \frac{1}{2}\left(\sum_{n=1}^{16} \sqrt{n}\right)$ n where n is a natural number.

Figure 5

Calculating the Area of Spiral of Theodorus and Characteristics of the Right Triangle Generated by Geometric Desmos Powered by Artificial Intelligence – Upper Right Corner the Figure is Modified



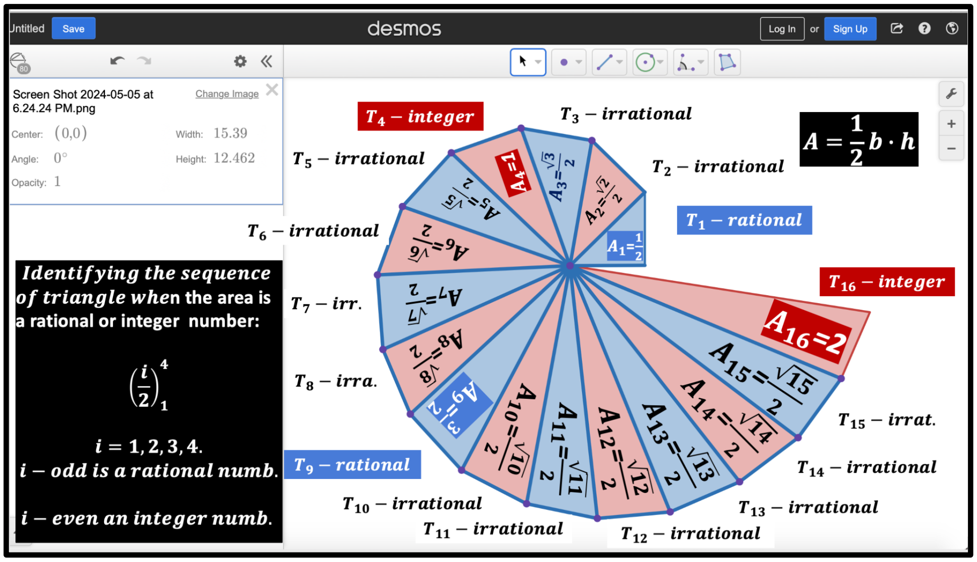
Source: Math project for students at the technology-focused, Urban High School in New Jersey; Polypad (n.d.).

Analyzing images in Figure 5 generated with digital technology enables us to delve deeper into explaining the patterns in the figure and discover new unique patterns. Studying mathematics and practicing different types of equations and sums helps develop and strengthen our abstract reasoning and pattern recognition (CreativeHuddle, n.d.). Some intriguing patterns emerge in the results of the areas of the triangles in the Theodorus spiral presented in Figure 6. These results, whether in terms of rational or irrational numbers, follow patterns that can be generated with specific equations.

In Figure 6 is presented the area of th $A_T = \sum_{i=1}^{16} \frac{\sqrt{n}}{2}$.(1) n = 16, which shows the total area of triangles in theodorus spiral, while results show 2 integers, 2 rational, and 12 irrational numbers. Identifying the sequences of triangles when results of area is rational or integer determines the expression $\left(\frac{i}{2}\right)_1^4$. In general, $i = 1, 2, 3,$ *and* 4. In the case $i - odd$ the result of the triangle area is a rational number, otherwise, $i - even$ the result is an integer number. There are a lot more irrational numbers than rational numbers (Thebright, 2021). Even in the thesaurus the results of the areas in the triangle contain more irrational numbers than rationals. The two irrational numbers follows this pattern: T_2T_3; $T_5T_6T_7T_8$; $T_{10}T_{11}T_{12}T_{13}T_{14}T_{15}$; in other words, the number of triangles with two irrational numbers follows the pattern: 2, 4, and 6. The number of irrational areas in triangle could be obtained with equation $i_T = 2n$, where n is an integer $n = 1, 2,$ *and* 3.

Figure 6

Calculating the Area of Spiral of Theodorus and Characteristics of the Right Triangle Generated by Geometric Desmos Powered by Artificial Intelligence



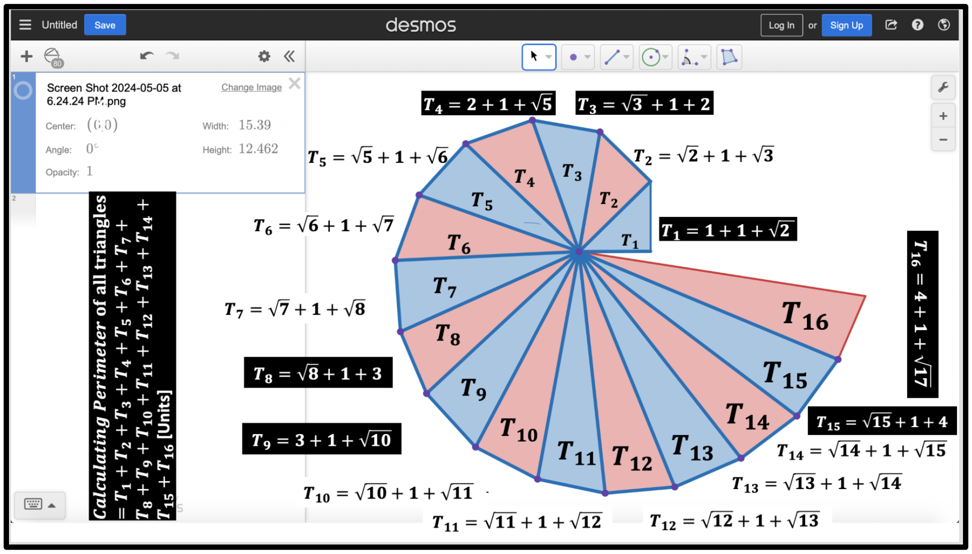
Source: Math project for students at the technology-focused, Urban High School in New Jersey.

Technology in education assists high school students and teachers in completing mathematical projects, thereby empowering them to showcase their creativity. Technology and creativity have always shared a symbiotic relationship, each influencing and enhancing the other (Sullivan, 2017). By analyzing the mathematical project 'Spiral of Theodorus', technology enables teachers and students to explore its depth and generate new mathematical ideas.

Another significant characteristic of the Theodorus spiral is the calculation of the perimeter of its triangles and the determination of the total perimeter. Since every triangle consists of three sides, each triangle in the Theodorus spiral shares a common side. For instance, the first triangle and the second one share a side with a length of $\sqrt{2}$ in both triangles $(T_1 = 1 + 1 + \sqrt{2})$ and $(T_2 = \sqrt{2} + 1 + \sqrt{3})$. Similarly, all triangles in the Theodorus spiral share at least one side. Seven triangles have two sides with rational numerical values and one side with an irrational numerical value. Conversely, nine triangles have two sides with irrational numerical values and one side with a rational numerical value. The perimeters of all triangles result in irrational numbers.

Figure 7

Describes the Perimeter of the Triangles in the Spiral of Theodorus Generated by Geometric Desmos Empowered by Artificial Intelligence



Source: Math project for students at the technology-focused, Urban High School in New Jersey.

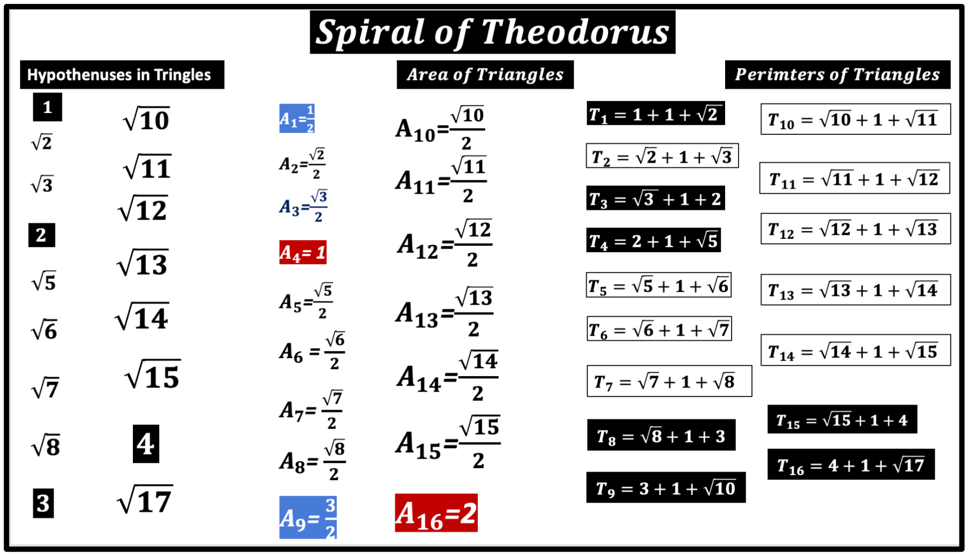
The total perimeter of triangles in the Spiral of Theodorus differs from the total perimeter of the Spiral of Theodorus itself. The total perimeter of triangles in the Spiral of Theodorus follows the equation $P_T = \sum_{n=1}^{16} \left(\sqrt{n} + 1 + \sqrt{n+1}\right)$ in a series form. Conversely, the equation for calculating the total perimeter of the Spiral of Theodorus is $P_{Th} = \sum_{n=2}^{17} \left(\sqrt{n} + 1\right)$. This latter equation for calculating the Spiral of Theodorus' perimeter can be rewritten as $P_{Th} = 17 + \sum_{n=1}^{17} \sqrt{n}$. Expanding the perimeter series further, it can be expressed as follows: $P_{Th} = 26 + \sqrt{2} + \sqrt{3} + \sqrt{5} + \sqrt{6} + \sqrt{7} + \sqrt{8} + \sqrt{10} + \sqrt{11} + \sqrt{12} + \sqrt{13} + \sqrt{14} + \sqrt{15} + \sqrt{17}$.

Observing the patterns in Figure 8 on hyponouses and areas of triangles show there is pattern of the irrational numbers in the triangles T_2T_3; $T_5T_6T_7T_8$; $T_{10}T_{11}T_{12}T_{13}T_{14}T_{15}$. Finding the number of irrational numbers of hypotheses respectively areas after the rational one is described by the equation: $i_A = 2n$ and $i_H = 2n$, where n = 1, 3 and 3.

Observing the patterns in the perimeter of triangles with two irrational numbers and one rational number follows this pattern: T_2; $T_5T_6T_7$; $T_{10}T_{11}T_{12}T_{13}T_{14}$; in other words, the number of triangles with two irrational numbers follows the sequence: 1, 3, and 5. The number of triangles with two irrational sides in a triangle could be obtained using the equation $i_T = 2n - 1$, where n is an integer n = 1, 2, and 3.

Figure 8

Categorizing Patterns That Occur in the Spiral of Theodorus (Hypotenuses in Triangles, Areas of Triangles, and Perimeters of Triangles)



Source: Math project for students at the technology-focused, Urban High School in New Jersey.

Technology plays a crucial role in fostering mathematical creativity in high schools. It enhances mathematical creativity by enabling the creation of accurately scaled figures, maintaining symmetry, addressing open-ended questions with multiple solutions, and solving problems that have multiple approaches. Creativity drives ideas, technology enables them (Swim & Goel, 2022). Furthermore, technology serves as a tool to evaluate mathematical creative ideas and validate their outcomes. Thus, technology and mathematical creativity complement each other harmoniously in modern education. Above all, the spiral of theodorus project provides multiple solutions of mathematical problems, imposing tasks, and modeling mathematical patterns.

Based on observations of mathematical projects focusing on the harmony between technology and mathematical creativity, several results are implied.

- Technology fosters mathematical creativity by modeling mathematical problems and geometrical figures.
- It assists in generating multiple solutions for open-ended questions and facilitates the identification of patterns in creative mathematical ideas.
- Technology enables teachers and students to modify mathematical problems, new models, or refine concepts, and create something new and unique.
- Technology converts knowledge into information; teachers and students then could transform that information into creative ideas.
- Technology assists students with creating art through mathematical equations or expressions.
- Teachers and students could draw creative clocks with mathematical tools.

- Mathematical creativity comes up with new ideas, while technology brings to real life the new ideas.

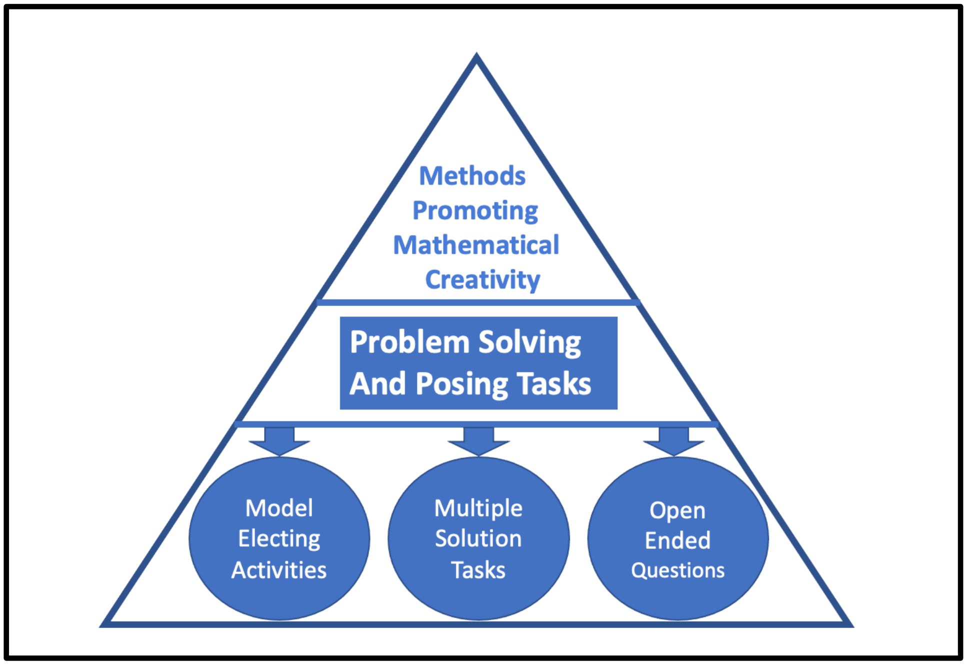
Relationship between technology and mathematical creativity appears on multiple occasions, but the paper focuses on analysis of mathematical projects that reveals the effects of technology in their outcomes.

Just like best practices in reading, writing, or classroom management, specific teaching strategies support creative thinking in mathematics (Kozlowski et al., 2019). Teaching approaches that promote mathematical creativity are based on problem-solving and task-posing activities. Three significant components of these activities include model-electing activities, tasks with multiple solutions, and open-ended questions. Integrating technology with these methods enhances mathematical creativity to a greater extent, facilitating easier and more effective knowledge transfer (Raja & Nagasubramani, 2018). Nowadays, technology makes teaching and learning more interactive, significantly transforming the human experience (Satell, 2014). Openness to experience has consistently been one of the most significant predictors of creativity (Meier et al., 2024). Therefore, specific teaching strategies blended with technology play a crucial role in fostering mathematical creativity, closely intertwining with experience.

An example of teaching approaches that promote mathematical creativity based on problem-solving and task-posing activities is illustrated in Figure 10. Project #4 is a high school mathematical project that requires the application of technology to solve and pose multiple tasks. Problem-solving is defined as finding a solution to a problem, whereas problem-posing involves reformulating a given problem or creating new problems or questions (Cai & Hwang, 2002; Divrik et al., 2020).

Figure 9

Teaching Approaches That Help Support Mathematical Creativity Modified With Powerpoint Slides



Source: Kozlowski et al. (2019).

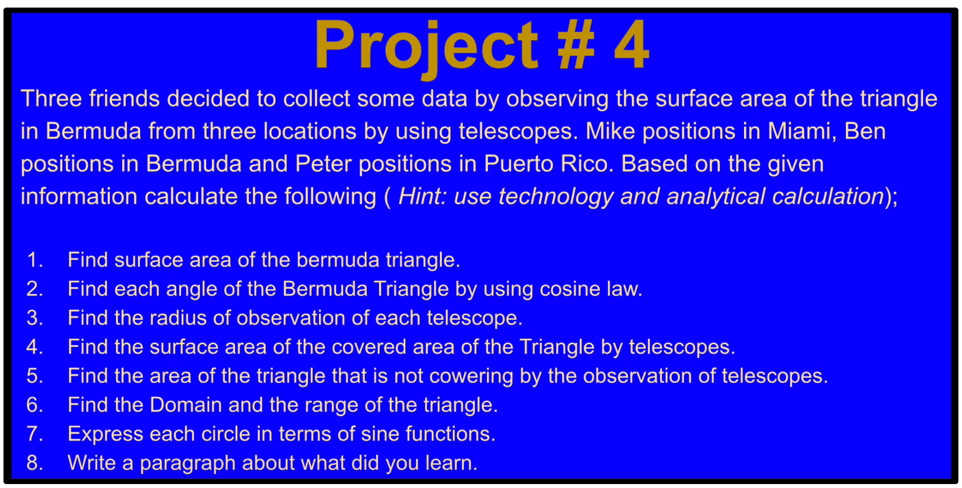
Mathematical Project #4 involves several steps or finding multiple solutions to given mathematical problems. While it is not explicitly required for students to pose a task, they are encouraged to modify the mathematical problems. Sometimes, posing a problem is more crucial than simply obtaining a solution, which can only be achieved through the application of mathematical or experimental processes (Santos et al., 2024).

In this case, students could modify the mathematical problem by applying sine laws, finding differences between the radii of circles, and expressing the circles in terms of cosines or other trigonometric functions. In the concluding paragraph, students can reflect on their experiences with the project.

Students' task in this real-world project is to work in groups. Each group gathers information from the internet about three locations and creates approximate data. Based on these numerical values (data), they answer questions, ensuring each final project differs slightly from another. Students collaborate within their groups, sharing their answers and solutions. If the project helps partners better understand their needs and provides a solution, students realize their acquired skills extend beyond academic settings (Acquaro & Goss, 2022). True collaboration involves students exchanging ideas, socially constructing knowledge, enhancing communication skills, and more (Project-Based Learning Network, 2024). Above all, students generate new creative ideas and may formulate new questions or mathematical problems.

Figure 10

Presents a High School Mathematical Project at the Technology-Focused, Urban High School in New Jersey That Incorporates the Mathematical Creativity Method, Problem Solving and Posing Tasks



Source: Authors' development.

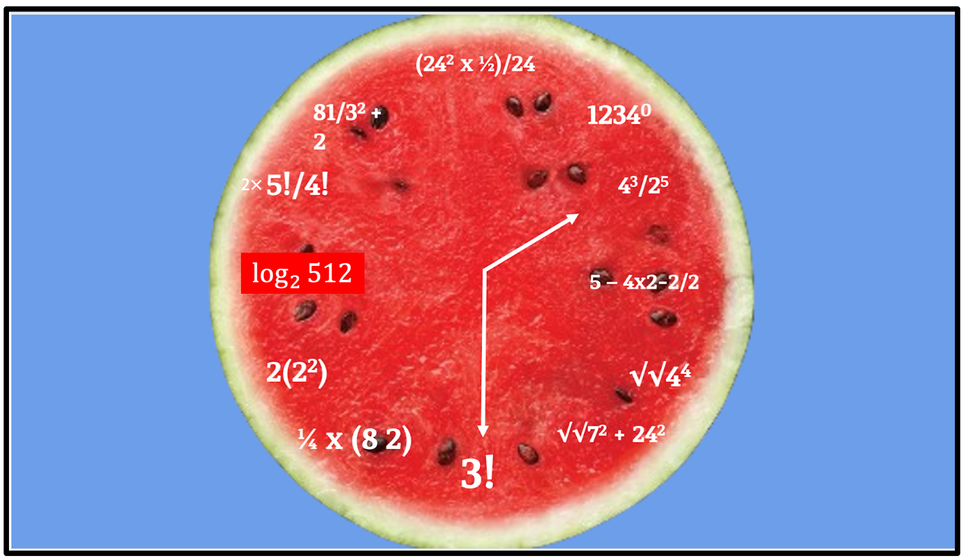
Usually, students at the technology-focused urban high school in New Jersey complete math projects using technology combined with creativity. The National Council of Teachers of Mathematics (NCTM) emphasizes the necessity of technological tools for engaging students (Aurora University Online, n. d.). Students share their slides in formats such as Google Slides, PowerPoint, or another digital form, enabling them to exchange ideas from any location. They blend unique ideas and utilize digital technology to create distinctive slides.

For example, upon examining the creative clocks in Figure 3 and Figure 11, similarities and differences emerge. Both wall clocks quietly perform their duties, their movements remind us that time is moving (Karadag, 2023). Both clocks incorporate mathematical expressions rather than integers or Roman numerals. Both figures exhibit symmetry with respect to the radius. Despite each clock having 12 mathematical expressions, they differ significantly in terms of shapes, colors, arrangement, and quantity of elements.

Mathematical projects at the technology-focused urban high school in New Jersey typically require completion of around 10 slides using digital technology. According to Mama Teaches (n.d.), these projects enable students to utilize research, problem-solving, critical thinking, and creativity skills. The initial slides serve as project introductions or titles, while subsequent slides contain the project's body. The final slide is dedicated to reflection. Generally, students create unique slides; titles feature decorative fonts and provide a brief project overview, while the body includes the main content. For example, Figure 11 depicts a project consisting of at least six slides, each explaining mathematical expressions corresponding to numbers on a clock. Figure 3 similarly illustrates various mathematical expressions related to clock numerals. In their last slide, students articulate their learning outcomes in a paragraph or more. As noted by Fintelman (2023), students are familiar with these routines, and their reflections are increasingly insightful.

Figure 11

Describes the Creative Clock of a Students' Group at the Technology-Focused, Urban High School in New Jersey

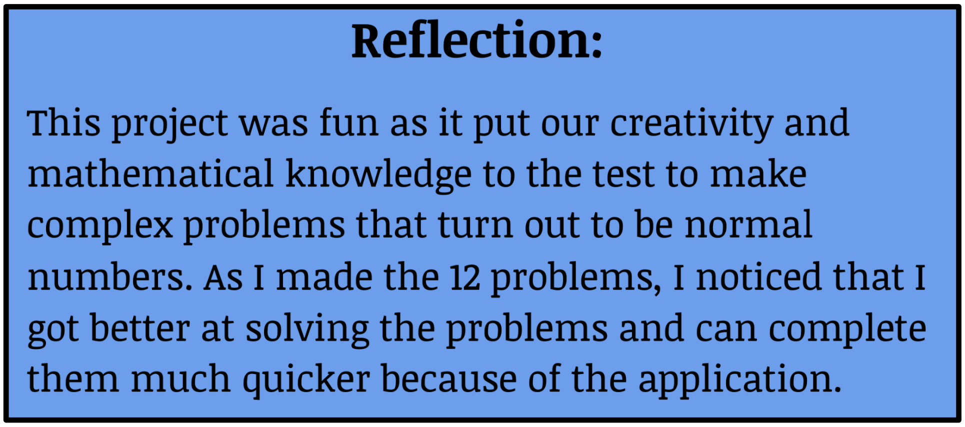


Note. Other groups created different creative clocks.

Reflecting on the process and compiling these mathematical projects enables students to engage in deeper, metacognitive thinking.

Figure 12

Students Reflection in the Last Slide of the Math Project Creative Clock on Watermelon

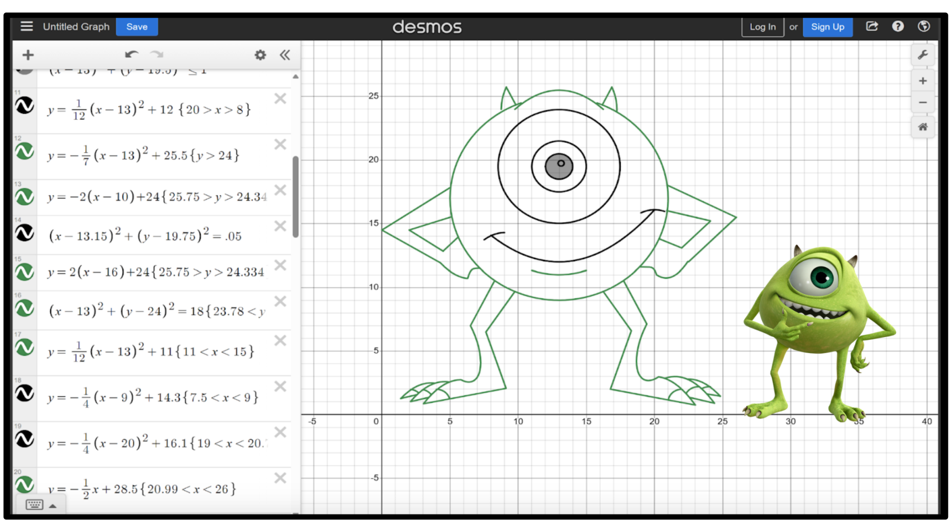


Source: Students project at the technology-focused, Urban High School in New Jersey.

The last paragraph presents the reflection of a student group on the "Creative Clock in the Watermelon" project. This math project not only nurtures artistic talent but also reinforces mathematical concepts (Raut & Pant, 2024). According to Figure 12, students emphasized creativity in a complex project that required several steps to complete. The idea was to write mathematical expressions instead of numbers on the clocks, which students found turned out to be normal numbers (numbers on the clock face). Students mentioned they created 12 problems, corresponding with their creative method of problem-solving and task posing. Problem-posing tasks are those that position students as generators or shapers of new problems based on real-life and mathematical situations (Cai et al., 2023). The students created the mathematical expressions and selected the shape of the vegetable (watermelon) as a clock. The teacher initially showed them the creative clock in Figure 3 as a model of what a creative clock might look like. Subsequently, the students developed their own model with digital technology: the creative clock in the watermelon or how students named it, Watermelon Clock.

Figure 13

Presents Mathematical art by Using Mathematical Equations and Digital Tools – Graphing Desmos



Source: Students' group work at the technology-focused, urban high school in New Jersey.

Mathematical projects in high school incorporate various elements such as digital technology, mathematical modeling, and open-ended questions. Mathematical modeling helps students delve deeper into mathematical examples relevant to real-world situations. Used across scientific disciplines, models are abstractions that respect reality and can lead to scientific advances, new discoveries, and informed decision-making (Neubert, 2020). Mathematical modeling significantly enhances creativity in high school math projects.

Additionally, at a technology-focused urban high school in New Jersey, mathematical projects often involve open-ended questions. Open-ended questions can be defined in several ways; simply put, they are questions with multiple correct answers (Think Grow Giggle, n.d.). These questions allow students to see their original ideas in action, making math projects more engaging. Since answers to open-ended questions may vary, students typically spend considerable time verifying or making sense of their results by the end of the math project.

Figure 13 presents an example of mathematical modeling and open-ended questions in group work at a technology-focused urban high school in New Jersey. Students engaged in creating a mathematical model to draw a cartoon character using mathematical equations. Experimenting with various equations within the Cartesian system resulted in a variety of graphs, each displaying distinct and often unpredictable shapes (Baez et al., 2024). The specific design of the cartoon character was achieved uniquely by this group. If another group were to choose the same character, they would likely produce shapes that are only slightly similar, using different mathematical equations.

Interestingly, while some groups selected the same real or cartoon character, each group modeled its shape differently using digital technology and distinct equations. Because the students' work blended technology with open-ended questions, the final results varied. Technology's expansive role in mathematics enhances comprehension and improves outcomes (Pllana, 2023). The students' mathematical creativity, visual creativity, and application of digital technology produced incredible work that surprised both teachers and students.

Discussion

The study showed that technology can indeed contribute to the development of mathematical creativity in high school students. This conclusion is confirmed by the observation of an increased level of interest and engagement of students in solving mathematical problems using interactive platforms and specialised software.

Our results are consistent with the work of other researchers who have also noted the positive impact of technology on the learning process. For example, a study by Baez et al. (2024a) found that interactive learning platforms can increase students' motivation and engagement in learning. At the same time, some studies, such as Kociemba (2022), did not find a significant impact of technology on the development of students' creativity, which may be due to differences in the choice of methodology or research context.

The findings are in line with a number of studies that highlight the positive impact of technology on mathematical creativity and the overall learning process. For example, Fintelman (2023) found that interactive learning platforms such as Khan Academy significantly increase student motivation and engagement. Johnson notes that students who use these platforms show a greater interest in mathematics and demonstrate improved test scores. It is also worth noting the study by Picha (2018), which found that the use of software for modelling mathematical processes promotes the development of creative thinking. The researcher argues that technology allows students to visualise complex mathematical concepts, which makes them easier to understand and stimulates the search for non-standard solutions. Our results support these findings, as the students who participated in our study also noted that visualising mathematical models helps them to better understand the material and find creative approaches to solving problems. At the same time, there are studies that do not fully coincide with the findings of this study. For example, Think Grow Giggle (2021) found no significant impact of technology on the development of students' creativity. Smith points out that the effectiveness of technology use depends on a number of factors, such as the quality of the learning content, teacher training, and individual student characteristics. He also emphasises the importance of integrating technology into the learning process in such a way that it complements rather than replaces traditional teaching methods. Our study partially confirms these findings, as we also noted that the key to success is the correct implementation of technology and teacher training.

Another interesting study comes from Mackenzie (2020), who investigated the impact of gamification on the learning process. He found that game elements integrated into learning platforms significantly increase student engagement and motivation. However, he also notes that excessive use of gamification can lead to a decrease in academic seriousness and concentration on learning. Our results partially coincide with the findings of the aforementioned researcher, as we also observed increased student motivation when using interactive platforms, but we believe that a balance between traditional teaching methods and technology is critical.

Our own research findings allow us to conclude that modern technologies have great potential for developing mathematical creativity in high school students. However, the effectiveness of technology use depends on several important factors. Firstly, technology should be integrated into the learning process in a way that complements rather than replaces traditional teaching methods. This means that teachers need to be well trained in the use of new technologies and understand how they can enhance learning.

Secondly, it is necessary to ensure the high quality of the learning content. Interactive platforms and software should not only be technically advanced, but also pedagogically sound. They should promote a deep understanding of mathematical concepts and encourage students to think creatively and find non-standard solutions.

Thirdly, the individual characteristics of students should be taken into account. Not all students respond equally to the use of technology in the learning process. Some may need more time to adapt to new teaching methods, while others may show more interest and engagement from the start.

Our study has several limitations. First, it only covered urban schools in New Jersey, which may limit the generalisability of the results to other regions. Secondly, we used only qualitative methods and a single data set, which did not allow for analysis over time. These limitations should be taken into account when interpreting the results and planning further research.

Based on our findings, we can conclude that modern technologies, such as interactive learning platforms and software for visualising mathematical models, can have a significant impact on the development of mathematical creativity in high school students. Not only does technology make learning more engaging, but it also contributes to a deeper understanding of mathematical concepts. They allow students to experiment with mathematical models, which stimulates their creativity and ability to solve complex problems. It is important to note that the key factor is the correct implementation of technology in the learning process and the training of teachers to use it effectively.

Our study makes an important contribution to science by deepening the understanding of how modern technologies can influence the development of mathematical creativity in high school students. It expands the scientific field on this issue by providing new data on the effectiveness of interactive platforms and software in the learning process. Our study also emphasises the need for a comprehensive approach to introducing technology into the curriculum, including teacher training and adaptation of teaching methods.

Our study has several limitations. First, it only covered urban schools in New Jersey, which may limit the generalisability of the results to other regions. Second, we used only qualitative methods and a single data set, which did not allow for analysis over time. These limitations should be taken into account when interpreting the results and planning further research.

Conclusion

The study confirms that technology does inspire mathematical creativity in high school. The use of modern technological tools, such as interactive platforms and specialised software, helps to increase students' interest in mathematical research and allows them to develop creative approaches to solving mathematical problems. The study examined several examples of mathematical projects implemented by teachers as models for students. In particular, projects on the beauty of circles, creative clocks, and Theodore's spiral were presented. These projects clearly demonstrate how technology can be used to create detailed shapes, develop a variety of patterns, and solve mathematical problems effectively. The teacher-designed mathematics projects provide compelling evidence that technology stimulates mathematical creativity. Thanks to the use of modern tools, students have the opportunity to dive deeper into the study of mathematical concepts, which contributes to the development of their creative thinking and ability to solve non-standard problems.

In addition, the introduction of technology in the learning process allows students to experiment with mathematical models, which stimulates their curiosity and encourages further research. Thus, the results of our study confirm that technology can be an effective tool for developing mathematical creativity in high school students.

The study made an important contribution to the scientific understanding of the impact of modern technologies on the development of mathematical creativity in high school. It expands the scientific field on this issue by providing new data on the effectiveness of interactive platforms and specialised software in the educational process. Our findings show that technology not only increases students' motivation and interest, but also contributes to a deeper understanding of mathematical concepts and the development of creativity.

Suggestions for future research

The correlation between technology and mathematical creativity, which technology inspires in this study, has limitations because it is only applied to literature review and observational methods (part of qualitative methods). However, this study has great potential to expand its research through interviewing students and teachers, conducting focus group discussions, and possibly empirical studies using statistical methods such as regression, t-tests, ANOVA, or other empirical approaches. Although students' mathematical projects include reflections on their work, interviewing students or teachers could provide more detailed answers to specific questions. Additionally, focus group discussions could narrow down topics and address specific questions regarding the positive, negative, or nonexistent correlations between technology and mathematical creativity. Therefore, there is ample opportunity to modify this study and present new, unexplored evidence that either supports or refutes this research. Furthermore, the study could explore the relationship b5etween technology and visual creativity from a different perspective.

Prospects for further research include the creation of interactive platforms that stimulate mathematical creativity, such as virtual reality, augmented reality, and gaming technologies, as well as the development of specialized software that allows students to create and visualize mathematical models.

Acknowledgements

The research work was conducted based on the mathematical projects at the high school, therefore we express our gratitude to the technology-focused, urban high school in New Jersey.

Conflict of Interest

None.

Funding

The Authors received no funding for this research

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