MEDITERRANEAN JOURNAL FOR RESEARCH IN MATHEMATICS EDUCATION

AN INTERNATIONAL JOURNAL

Volume 20. 2024

SPECIAL EDITION: MATHEMATICS AND STEAME EDUCATION

CYPRUS MATHEMATICAL SOCIETY
ΚΥΠΡΙΑΚΗ ΜΑΘΗΜΑΤΙΚΗ ΕΤΑΙΡΕΙΑ
Nicosia - Cyprus

Editor
Gregoris Makrides

Mediterranean Journal for Research in Mathematics Education

An International Journal
of Cyprus Mathematical Society

ISSN 1450-1104 Cyprus Mathematical Society

MEDITERRANEAN JOURNAL FOR RESEARCH IN MATHEMATICS EDUCATION

AN INTERNATIONAL JOURNAL

Volume 20. 2024

SPECIAL EDITION: MATHEMATICS AND STEAME EDUCATION

CYPRUS MATHEMATICAL SOCIETY
ΚΥΠΡΙΑΚΗ ΜΑΘΗΜΑΤΙΚΗ ΕΤΑΙΡΕΙΑ
Nicosia - Cyprus

Editor
Gregoris Makrides

MEDITERRANEAN JOURNAL FOR

RESEARCH IN MATHEMATICS EDUCATION

Volume 20. 2024

CONTENTS

Mediterranean Journal for
Research in Mathematics Education
Vol. 20, 2024

Beyond Tradition: Fostering Creative Thinking Through Non-Standard Problems and Mathematics Competitions

Applebaum, Mark
Kaye Academic College of Education, Azri'el Nitsani St 6, Be'er Sheva, 8414201, Israel, mark@kaye.ac.il
https://orcid.org/0000-0002-1131-6188

Lambrou, Michael
University of Crete, Athina Palace, 713 00, Iraklio, Greece, lambrou@uoc.gr

Corresponding author: Mark Applebaum, Ein Saharonim, 14, Lehavim, 85338, Israel, +972546400722, mark@kaye.ac.il

Author contributions: Applebaum, M., & Lambrou, M. Both authors approved the final version of the article.
Declarations: The authors declare that there are no conflicts of interest regarding the publication of this paper. All research was conducted following ethical standards for the discipline.
Data availability and sharing policy: The approach used in this paper ensures compliance with the journal's data-sharing policies, promotes transparency, and facilitates the replication and verification of our research findings by others in the field.

ABSTRACT: *After a brief introduction to the value of Mathematics and the approach adopted in classical times, we discuss issues related to the benefits of teaching Mathematics via attractive, non-standard problems. The necessity of creative thinking skills in the 21st Century and its value to society is highlighted, aligning with the aims of STEM and PISA. We argue that non-standard but elegant problems, ranging from tractable to challenging, are useful tools for developing creative thinking. We then focus on the Kangaroo Mathematical Contest, presenting examples of Kangaroo tasks and discussing how they support the development of creative thinking. Suggestions for improving mathematical curricula and teaching perspectives are summarized.*

Key words: *Creative thinking, History of Mathematics, Math competitions*

Introduction

The central theme of this paper is the enhancement of Mathematics teaching through engaging non-standard problems. This requires an understanding of historical perspectives, focusing on how the concept and teaching of Mathematics have evolved. This section delves into Plato's (427 – 348 B.C.) contributions to mathematical thought and education, providing a deeper understanding of his influence and relevance today.

Plato, one of the most influential philosophers of classical Greece, had profound views on the role and value of Mathematics in education. His philosophy emphasized that Mathematics was not merely a collection of technical skills but a crucial discipline for training the mind in logical and structured thinking (Plato, 1991).

Plato founded the Academy in Athens, the first institution of higher learning in the Western world. At the entrance of the Academy, an inscription famously read, "Let no one destitute of Geometry enter my doors" (Plato, 2002). This inscription highlights Plato's fundamental importance on Geometry and, by extension, on Mathematics. For Plato, Geometry was about practical knowledge and cultivating a disciplined mind capable of abstract thought and logical reasoning (Barrow, 2012).

In his dialogues, particularly "The Republic," Plato outlines his vision of education to achieve the highest forms of knowledge and understanding. He argues that Mathematics, with its emphasis on deductive reasoning and abstract thinking, is essential for training philosophers and future leaders (Plato, 2000). According to Plato, the study of Mathematics helps individuals ascend from the world of sensory perception to the realm of intellectual understanding, ultimately leading to the apprehension of the Forms, the highest and most perfect realities (Plato, 1997).

Plato's educational framework, as detailed in "The Republic," consists of a rigorous curriculum designed to develop the intellect and character of students. Mathematics holds a central place in this curriculum, starting with *Arithmetic* and progressing through *Geometry*, *Astronomy*, and *Harmonics*. Each of these disciplines contributes to the development of reason and the ability to think abstractly (Plato, 2000).

- *Arithmetic*. Plato believed that the study of numbers and their properties was fundamental to the development of logical thinking. Arithmetic trains the mind to recognize patterns and relationships, fostering an understanding of the abstract principles underlying the physical world (Plato, 2000).
- *Geometry*. For Plato, Geometry was the study of eternal truths. It allows students to grasp the concept of ideal forms, such as perfect circles and triangles, which exist only in the realm of thought. This understanding helps students appreciate the difference between the imperfect physical world and the perfect world of ideas (Plato, 2000).
- *Astronomy*. Plato viewed Astronomy as the application of Geometry to the heavens. Studying the movements of celestial bodies through mathematical principles encourages students to think about the cosmos systematically and rationally (Plato, 2000).
- *Harmonics*. The study of Harmonics, or the mathematical principles of musical harmony, integrates numerical ratios with sensory experience. Plato believed that understanding the mathematical basis of music could enhance one's appreciation of beauty and order (Plato, 2000).

Plato’s pedagogical approach emphasized the importance of engaging students in a manner that stimulates their curiosity and intellectual growth. In "The Laws," he suggests that Greek children should playfully learn Arithmetic, like the methods used in Egypt, where children engaged in Arithmetical games for amusement (Plato, 1999). This approach aligns with modern educational theories that advocate for learning through play and discovery, particularly in early childhood education.

Plato's dialogues also highlight the Socratic method of teaching, which involves asking probing questions to stimulate critical thinking and illuminate ideas. This method encourages students to think deeply and independently, fostering an environment where they can explore and understand complex concepts (Plato, 1997).

Plato's influence on the teaching and understanding of Mathematics extended well beyond his time. His emphasis on the abstract, logical, and philosophical dimensions of Mathematics laid the groundwork for future generations of mathematicians and philosophers. The Academy continued to be a center of mathematical thought, producing notable scholars such as Eudoxus and contributing to the development of mathematical theories (Barrow, 2012).

The Platonic tradition also influenced later educational frameworks, including the Quadrivium in Medieval Western education, which consisted of Arithmetic, Geometry, Astronomy, and Music. This tradition underscored the belief that a well-rounded education must include rigorous training in Mathematics to cultivate rational and philosophical thinking (Barrow, 2012).

Plato's ideas about the value of Mathematics and its role in education remain relevant in contemporary discussions about educational reform and pedagogy. The emphasis on critical thinking, logical reasoning, and the exploration of abstract concepts continues to resonate with educators seeking to develop these skills in students (Barrow, 2012).

Innovative teaching methodologies, such as inquiry-based learning and problem-based learning, reflect Platonic principles by encouraging students to engage deeply with mathematical concepts and to approach problems creatively and thoughtfully (Gravemeijer, 2007). The integration of historical perspectives, such as those of Plato, into modern curricula can provide students with a richer understanding of Mathematics and its enduring significance (Barrow, 2012).

Plato's contributions to the philosophy of Mathematics and education highlight the profound and lasting value of mathematical study. His belief in the importance of Mathematics for developing logical and abstract thinking continues to influence educational practices today. By drawing on Plato's insights, educators can inspire students to appreciate the beauty and rigor of Mathematics, fostering a lifelong love for the discipline and preparing them for the intellectual challenges of the future.

Creative Thinking in Mathematics Education

Creativity is increasingly recognized as a vital competency for the 21st century, especially in education. This chapter explores the importance of fostering creative thinking within the context of mathematics education, delving into contemporary theories, definitions, and methodologies that emphasize creativity as a core component of effective teaching and learning.

Creativity is crucial for developing innovative solutions and adapting to new and complex problems. As societies and technologies evolve, the ability to think creatively is essential for personal, academic, and professional success (Puccio, 2017; Thijs et al., 2014). The integration of creativity into education aligns with modern perspectives on learning, which emphasize active knowledge construction, deeper understanding, and the ability to function effectively within various contexts (Oosterheert & Meijer, 2017).

In mathematics education, fostering creativity involves encouraging students to approach problems in novel ways, explore multiple solutions, and engage deeply with mathematical concepts. This shift from traditional rote learning to a more dynamic, problem-solving approach requires innovative teaching strategies and a supportive learning environment.

Creativity in mathematics has been the subject of extensive research, resulting in diverse definitions and interpretations. Despite this diversity, common themes include problem-solving, the generation of new ideas, and the ability to view problems from different perspectives.

Ervynck's Model of Mathematical Creativity: Ervynck (1991) outlines mathematical creativity through stages of engagement with mathematical ideas. The preliminary technical stage involves learning standard procedures and techniques. The algorithmic activity stage involves applying these techniques to solve problems. The creative activity stage represents the highest level of engagement, where students generate original ideas and solutions.

Poincaré's Four-Stage Process: Poincaré (1948) describes the creative process in four stages: preparation, incubation, illumination, and verification. This model highlights the nonlinear and iterative nature of creativity, emphasizing the importance of both conscious and subconscious processes in generating new insights.

Liljedahl and Sriraman (2006) distinguish between professional creativity, which involves extending mathematical knowledge or opening new questions, and educational creativity, which may involve novel solutions or new perspectives on existing problems. This distinction recognizes the different expectations and outcomes at each level.

The PISA framework introduces creative thinking as a competence that involves the generation, evaluation, and improvement of ideas. This framework emphasizes the practical application of creativity in solving problems and advancing knowledge.

The Role of Creativity in Problem Solving

Creative problem-solving is essential for tackling non-routine and complex mathematical problems. As Polya (1954) suggests, the work of a student solving a difficult problem is akin to the creative work of an inventor. This comparison underscores the importance of challenging students with problems that require innovative thinking and the application of diverse strategies.

Creativity in mathematics involves divergent thinking, the ability to generate multiple solutions and view problems from various angles. This contrasts with convergent thinking, which focuses on finding a single correct solution. Encouraging divergent thinking helps students develop flexibility and adaptability in their problem-solving approaches.

Polya (1954) emphasizes heuristic problem-solving, where students use general strategies and principles to explore and solve problems. This approach fosters creativity by encouraging students to think beyond standard procedures and develop their own methods.

Krutetskii (1976) highlights the importance of abstraction and generalization in mathematical creativity. These skills enable students to identify underlying patterns and principles, which can be applied to a wide range of problems. Developing these skills requires engaging with complex and non-routine problems that challenge students to think deeply and creatively.

Fostering Creativity in the Classroom

To cultivate creativity in mathematics education, teachers must create a supportive and stimulating learning environment. This involves adopting teaching strategies that encourage exploration, experimentation, and the generation of new ideas (Sawyer, 2006) .

Inquiry-based learning involves posing questions, problems, or scenarios rather than presenting facts. This approach encourages students to investigate, explore, and construct their understanding of mathematical concepts (Hmelo-Silver et al., 2007). Inquiry-based learning fosters creativity by allowing students to take ownership of their learning process and develop their problem-solving skills (Prince & Felder, 2007).

Problem-based learning (PBL) centers around real-world problems that require students to apply mathematical concepts and skills. PBL encourages collaboration, critical thinking, and creative problem-solving, as students work together to find solutions to complex and open-ended problems (Savery, 2006). This approach aligns with the need to develop students' ability to think creatively and apply their knowledge in practical contexts (Hmelo-Silver, 2004).

Collaborative learning activities, such as group projects and discussions, provide opportunities for students to share ideas, challenge each other's thinking, and develop new perspectives. Collaboration fosters creativity by exposing students to diverse viewpoints and encouraging them to build on each other's ideas (Johnson & Johnson, 2009). Such interactions help students refine their thoughts and approach problems from different angles (Gillies, 2016).

Incorporating non-routine problems into the curriculum is essential for developing creative thinking. These problems require students to apply their knowledge in novel ways and explore multiple solution paths (Silver, 1997) . Teachers should select appropriately challenging problems and provide opportunities for creative exploration (Leikin, 2009).

Developing a growth mindset, the belief that abilities can be developed through effort and perseverance, is crucial for fostering creativity (Dweck, 2006). Teachers can promote a growth mindset by praising effort, encouraging risk-taking, and framing challenges as opportunities for growth and learning (Dweck, 2010). This approach helps students see mistakes as part of the learning process and motivates them to persist in the face of difficulties (Boaler, 2013).

The Kangaroo Contest

The Kangaroo Mathematics Contest is an international competition that stands out for its inclusive and engaging approach to mathematics. Unlike traditional contests that often focus on identifying exceptionally gifted students, the Kangaroo Contest aims to inspire a broad range of participants, encouraging mathematical curiosity and creativity among students of all abilities and playing a significant role in fostering creativity. These competitions challenge students with non-routine problems that require creative and critical thinking. Participating in competitions helps students develop resilience, perseverance, and a love for mathematics.

The Kangaroo Contest was founded in 1991 by André Deledicq, a French mathematics teacher inspired by the success of Australian mathematics competitions. The contest quickly gained popularity in Europe and beyond, growing to include millions of participants from over 100 countries. The name "Kangaroo" pays homage to the Australian origins of the competition format.

The contest's philosophy is rooted in the belief that mathematics should be accessible, enjoyable, and stimulating for all students. By offering a wide range of problems that vary in difficulty, the Kangaroo Contest aims to demystify mathematics and show that it is not just for a select few but can be appreciated and enjoyed by everyone. This inclusive approach helps to break down the barriers that often make mathematics seem intimidating or inaccessible (Bicknell, 2008).

The Kangaroo Contest is structured as a multiple-choice test with problems arranged in increasing order of difficulty. The problems are carefully selected and categorized during an annual assembly of national representatives, ensuring a diverse and balanced set of challenges.

The problems are divided into categories based on difficulty: easy, medium, and hard. This progression allows students to build confidence as they solve simpler problems before tackling more challenging ones. The Kangaroo Contest includes a range of problems, encouraging students to engage with mathematics at their level. This diversity helps students build confidence and develop their problem-solving skills incrementally. By providing opportunities for all students to participate, competitions can inspire a broader interest in mathematics and creativity.

Many Kangaroo problems involve real-world scenarios, making mathematics relevant and engaging for students. These problems demonstrate the practical applications of mathematical creativity and encourage students to think about how they can use their skills in everyday life.

The contest is organized into different age groups, from primary school students to high school seniors. This ensures that the problems are age-appropriate and relevant to the participants' level of mathematical understanding.

The scoring system is designed to discourage random guessing. Correct answers are rewarded with points, while incorrect answers result in penalties. However, there is also a system of bonus points to ensure that students do not end up with negative scores. This encourages careful thinking and strategic problem-solving.

Creativity in mathematics education is essential for preparing students to navigate an increasingly complex and dynamic world (Sawyer, 2006). By fostering creative thinking through innovative teaching strategies, supportive learning environments, and engaging problem-solving activities such as the Kangaroo contest, educators can help students develop the skills and mindset needed for success in mathematics and beyond. Incorporating historical perspectives, such as those of Plato, and modern frameworks, like PISA, provides a rich foundation for understanding and nurturing mathematical creativity (Sriraman, 2004).

The Kangaroo Contest is designed to foster creativity and problem-solving skills in several ways:

- By presenting a variety of problem types, the contest encourages students to apply different strategies and think outside the box. This diversity helps develop flexible thinking and adaptability.
- Many problems are set in real-world contexts, making mathematics relevant and engaging. This approach helps students see the practical applications of mathematical concepts and encourages them to explore how mathematics relates to their everyday lives.
- The contest's structure, with problems of increasing difficulty, helps build perseverance. Students learn to tackle challenging problems step by step, developing resilience and confidence in their problem-solving abilities.
- By allowing all interested students to participate, the Kangaroo Contest promotes a positive attitude towards mathematics. This inclusivity helps to reduce anxiety and build a supportive community of learners.

Participating in the Kangaroo Contest has a significant impact on students' attitudes towards mathematics and their development of creative thinking skills. Research and anecdotal evidence suggest several benefits.

- Students who participate in the Kangaroo Contest often report higher levels of engagement and interest in mathematics. The contest's fun and challenging problems help to spark curiosity and excitement about the subject.
- The diverse and non-routine problems presented in the contest help students develop their problem-solving skills. They learn to approach problems from different angles, use creative strategies, and think critically.
- Successfully solving problems in the Kangaroo Contest boosts students' confidence in their mathematical abilities. This increased self-efficacy can lead to greater participation in mathematics classes and further academic pursuits.
- The contest encourages a growth mindset by rewarding effort and strategic thinking. Students learn that perseverance and hard work are key to overcoming challenges and achieving success.

The Kangaroo Contest provides valuable resources for teachers and educators. The problems and solutions from past contests are made available, offering a rich repository of materials for classroom use. Teachers can incorporate these problems into their lessons to enhance students' learning experiences and promote creative thinking.

Teachers can use Kangaroo problems as part of their regular curriculum to introduce non-routine problem-solving activities. These problems can be used for group work, individual practice, or as part of math clubs and enrichment programs.
The contest also offers professional development opportunities for teachers, helping them to develop strategies for fostering creativity and problem-solving skills in their students. Workshops and training sessions provide educators with tools and techniques for effectively integrating these approaches into their teaching.
The Kangaroo Mathematics Contest exemplifies how mathematical competitions can be more than just a means to identify talent. By fostering a love for mathematics among a diverse student population, the contest promotes creative thinking, problem-solving skills, and a positive attitude
toward the subject. Through its inclusive and engaging format, the Kangaroo Contest demonstrates that mathematics can be both enjoyable and intellectually stimulating, encouraging students to explore, think critically, and embrace the challenges and joys of mathematical problem-solving.
The success of the Kangaroo Contest highlights the importance of innovative and inclusive approaches to mathematics education. By providing opportunities for all students to engage with creative and challenging problems, the contest helps to cultivate a generation of learners who are not only proficient in mathematics but also enthusiastic and confident in their abilities. As educators, it is essential to continue supporting and expanding such initiatives, ensuring that all students could experience the beauty and power of mathematics.

Examples of Kangaroo Contest Tasks

Example 1:

The problems presented in the Kangaroo Contest are known for their creativity and ingenuity. They often involve real-world scenarios, puzzles, and games that require logical reasoning and inventive solutions. Below are a few examples of problems from past Kangaroo contests, a short discussion about the qualities of such non-standard problems, and an analysis of these tasks according to different definitions of creativity.

Grades 1-2 (2021): Four identical pieces of paper are placed as shown. Michael wants to punch a hole that goes through all four pieces. At which point should Michael punch the hole?

(A) A (B) B (C) C (D) D (E) E

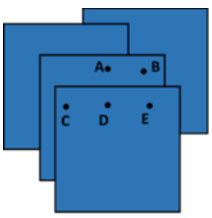


Figure 1. Four pieces and one hole

Example 2:

This problem involves spatial reasoning and visualization, requiring students to mentally manipulate the pieces of paper to determine the correct point. Unlike standard problems that may involve direct computation or simple geometry, this one challenges students to visualize the overlap of multiple layers, a skill not typically addressed in basic arithmetic or early geometry lessons.

Grades 3-4 (2019): The weight of a toy dog is a whole number. How much does one toy dog weigh?

(A) 8 kg (B) 9 kg (C) 10 kg (D) 11 kg (E) 12 kg

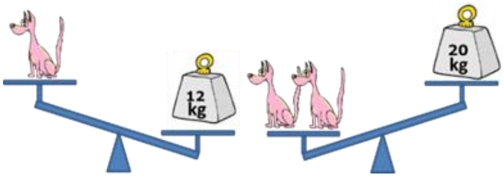


Figure 2. A dog weighting

Example 3:

This problem involves logical deduction and requires students to think critically about the information given. It's not a straightforward arithmetic calculation but requires interpreting the problem's constraints and possibly using trial and error or other logical strategies to find the correct answer. This deviates from routine problems where the procedure is usually direct and predictable.

Grades 5-6 (2020): A dog and a cat walk in the park along the path marked by the thick black line. The dog starts from P at the same time as the cat starts from Q. The dog walks three times as fast as the cat. At which point do they meet?

(A) at A (B) at B (C) at C (D) at D (E) at E

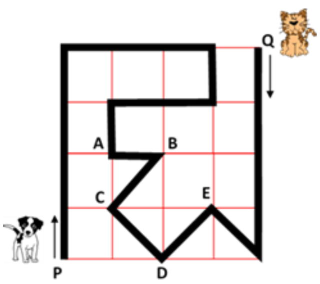


Figure 3. A dog meets a cat

Example 4:

This problem involves understanding ratios and speed and requires students to apply these concepts to a real-world scenario. It's non-standard because it combines different mathematical concepts and asks students to visualize and calculate the movements of both animals simultaneously. Such integration of multiple concepts and the need for visualization is not typical in standard textbook problems.

Grades 7-8 (2022): Several numbers were written on a piece of paper. The sum of these numbers was 22. The teacher deleted each number and replaced it with its difference from 7. The sum of the new numbers was 34. How many numbers were written on the paper initially?

(A) 7 (B) 8 (C) 9 (D) 10 (E) 11

Example 5:

This problem involves algebraic reasoning and understanding of operations. It requires students to set up and solve an equation based on the transformation of numbers. This kind of problem is non-standard because it goes beyond basic arithmetic operations, requiring a deeper understanding of algebraic relationships and manipulation of equations, which is not typically found in routine practice problems.

Grades 9-10 (2019): A graph consists of 16 vertices and some edges that connect them as in the picture. An ant is now at the vertex labelled A. At each move, it can walk from one vertex to any neighbouring vertex crawling along a connecting edge. At which of the vertices labelled: P Q R S T can the ant be after 2019 moves?

(A) only P, R or S, not Q and T (B) only P, R, S or T, not Q (C) only Q

(D) only T (E) all of these are possible

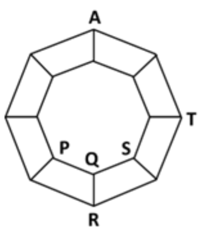


Figure 4. Find the ant

Example 6:

This problem challenges students' understanding of graph theory and combinatorics. It involves complex movement and counting principles over many iterations (2019 moves). Unlike standard problems which might focus on simpler graph traversal or counting, this one requires deep thinking about the graph's properties and the ant's behavior over many moves.

Grades 11-12 (2021): A large square is divided into smaller squares as shown. A shaded circle is inscribed inside each of the smaller squares. What proportion of the area of the large square is shaded?

(A) $8\pi/9$ (B) $13\pi/16$ (C) $3/\pi$ (D) $3/4$ (E) $\pi/4$

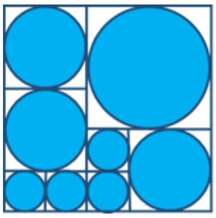


Figure 5. Eight circles

This problem involves geometric reasoning and area calculations. It requires students to understand the relationship between the areas of the circles and the squares and to compute proportions. It's non-standard because it combines geometry with fractional and proportional reasoning and requires students to apply these concepts in a non-routine way to solve the problem.
Now we illustrate how the presented problems connect to the presented definitions of creativity, as defined by the theoretical frameworks discussed in the paper.

Stages of *Ervynck's Model of Mathematical Creativity are the preliminary* technical stage, algorithmic activity stage, and creative activity stage.

Grades 1-2 (2021): Spatial reasoning and visualization problem
This problem moves students from the preliminary technical stage, where they might simply recognize shapes, to the creative activity stage, where they must visualize and manipulate objects mentally to find the solution. This progression fosters creative thinking as students must go beyond routine recognition to creative manipulation.

Grades 9-10 (2019): Graph theory and combinatorics problem
Initially, students use their technical knowledge of graphs (preliminary stage), then apply algorithmic activity to navigate through the graph, and finally engage in creative activity by devising strategies for predicting the ant's position after 2019 moves. This deep engagement with the problem exemplifies the transition through Ervynck's stages.

Poincaré's Four-Stages Process are: preparation, incubation, illumination, and verification

Grades 3-4 (2019): Logical deduction problem involving weights
Students prepare by understanding the problem and reviewing relevant concepts. During incubation, they might subconsciously explore possible solutions. The moment of illumination occurs when they identify the correct logical steps, and verification is achieved by checking their solution against the problem's conditions. This process encapsulates Poincaré's stages of creative thinking.

Grades 5-6 (2020): Ratio and speed problem with a dog and a cat
Preparation involves understanding the ratio and speed concepts. Incubation allows students to ponder how these concepts apply to the paths taken by the dog and the cat. Illumination occurs when they realize the intersection point, and verification comes from calculating the exact meeting point, demonstrating the full cycle of creative problem-solving.

Liljedahl and Sriraman's Educational and Professional Creativity

Educational creativity involves novel solutions or new perspectives on existing problems, while professional creativity extends mathematical knowledge or opens new questions.

Grades 7-8 (2022): Algebraic reasoning problem with sums and differences
This problem engages educational creativity as students find novel solutions to understand the transformation from the original numbers to their differences from 7. By doing so, they apply algebraic reasoning in innovative ways, aligning with the definition of educational creativity.

Grades 11-12 (2021): Geometric reasoning problem with shaded areas
Students employ educational creativity by using geometric principles to determine the proportion of the shaded area. This requires them to apply their knowledge in new ways, finding unique solutions to a non-routine problem, fitting the definition of educational creativity.

The PISA 2021 Framework includes the generation, evaluation, and improvement of ideas.

Grades 1-2 (2021): Spatial reasoning and visualization problem
Students generate ideas by visualizing different punch points, evaluate these by considering which would intersect all pieces, and improve their strategies by re-visualizing until they find the optimal solution. This iterative process aligns with PISA's framework of creative thinking competence.

Grades 9-10 (2019): Graph theory and combinatorics problem
The process of predicting the ant's position involves generating possible paths, evaluating the likelihood of each, and improving their strategies by considering different combinations. This comprehensive engagement reflects the generation, evaluation, and improvement aspects of creative thinking as defined by PISA.

Each of the presented Kangaroo problems aligns with the different definitions of creativity by requiring students to engage in higher-order thinking, move beyond routine procedures, and develop innovative solutions. Whether through visualization, logical deduction, algebraic reasoning, or geometric calculations, these problems foster the critical aspects of creativity discussed in the theoretical frameworks. This connection underscores the value of non-routine problems in enhancing creative thinking and problem-solving skills in mathematics education.

From Plato's Ideas to the Kangaroo Contest tasks

Plato's educational philosophy, particularly his emphasis on the abstract and logical dimensions of Mathematics, provides a foundational context for understanding the value of the presented problems in fostering creative thinking. Plato believed that education should cultivate the mind's ability to engage with abstract concepts and develop logical reasoning skills. His methods, which included structured learning complemented by playful and engaging activities, remain highly relevant in contemporary mathematics education.
Plato's focus on Geometry to train the mind in logical reasoning is evident in the problems designed for the Kangaroo Contest. For instance, the problem for Grades 1-2 (2021) that involves spatial reasoning and visualization echoes Plato's use of geometric principles to foster abstract thinking.
By asking students to determine where to punch a hole to intersect all pieces of paper, the problem encourages them to visualize and manipulate shapes mentally, developing their capacity for geometric abstraction and logical deduction.
Plato's advocacy for learning through inquiry and exploration is reflected in the problem for Grades 5-6 (2020) involving the dog and cat moving at different speeds. This problem requires students to explore the relationship between distance, speed, and time, engaging in an inquiry-based approach to find where the two animals meet. This process mirrors Plato's Socratic method of questioning and exploration, encouraging students to actively engage with mathematical concepts and discover solutions through critical thinking and reasoning.
The problems presented in the Kangaroo Contest also align with Plato's belief in making learning relevant and engaging. The real-world context of the problem for Grades 9-10 (2019), which involves graph theory and combinatorics to predict the ant's position, demonstrates how abstract mathematical concepts can be applied to practical situations. This not only makes mathematics more relatable for students but also underscores the importance of developing logical reasoning skills that can be transferred to various real-world scenarios.

Plato emphasized the importance of logical reasoning as a cornerstone of intellectual development. The algebraic reasoning problem for Grades 7-8 (2022), which requires students to deduce the number of original numbers based on their transformed sums, directly engages students in the type of logical deduction that Plato valued. By challenging students to think critically and logically, this problem fosters the development of reasoning skills that are essential for deeper mathematical understanding.

Plato’s educational methods were designed to inspire a lifelong love of learning and intellectual curiosity. The inclusive and engaging format of the Kangaroo Contest, which allows all interested students to participate and tackles problems of varying difficulty, promotes a growth mindset. Students are encouraged to view challenges as opportunities for growth, reflecting Plato's belief in the transformative power of education to develop resilient and curious minds.

By incorporating problems that require spatial reasoning, logical deduction, exploration of real-world contexts, and critical thinking, the Kangaroo Contest embodies Plato's educational ideals. These problems not only develop students’ mathematical skills but also foster the abstract thought and logical reasoning that Plato championed. Through this approach, the contest aligns with Plato's vision of education to cultivate the mind's ability to engage with complex concepts and develop a lifelong love for learning.

Discussion and Conclusion

The journey through the historical context of mathematics, the importance of creative thinking in mathematics education, and the specific case of the Kangaroo Contest reveals a coherent narrative: Mathematics, traditionally perceived as a rigid and challenging discipline, can be transformed into an engaging and stimulating field of study through innovative teaching methods and inclusive competitions.

Connecting Historical Perspectives to Modern Education

Plato’s educational philosophy, with its emphasis on the abstract and logical dimensions of Mathematics, underscores the timeless value of the discipline. His approach to teaching, advocating for structured learning complemented by playful and engaging methods, remains highly relevant. The emphasis on Geometry at Plato’s Academy and the Socratic method of inquiry reflects a deep understanding of the role of critical thinking and structured problem-solving in intellectual development (Plato, 1991). By integrating these historical perspectives into contemporary education, we can foster a richer and more meaningful engagement with Mathematics (Barrow, 2012).

Modern educational theories and practices, as discussed in the chapter on creative thinking in Mathematics education, echo Plato’s insights. The shift from rote memorization to active problem-solving and knowledge construction aligns with the ancient emphasis on inquiry and exploration (Gravemeijer, 2007). Creativity, defined through diverse frameworks, is recognized as essential for effective problem-solving and adapting to new challenges (Sriraman, 2004). This alignment suggests that drawing on historical wisdom can inform and enhance modern pedagogical strategies. Plato's approach, particularly his advocacy for learning through inquiry and exploration, aligns with contemporary methods like inquiry-based and problem-based learning (Oosterheert & Meijer, 2017; Gravemeijer, 2007). The use of non-routine problems, as exemplified by the Kangaroo Contest, provides a practical and effective means of fostering these skills in students.

The Role of Non-Routine Problems

Non-routine problems, as highlighted throughout the paper, are crucial for developing creative thinking and problem-solving skills. These problems require students to apply their knowledge in novel ways, fostering a deeper understanding and appreciation of mathematical concepts (Ervynck, 1991). The Kangaroo Contest exemplifies this approach, presenting problems that are accessible yet challenging, and that encourage diverse strategies and innovative thinking.

For example, the problem for Grades 1-2 (2021) that involves spatial reasoning and visualization is non-standard because it challenges students to think about geometry in a practical, hands-on way. Such problems develop students' ability to visualize and manipulate objects mentally, a key skill in mathematical thinking (Battista, 2007). Similarly, the problem for Grades 9-10 (2019) involving graph theory and combinatorics goes beyond routine graph traversal exercises, requiring deep understanding and strategic thinking, illustrating the value of complex, non-routine problems in education (Yazgan, 2015). The structure and philosophy of the Kangaroo Contest demonstrate the effectiveness of non-routine problems in engaging a wide range of students. By offering problems that vary in difficulty and cover real-world scenarios, the contest makes Mathematics relevant and exciting (Clark, 2009). This approach not only helps to demystify Mathematics but also promotes a positive attitude towards the subject, encouraging students to explore and enjoy the challenges it presents (Bicknell, 2008).

Impact on Students and Educational Practices

The impact of the Kangaroo Contest on students underscores the importance of inclusive and engaging approaches to Mathematics education. Students who participate in the contest report increased engagement, improved problem-solving skills, and enhanced confidence in their mathematical abilities. These outcomes highlight the potential of competitions and non-routine problems to transform students' perceptions of Mathematics and inspire a lifelong love for the subject (Beghetto, 2010). The fun and challenging problems help to spark curiosity and excitement about the subject, fostering a lifelong love for Mathematics (Barbot et al., 2016; Plucker et al., 2004).

Furthermore, the contest provides valuable resources and support for teachers, helping them to integrate creative problem-solving activities into their curriculum (Oosterheert & Meijer, 2017). By incorporating Kangaroo problems and similar tasks, educators can create a more dynamic and stimulating learning environment that nurtures creativity and critical thinking (Sternberg, 2007).

The inclusive nature of the Kangaroo Contest, which allows all interested students to participate, promotes a positive and supportive community of learners. This inclusivity helps reduce anxiety and build confidence, encouraging students to view Mathematics as an accessible and enjoyable field of study (Spencer & Lucas, 2018). This is crucial for developing a growth mindset, where students believe that their abilities can improve with effort and perseverance (Dweck, 2006). Moreover, these competitions help students develop resilience, perseverance, and a growth mindset.

Educators play a crucial role in this process. By integrating historical perspectives, fostering creative problem-solving, and leveraging inclusive competitions, educators can create a dynamic and stimulating learning environment.

In conclusion, to inspire a lifelong love for Mathematics, educators must highlight its beauty, creativity, and relevance. Drawing on historical wisdom, such as Plato's educational philosophy, can provide a rich foundation for modern teaching practices. Fostering creative problem-solving through non-routine problems and competitions like the Kangaroo Contest can make Mathematics an exciting and integral part of education. This approach not only cultivates critical thinking and innovation but also prepares students for the intellectual challenges of the future. Through supportive learning environments and innovative teaching methods, we can equip students with the creative prowess needed to excel in both their academic and future professional lives, ensuring that they view Mathematics not just as a subject but as a fascinating lens through which to understand and navigate the world.

References

Barbot, B., Besançon, M., & Lubart, T. (2016). The generality-specificity of creativity: Exploring the structure of creative potential with EPoC. *Learning and Individual Differences*, *52*, 178-187.

Barrow, R. (2012). Plato, utilitarianism and education. *Educational Philosophy and Theory*, *44*(8), 793-805.

Battista, M. T. (2007). The development of geometric and spatial thinking. In F. K. Lester Jr. (Ed.), *Second handbook of research on mathematics teaching and learning* (pp. 843-908). Information Age Publishing.

Beghetto, R. A. (2010). Creativity in the classroom. In J. C. Kaufman & R. J. Sternberg (Eds.), *The Cambridge handbook of creativity* (pp. 447-463). Cambridge University Press.

Bicknell, B. (2008). Gifted students and the role of mathematics competitions. *Australian Primary Mathematics Classroom*, *13*(4), 16-20.

Boaler, J. (2013). *Ability and Mathematics: The Mindset Revolution that is Reshaping Education*. Forum, 55(1), 143-152.

Clark, A. (2009). Problem Solving in Singapore Math. Houghton Mifflin Harcourt Publisher. Retrieved from http://storage.cloversites.com

Dweck, C. S. (2006). *Mindset: The new psychology of success*. Random House.

Dweck, C. S. (2010). *Even geniuses work hard. Educational Leadership*, *68*(1), 16-20.

Ervynck, G. (1991). Mathematical creativity. In D. Tall (Ed.), *Advanced mathematical thinking* (pp. 42–52). Kluwer Academic Publishers.

Gillies, R. M. (2016). Cooperative Learning: Review of Research and Practice. *Australian Journal of Teacher Education*, *41*(3), 39-54.

Gravemeijer, K. (2007). Emergent modeling as a precursor to mathematical modeling. In W. Blum, P. L. Galbraith, H.-W. Henn, & M. Niss (Eds.), *Modelling and applications in mathematics education: The 14th ICMI study* (pp. 137-144). Springer US.

Hmelo-Silver, C. E. (2004). Problem-based learning: What and how do students learn*?* *Educational Psychology Review, 16*(3), 235-266.

Hmelo-Silver, C. E., Duncan, R. G., & Chinn, C. A. (2007). Scaffolding and achievement in problem-based and inquiry learning: A response to Kirschner, Sweller, and Clark (2006). *Educational Psychologist*, *42*(2), 99-107.

Johnson, D. W., & Johnson, R. T. (2009). An educational psychology success story: Social interdependence theory and cooperative learning. *Educational Researcher, 38*(5), 365-379.

Krutetskii, V. A. (1976). *The Psychology of Mathematical Abilities in School Children* (J. Teller (Trans.), J. Kilpatrick (Ed.)) Chicago, IL: University of Chicago.

Leikin, R. (2009). Exploring mathematical creativity using multiple solution tasks. In R. Leikin, A. Berman, & B. Koichu (Eds.), *Creativity in mathematics and the education of gifted students* (pp. 129-145). Brill.

Liljedahl, P., & Sriraman, B. (2006). Musings on mathematical creativity. *For the Learning of Mathematics, 26*(1), 20-23.

Oosterheert, I. E., & Meijer, P. C. (2017). What it takes to cultivate creativity in education. *Pedagogische Studiën, 94*, 196–210.
Plato. (1991). *The Republic* (2nd ed., translated by Allan Bloom). Basic Books.
Plato. (1997). *Plato: Complete Works* (edited by John M. Cooper). Hackett Publishing.
Plato. (1999). *The Laws* (translated by Trevor J. Saunders). Penguin Classics.
Plato. (2000). *The Republic* (translated by Benjamin Jowett). Dover Publications.
Plato. (2002). *The Dialogues of Plato* (translated by Benjamin Jowett). Cosimo Classics.
Plucker, J. A., Beghetto, R. A., & Dow, G. T. (2004). Why isn't creativity more important to educational psychologists? Potentials, pitfalls, and future directions in creativity research. *Educational Psychologist, 39*(2), 83-96.
Poincaré, H. (1948). *Science and method*. New York: Dover.
Polya, G. (1954). *Mathematics and plausible reasoning: Induction and analogy in mathematics* (Vol. II). Princeton, NJ: Princeton University Press.
Prince, M. J., & Felder, R. M. (2007). The many faces of inductive teaching and learning. *Journal of College Science Teaching*, 36(5), 14-20.
Puccio, G. J. (2017). From the dawn of humanity to the 21st century: Creativity as an enduring survival skill. *The Journal of Creative Behavior, 51*(4), 330-334.
Savery, J. R. (2006). Overview of problem-based learning: Definitions and distinctions. *Interdisciplinary Journal of Problem-based Learning, 1*(1), 9-20.
Sawyer, R. K. (Ed.). (2006). *The Cambridge handbook of the learning sciences*. Cambridge University Press.
Silver, E. A. (1997). Fostering creativity through instruction rich in mathematical problem solving and problem posing. *ZDM, 29*(3), 75-80.
Spencer, E., & Lucas, B. (2018). Understanding the role of creative self-efficacy in youth social action. *University of Winchester*.
Sriraman, B. (2004). The characteristics of mathematical creativity. *The Mathematics Educator, 14*(1), 19–34.
Sternberg, R. (2007). Creativity as a habit. In A.-G. Tan (Ed.), *Creativity. A handbook for teachers* (pp. 3–25). World Scientific Publishing.
Thijs, A., Fisser, P., & van der Hoeven, M. (2014). 21e eeuwse vaardigheden in het curriculum van het funderend onderwijs. *Enschede: SLO*.
Yazgan, Y. (2015). Sixth graders and non-routine problems: Which strategies are decisive for success? *Educational Research and Reviews, 10*(13), 1807-1816.

Mediterranean Journal for Research in Mathematics Education
Vol. 20, 2024

The development of a STEAME Competence Framework for Teacher Facilitators as part of a STEAME ecosystem for school education

Editors: *Thomas Economou (Doukas School), Silvia Alcaraz Dominguez (University of Barcelona), Elpiniki Margariti (Doukas School) and partners*

Authors: STEAME Academy project participants (www.steame-academy.eu)

Introduction

In contrast to the stationary, slow-evolving, teacher-centered school teaching approach of the past decades, technology and the common perception of the desired skillset of the 21st century world citizen, have both played a major role in transforming the education scene. STEM and STEAM (Science – Technology – Engineering – Mathematics) education have been in the spotlight due to the nature of their existence and the way they were developed, aiming from the get-go to meet the needs of the labor market by supporting students to develop a set of skills and competences that are aligned with what is missing or is valuable to the world of business. STEM/STEAM aims to engage students in project-based interdisciplinary learning activities to acquire and develop knowledge and skills related to the achievement of learning objectives deriving from two or more subjects (e.g., math, science, technology, etc.). Recently, STEAME education emerged adding the last -E which stands for Entrepreneurship, aiming, among others, to further bridge the gap between school education and the industries. The aim of this paper is to explore STEAME education, identify the need for a common STEAME teacher facilitators competence framework, present the development of such a framework, the framework itself, and the process of validating it.

STEAME Project-based Learning

STEAME project-based learning (PBL) integrates Science, Technology, Engineering, Arts, Mathematics, and Entrepreneurship into an interdisciplinary approach that focuses on real-world applications and creative problem-solving. Unlike traditional education methods, where subjects are often taught in isolation, STEAM emphasizes the interconnectedness of these disciplines. This approach encourages students to think critically, collaborate, and apply knowledge from different domains to solve complex, practical problems. STEAM also encourages creativity, improvement of social skills, showing positive impacts on cognitive development and literacy [1] while emphasizing in preparing students for real-world challenges by fostering a holistic and integrated curriculum that enhances practical skills essential for the modern workplace [2],[3].

At the heart of STEAME education is project-based learning (PBL), where students work on extended tasks that mimic real-world challenges and are centered around inquiry, research, and hands-on activities. PBL allows students to apply theoretical knowledge in meaningful contexts, promoting deeper learning and engagement. According to Capraro and Slough (2013) [4], project-based learning in STEM/STEAM environments enhances students' motivation by involving them in tasks that are relevant to their lives and futures. PBL enhances student engagement by allowing learners to take control of their projects, fostering a sense of purpose and investment in their education. This approach helps cultivate curiosity and a passion for STEAM subjects [5],[6]. PBL connects theoretical concepts to practical, real-world problems, helping students understand the relevance of their learning. This connection not only deepens their understanding but also inspires interest in STEAM careers [7] and encourages them to ask questions, make informed decisions, and approach problems from multiple perspectives, which are essential skills for success in modern society [8]. Students are motivated to think outside the box and explore innovative solutions to problems while the freedom to experiment fosters creativity, which is vital in both academic and professional settings [9].

STEAME Eco-System

The concept of STEAME education has been explored through a set of projects in the form of cooperative partnerships in the field of school education, under the European ERASMUS+ programme, with the participation of several universities, national educational authorities, schools, research organizations, and representatives from the industry. Namely the projects are STEAME: Guidelines for Developing and Implementing STEAME Schools (2019-2021) [10], STEAME GOES HYBRID: Blueprint Guidelines and Policy Recommendations (2020-2022) [11], European Networking of STEAME School Students for Exchange and Co-creation (2021-2022) [12], and STEAME TEACHER FACILITATORS ACADEMY (2023-2026) [13].

The aforementioned European projects developed or are currently developing the following (figure 1): STEAME (Guidelines for dynamic and adaptive STEAME curricula, Guidelines for STEAME, Activities in Schools for two age groups, Guidelines for STEAME School Organizational Structure), STEAME-HYBRID (Blueprint Guidelines for Hybrid STEAME activities, Training Programme for facilitating the implementation of STEAME, L&C Plans by SE teachers, and Piloting the Blueprint Guidelines, STEAME HYBRID Blueprint at a glance: Policy Recommendations and School Label Development), STEAME STUDENT (European STEAME School Student Network, STEAME STUDENT platform), and STEAME Teacher Academy (STEAME Teacher Facilitators Competence Framework for student and serving teachers, STEAME Teacher Facilitators Learning Modules/Workshops, International Sharing Observatory for STEAME Learning Facilitators, Development of the STEAME Facilitators Community of Practice/Mentoring and Certification Programme, Policy Recommendations, and European Federation of STEAME Teacher Facilitators Academies – Exploitation and Governance Plan).

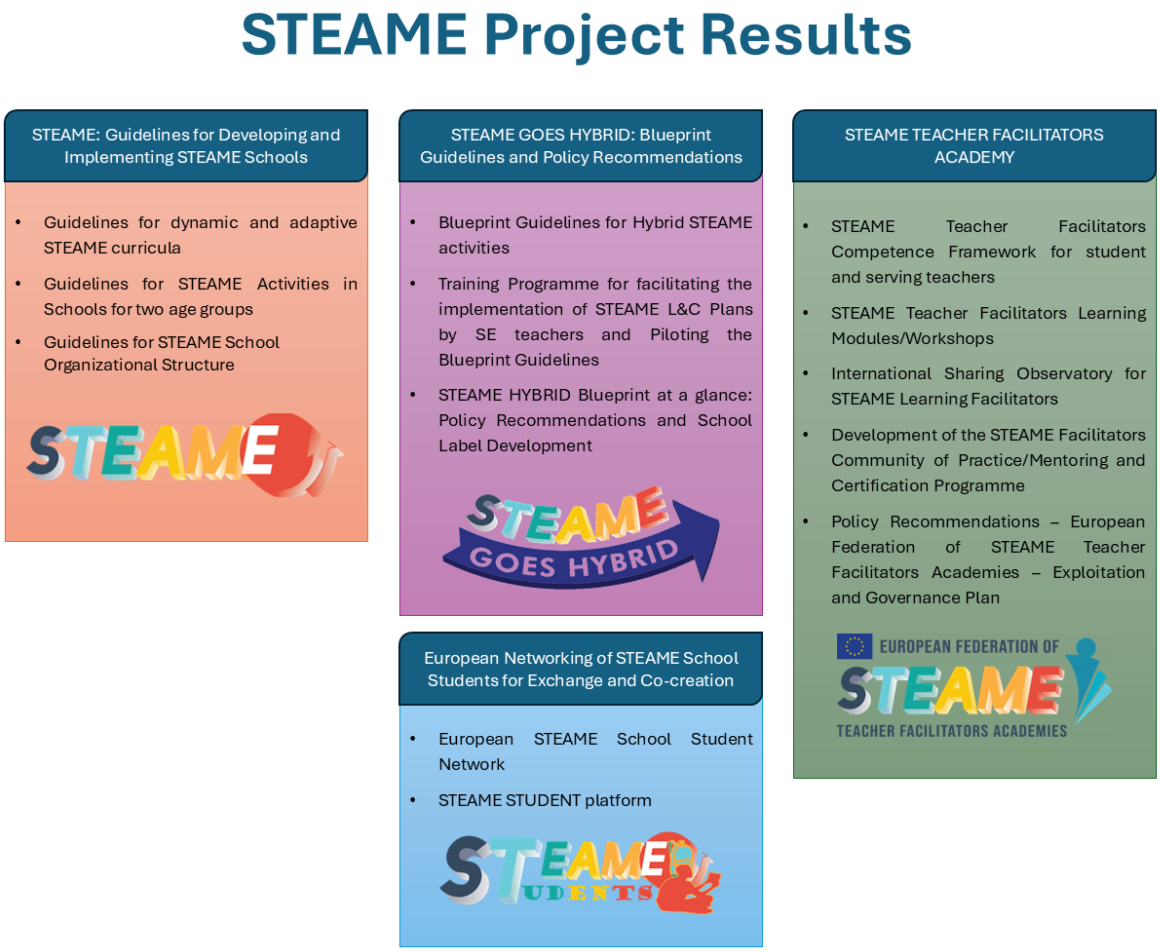


Figure 1. STEAME Project Results

Need for a STEAME Teacher Facilitators Competence Framework

There is a lack in the existence of STEAME competence frameworks for teachers, which would be essential for preparing educators to effectively deliver STEAME education. When considering STEAM, there are only a few cases of competence frameworks for teachers, with one example being the STEAMComp Edu: STEAM Competence Framework for Educators [14], which outlines 41 core competencies organized into 16 areas across five perspectives.

STEAME education integrates a number of subjects (disciplines) and therefore needs to be facilitated by educators that may collaborate to develop and facilitate the implementation of interdisciplinary project-based learning activities. A STEAME competence framework would identify the competences that would enable a teacher to effectively facilitate students' learning through interdisciplinary PBL STEAME. The combination of disciplines, (STEAM) fosters critical thinking, creativity, collaboration, and problem-solving skills, competences [15] which are essential for addressing modern challenges and

preparing students for future careers in a rapidly evolving job market [16].
A STEAME competence framework would help teachers shift from a teacher-centered to a student-centered approach, moving from lecture-based lessons to PBL, fostering, this way, student-centered, inquiry-based, and project-driven learning, where students explore real-world problems and create solutions. Student-centred learning fosters an environment where students take an active role in their learning, leading to more meaningful and deeper learning experiences and exponential personal development, cultivating independent learning, critical thinking and collaboration among students [17].
As mentioned early on, STEAME aims not only in achieving curriculum related learning objectives, but also in developing 21st century skills for students, such as problem-solving, collaboration, creativity, and digital literacy. A commonly accepted competence framework would ensure that teachers are capable of integrating these skills into their teaching, aligning themselves to the latest education trends and workforce demands. These skills may be categorized in several categories, an example being Learning Skills (critical thinking, creativity, etc.), Literacy Skills (information, media, technology), and Life Skills (flexibility, leadership, initiative, etc.) [18]. It is important to integrate these skills into educational experiences to prepare students for college and future careers, considering that employers increasingly value soft skills as vital for success in higher education and the workforce, especially as students face jobs that may not yet exist [19].
Additionally, a STEAME teacher facilitators framework would be able to support teachers' collaboration, by emphasizing the importance of collaboration skills (communication, co-teaching, interdisciplinary planning, etc.). STEAM education encourages teachers to work together across disciplines, leveraging their collective expertise to create a holistic learning environment. By collaborating, teachers can design project-based learning experiences that engage students in real-world problem-solving. This synergy between disciplines not only enriches the curriculum but also models collaborative practices for students, preparing them for future teamwork in their careers [20].
Finally, such a framework would support teachers' professional development while contributing to the professional identity and recognition of STEAME educators, thus offering them a clear pathway for career development.
In conclusion, a STEAME framework would have to address the need for interdisciplinary teaching, equipping teachers with the skills for project-based and student-centered learning and ensuring the integration of 21st-century skills into the curriculum. By clearly defining the competencies required, such a framework would support professional growth, collaboration, and the development of a cohesive STEAME curriculum, ultimately benefiting both teachers and students.

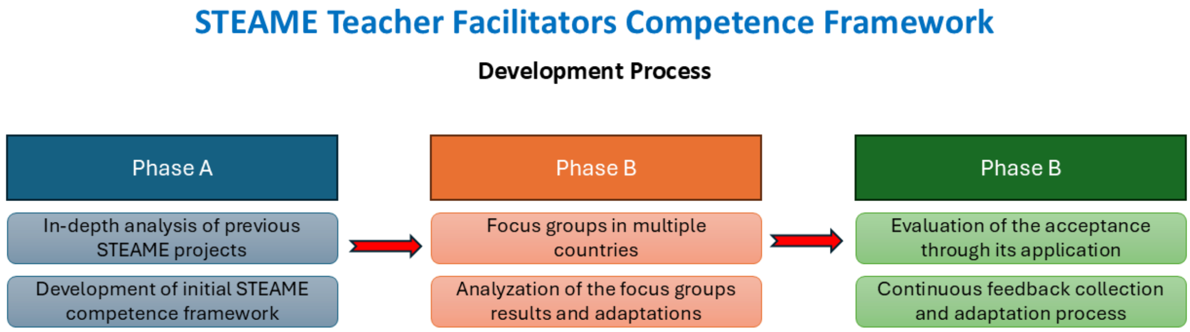


Figure 2. STEAME Teacher Facilitator Competence Framework – Development Process

Development of STEAME competence framework

The development process of the STEAME competence framework, given the need to have a transnational relevance, was designed to encompass three main phases, the design and development of the competence framework, the organization of focus groups in several countries to refine and validate it, and finally its application through its use in the development of a series of STEAME teacher professional development workshops, delivered in a number of different countries, to evaluate and confirm its acceptance within the educational community (*figure 2*). All of the above are realized by the ERASMUS+ project, STEAME Teacher Facilitators Academy (Ref. no: 101102619).

For the first phase of the development process, 25 STEAME/STEAM projects, mainly implemented by a transnational consortium and in their majority being funded by the European Union under the ERASMUS+ programme, were analyzed in-depth, in an effort to identify and map the different competences that were considered to be of importance for a successful STEAM/STEAME teacher to have acquired. The projects that were analyzed were all relevant to school education and to STEAM or STEAME. Many of them have developed training courses for teachers, to support them in acquiring/enhancing important competences that enable them to be successful STEAM/STEAME education teachers. The analyzation of all the results and outcomes of these projects led to a set of competences that were deemed to be of importance for a STEAME educator.

The collection of competences was further analyzed and grouped in a meaningful way to allow for a clear understanding but more importantly to be of added value as an input in any design of a strategy for the development of STEAM/STEAME teachers' professional capacity. The categories under which the competences were grouped were PLB for STEAME in context, PBL as a pedagogical approach to STEAME education, Student agency in STEAME PBL teaching, and Sustainability of PBL applied to STEAME. The 12 competences identified were Design and plan STEAME projects, Consider formal education standards in STEAME projects, Monitoring STEAM projects and reporting, Embed learning in meaningful and authentic STEAME projects, Support STEAME projects with the right learning climate, Involve students in STEAME projects, Promote student self-regulation and metacognition in STEAME projects, Engage and coach to support learning, Reflection on importance as a STEAME project facilitator, Apply creativity and innovation in STEAME projects, and Keep learning about STEAME projects and share knowledge (*Figure 3*).

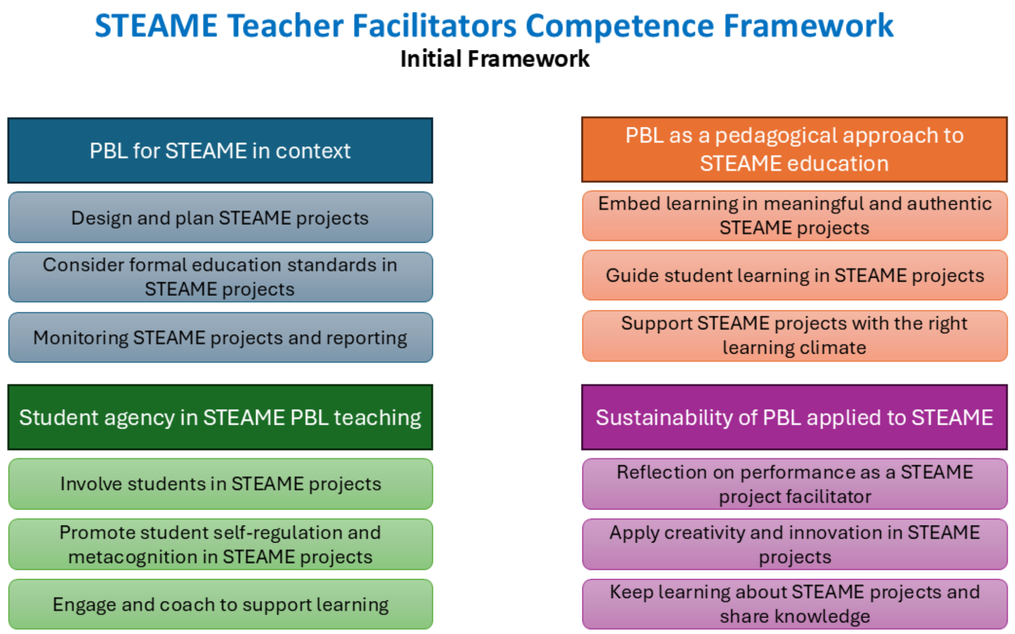


Figure 3. STEAME Teacher Facilitator Competence Framework – Initial Framework

Each competence was further specified as having a three-level scale of mastery, the performance levels. Each performance level was a statement regarding the ability of a teacher to apply in practice the competence in focus. An example of these levels, for the Design and plan STEAME projects competence, of the first competence area, is:
Level 1: Partial integration of STEAME projects into the school's culture, with some inconsistencies. Occasional involvement of external actors, with roles and contributions only loosely defined.
Level 2: STEAME projects are fully integrated into the school's culture, aligning with existing practices and values. Regular involvement of external actors, with clearly defined roles and meaningful contributions to the projects.
Level 3: STEAME projects are not only integrated but are driving forces within the school culture, inspiring continuous innovation and improvement. Extensive collaboration with a wide array of external actors, leading to groundbreaking initiatives and partnerships that transcend traditional boundaries.
Similarly, three performance levels were identified for each competence for the framework. All levels of this initial STEAME Teacher Facilitators Competence Framework (competence areas, competences, competence's performance levels) were subject to validation through the focus groups, organized in several EU countries.

Validation process of Framework through focus groups of experts across Europe

An integral part of the development process of the competence framework is its validation and refinement phase which encompasses a well-defined, guided, process of collecting valuable feedback from a team of individuals with specific characteristics in terms of their professional capacity, their expertise, and their experience in the field of education and/or STEAM/STEAME. To engage the aforementioned individuals in a meaningful process of collecting their valuable feedback, the proposed and later chosen approach was to conduct focus groups of small teams of experts in multiple locations, ensuring, thus, both a high level of engagement of all participants as well as a wide geographical distribution of them. The focus groups of teachers and experts were organized in Poland (Pedagogical University of Krakow), Cyprus (Cyprus Pedagogical Institute, Cyprus Mathematical Society, and European Association of Career Guidance), Portugal (University of the Algarve), Greece (University of Aegean and Doukas School), Romania (Spiru Haret University and IDEA), Bulgaria (Paisii Hilendarski University of Plovdiv and Prof. Ivan Apostolov English Language School), Spain (University of Barcelon), Belgium (European Association of Geographers).

A total of 111 individuals participated in the 12 realized focus groups of experts (45 males – 40%, 66 females – 60%), more or less evenly distributed among the different locations. 52 (46.8%) were in service educators/teachers, 7 were education managers (directors, head of departments, coordinators, etc.) (6.3%), 44 were academics (39.6%), 4 were education policy makers (3.6%), and 4 were described as other (1 education inspector, 2 education consultants, and 1 teacher trainer) (3.6%).

To collect the experts' feedback in a manner that would guarantee the ability to further process the information retrieved, a common process was established and a guide for the focus group facilitators was developed. The guide for the focus group facilitators described the focus group methodology, the aspects to be taken into account before the focus group realization (focus group participants, informed consent, ethical aspects, and session logistics), steps to conduct the session, and the process of capturing and recording the feedback to facilitate the data analysis. The discussion topics – questions (*Figure 4*), were predefined and the feedback was to be collected in a structured manner and to be recorded in a commonly shared collaborative file, ensuring a common data structure. The questions focused on the different parts and elements of the competence framework, the competence areas, the competences, the skills to which they refer, and their performance levels.

Theme	Question
Areas	1.1.What is your opinion about these areas?
	1.2. Do you consider that there is a good level of consistency between the areas?
	1.3. Do you consider that all areas have the same level of relevance?
	1.4. Would you add or remove any of the areas described? Why?
	1.5. Do you think that writing facilitates understanding of the area?
Competences	2.1. What is your opinion about the competences proposed?
	2.2. Do you consider that there is a good level of consistency between the competences?
	2.3. Do you consider that all the competences have the same level of relevance?
	2.4. Would you add or remove any of the competences described? Why?
	2.5. Do you think that writing facilitates understanding of the competence?
Levels of achievement	3.1 What is your opinion about the achievement levels proposed?
	3.2. Do you consider that there is a good level of consistency between the levels of attainment?
	3.3. Would you add or remove any of the levels described? Why?
	3.4. Do you think that writing facilitates understanding of the domain?
Closing	4.1. Do you have any aspect that wasn't discussed in this session that you would like to discuss?
	4.2. 2 Are there any notes, opinions, or worries you would like to share regarding the themes discussed or the scope of the project? "

Figure 4. Focus Group Topics – Questions

Post-validation competence framework refinement

Following the realization of the focus groups and the collection of data through the experts' feedback, the data analysis commenced to allow for the identification of opportunities to improve the competence framework. The data was well-organized per focus group location before their consolidation that would allow for an overall analysis. The different observations were grouped similarly to the structure of the topics-questions, which were organized based on the different aspects of the framework. This allows for targeted observations which would indicate specific improvements. The report of the consolidated analysis led to a specific number of possible changes to be made that would improve the framework.

The STEAME Teacher Facilitator Competence Framework [20], following the changes and adaptations that were a result of the observations upon the consolidated focus group data analysis, is as follows:

Area 1: Contextualization of STEAME projects

Competence 1: Design and implement context-bound STEAME projects
To design and implement STEAME projects that are integrated in a specific school culture while effectively involving actors from the community, to address contemporary social and environmental challenges.

Competence 2: Consider formal education standards in STEAME projects
To consider formal education standards, including the curriculum, performance indicators, or others that are relevant in the sociocultural context where STEAME projects are designed and implemented.

Competence 3: Monitoring STEAME projects and reporting
To practice monitoring and reporting of STEAME projects, including foreseeing possible deviations from the plan, and act where needed to ensure their correct development.

AREA 1 – RUBRIC

Competence / level	**Level 1**	**Level 2**	**Level 3**
Competence 1. Design and implement context-bound STEAME projects	Partial integration of STEAME projects into the school's culture, with some inconsistencies	STEAME projects are fully integrated into the school's culture, aligning with existing practices and values.	STEAME projects are not only integrated but are driving forces within the school culture, inspiring continuous innovation and improvement.
	Occasional involvement of external actors, with roles and contributions only loosely defined.	Regular involvement of external actors, with clearly defined roles and meaningful contributions to the projects.	Extensive collaboration with a wide array of external actors, leading to ground-breaking initiatives and partnerships that transcend traditional boundaries.
Competence 2. Consider formal education standards in STEAME projects	Basic understanding of formal education standards and attempts to align STEAME projects with them.	Basic understanding of formal education standards and aligns STEAME projects with them to some extent.	Exceptional mastery of formal education standards, incorporating them seamlessly into project design and implementation.
	STEAME projects have basic connections to standards but lack detailed alignment.	STEAME Projects show alignment with standards, but there are occasional gaps in content coverage.	Projects are innovative, pioneering new approaches to teaching and learning while aligning with standards.

Competence 3. Monitoring STEAME projects and reporting	Limited ability to foresee potential deviations on STEAME projects	Solid ability to foresee potential deviations of STEAME projects and proactively plans to address them	Solid ability to foresee potential deviations, applying innovative and ground -breaking strategies to address them
	Intuitive application of basic monitoring measures	Ability to choose the most suitable monitoring strategy for each STEAME project	Ability to choose the most suitable monitoring strategy for each STEAME project and can justify the choice
	Ability to informally report on the progress of STEAME projects, providing basic insight	Delivers comprehensive reports on the development of STEAME projects, to the extent that they include different sources of evidence and some level of analysis	Delivers comprehensive reports on the development of STEAME projects, to the extent that they include different sources of evidence and systematic analysis providing not only detailed insights but also actionable recommendations for continuous improvement

Table 1. Competence Area 1 Rubric

Area 2: Methodological aspects of STEAME projects

Competence 4: Embed learning in truly interdisciplinary STEAME projects
To facilitate student learning in and across two or more STEAME subjects where the disciplines interact, supported by appropriate resources.

Competence 5: Guide student learning in STEAME projects
To scaffold a diverse range and styles of student learning in STEAME projects, where the project is understood as an inductive process of developing new knowledge, skills, attitudes or competencies by doing research-like activities and oriented to action.

Competence 6: Support STEAME projects with the right learning environment and resources

Description: To create a learning environment that fosters collaboration among students, across groups of students, and with the teacher and other stakeholders involved in STEAME projects.

AREA 2 – RUBRIC

Competence / level	Level 1	Level 2	Level 3
Competence 4: Embed learning in truly interdisciplinary STEAME projects	Projects integrate at least two STEAME subjects with limited interaction between STEAME disciplines	Projects integrate two or more STEAME subjects with interaction between STEAME disciplines	Projects integrate two or more STEAME subjects with substantial interactions between STEAME disciplines
	The disciplines represented in the project, especially Arts and Entrepreneurship, add value to student learning.	The disciplines represented in the project, especially Arts and Entrepreneurship, add a lot of value to student learning.	The project shows an in-depth understanding of the disciplines represented in it, especially Arts and Entrepreneurship, and they are addressed in a way that adds a lot of value to student learning.
	Projects show signs of student involvement in designing, developing, and constructing hands-on solutions to a problem.	Projects show a moderate level of student involvement in designing, developing, and constructing hands-on solutions to a problem.	Projects show a moderate level of student involvement in designing, developing, and constructing hands-on solutions to a problem.
Competence 5: Guide student learning in STEAME projects	Basic attempts to scaffold student learning through project-like activities.	Proficient use of a variety of scaffolding techniques to support student learning in STEAME projects.	Mastery of diverse scaffolding techniques, providing highly effective support for student learning in STEAME projects.
	Scaffolding strategies are limited in scope and may not effectively support all students.	Scaffolding strategies are tailored to individual and group needs, ensuring effective support for all students.	Scaffolding strategies are personalised, differentiated, and seamlessly integrated into STEAME projects, fostering high levels of student engagement and understanding.

	Limited adaptability in responding to diverse student learning needs	Adaptability in responding to challenges, adjusting scaffolding methods based on student progress and feedback.	Exceptional adaptability and sensitivity to diverse student needs, creating an inclusive and empowering learning environment for all students.
Competence 6: Support STEAME projects with the right learning environment and resources	Projects include basic collaborative activities within the classroom, such as group discussion, peer-review or jigsaw	Projects include diverse and well-structured collaborative activities that align with learning objectives and engage all students.	STEAME projects are framed in a transformative learning environment where collaboration is a fundamental aspect, fostering creativity, critical thinking, and mutual support among students, teachers, and other organisations.
	Collaborative activities have some level of depth or integration with the curriculum.	Projects promote teamwork, communication, and problem-solving skills among students, facilitating a positive and inclusive collaborative environment.	Projects promote teamwork, communication, and problem-solving skills among students, among groups of students and the teacher, as well as among students and other actors outside of school, thus facilitating a positive and inclusive collaborative environment.
	Demonstrates a willingness to learn and explore collaboration with other teachers and / or organisations outside of the school, although implementation may be limited.	Engages with stakeholders, such as parents, experts, or community members, to enrich collaborative learning experiences and broaden students' perspectives	Actively collaborates with a wide range of stakeholders, fostering partnerships, organizing collaborative events, and creating a supportive network that enhances students' learning experiences and opportunities.

Table 2. Competence Area 2 Rubric

Area 3: Student agency in STEAME PBL teaching

Competence 7: Involve students in STEAME projects
To consider students' curiosity, suggestions, or any other form of interest in determining the project to be developed or its development.

Competence 8: Promote student self-regulation and metacognition in STEAME projects
To apply metacognition to promote students' awareness and regulation of their own learning in STEAME projects.

Competence 9: Engage and coach to support learning
To encourage and maintain student involvement by tapping into their personal and moral implication in the STEAME project.

AREA 3 – RUBRIC

Competence / level	Level 1	Level 2	Level 3
Competence 7: Involve students in STEAME projects	Partial involvement of students in determining the project to be developed.	Substantial involvement of students in determining the project to be developed.	Very substantial involvement of students in determining the project to be developed.
	Identifying to some extent the students' interests around STEAME projects.	Identifying to some extent the students' interests around STEAME with a variety of methods and techniques.	Identifying and organising the students' interests around STEAME with a wide range of methods and techniques.
	Partially listening to students' suggestions.	Considering students' suggestions in some parts of the project.	Proactively considering students' suggestions to the project and helping to structure them.
Competence 8: Promote student self-regulation and metacognition in STEAME projects	Planning a few checkpoints to encourage general reflection throughout the project.	Planning and setting a few checkpoints to encourage reflection about a few aspects of the project throughout it.	Planning and setting a few checkpoints to encourage productive reflection about all important aspects of the project throughout it.
	Sharing assessment criteria with students after the project has started.	Sharing assessment criteria with students in a timely way.	Building together and sharing assessment criteria with students in a timely way.

	Promoting reflection on the learning progress towards the end of the project.	Promoting reflection on the learning progress during the project progress, and giving feedback to students.	Promoting reflection on the learning progress during the project progress, giving feedback to students and giving time to new metacognition and learning regulation transfer.
Competence 9: Engage and coach to support learning	Connects STEAME projects to students' emotional domain	Connects STEAME projects to students' emotional domain and moral values	Connects STEAME projects to students' emotional universe and moral values in an unexpected way
	Setting a few control points during the project.	Guiding students in setting some control points during the project.	Guiding students in setting control points during the project in a systematic way, also giving social spaces of debate and discussion of the progress of the project.
	Promoting a work environment where students can express themselves but their opinions and suggestions are not considered.	Promoting a work environment where students can express themselves and their opinions and suggestions are considered.	Promotes and manages a safe environment where all voices are heard and respected in a democratic way.

Table 3. Competence Area 3 Rubric

Area 4: Sustainability of PBL applied to STEAME

Competence 10: Reflect on performance as a STEAME project facilitator

To critically reflect on one's performance as a facilitator of STEAME projects based on empirical evidence from students and peers, with the ultimate intention to deliver better PBL experiences across STEAME subjects.

Competence 11: Apply creativity and innovation in STEAME projects
To adapt to quick changes that affect the teacher's task in the design, the implementation or the evaluation of STEAME projects.

Competence 12: Keep learning about STEAME projects and share knowledge
To stay informed, updating one's skills, and expanding expertise in the fields of Science, Technology, Engineering, Arts, Mathematics, and Entrepreneurship and actively sharing this acquired knowledge and expertise with others, including colleagues, students, parents, and the community.

AREA 4 – RUBRIC

Competence / level	Level 1	Level 2	Level 3
Competence 10: Reflect on performance as a STEAME project facilitator	Intuitively reflecting on the teaching role in STEAME projects.	Reflecting on the teaching role in STEAME projects with a sense of purpose.	Reflecting on the teaching role in STEAME projects with a sense of purpose, in a systematic way.
	Taking the negative aspects of previous performance into account when defining new STEAME projects.	Taking negative, positive and neutral aspects of previous performance into account when defining new STEAME projects.	Taking negative, positive and neutral aspects of previous performance into account when defining new STEAME projects and other aspects that played a role and can be solved.
	Involving students in the reflection and critical assessment of delivered STEAME projects.	Involving students and other teachers in the reflection and critical assessment of delivered STEAME projects.	Involving students, other teachers and other stakeholders in the reflection and critical assessment of delivered STEAME projects.
Competence 11: Apply creativity and innovation in STEAME projects	Awareness that STEAME projects are not innovative in nature, but that thinking outside of the box is needed to ensure their added value.	Thinking outside of the box to ensure the added value of STEAME projects.	Thinking outside of the box and establishing mechanisms to ensure the added value and sustainability of STEAME projects

	Openness to incorporate changes and modifications in the design, implementation, or evaluation of STEAME projects.	Partially incorporating changes in the design, implementation, or evaluation of STEAME projects.	Systematically reviewing and incorporating changes and innovations in both the design and implementation and evaluation of STEAME projects.
	Using innovative tools, resources, or methods in an intuitive way.	Using innovative tools, resources, or methods in a reasoned way.	Proactively searching for and using innovative tools, resources, or methods in a reasoned way and for the constant improvement of the learning process.
Competence 12: Keep learning about STEAME projects and share knowledge	Mastering the disciplinary and pedagogical knowledge received in initial training.	Moderate participation in teaching training spaces that complement the disciplinary and pedagogical knowledge received in initial training.	Shows a commitment to continuing training and participates in training spaces.
	Sharing the teaching role with another colleague within the school.	Promoting and participating in interdisciplinary work teams about STEAME projects within the school.	Promotes co-working experiences about STEAME projects inside and outside the school, with colleagues, experts, etc.
	Recognising the importance of being part of communities and participating occasionally.	Recognising the importance of being part of communities and frequently participating in them.	Engaging and promoting spaces for interaction with other teachers, communities of practice, etc.

Table 4. Competence Area 1 Rubric

Conclusion

STEAME education allows for the alignment of the development of students' skills throughout their school life with the needs of the labor market allowing them to develop and become successful 21st century citizens and professionals. Project-based learning has the potential when used within the context of STEAME education to encourage students to think critically, collaborate, and apply knowledge from different domains to solve complex, practical, real-world problems. Thus, STEAME project-based learning may effectively support the achievement of learning objectives from multiple subjects, through its interdisciplinarity, while fostering the acquisition of valuable skills and competences.

The development of the STEAME Competence Framework for Teacher Facilitators marks a step towards bridging the gap between traditional education and the dynamic, interdisciplinary demands of the 21st-century learning environment. By emphasizing project-based, student-centered learning, the STEAME Teacher Facilitators Competence Framework enables educators to foster the essential skills of critical thinking, creativity, collaboration, and entrepreneurship. It aligns with the evolving educational landscape, where the integration of real-world problem-solving and interdisciplinary knowledge is important in preparing students for future careers.

The validation process through focus groups across Europe underscored the importance of refining the framework to meet the needs of educators in diverse settings. Feedback from experts and teachers confirmed the relevance and applicability of the competences. The structured approach (competence areas, competences, performance levels) ensures that teachers can progressively enhance their competences, facilitating a more effective transition to STEAME education.

The framework not only supports teachers' professional growth but also promotes collaboration across disciplines, contributing to the creation of a cohesive STEAME curriculum that prepares students for future challenges.

References

[1] Bush, A., Conradty, C., & Bogner, F. X. (2020). The impact of STEAM education on student motivation and self-efficacy: A systematic review. International Journal of STEM Education, 7(1), 1-18. https://doi.org/10.1186/s40594-020-00206-8

[2] Lin, Y., & Tsai, C. (2021). STEAM in education: A bibliometric analysis of performance and co-word analysis. Education Sciences, 11(7), 345. https://doi.org/10.3390/educsci11070345

[3] Arduino. (n.d.). Benefits of STEAM education. Retrieved from https://www.arduino.cc/en/Guide/STEAM

[4] Capraro, R. M., & Slough, S. W. (2013). Why PBL? Why STEM? Why now? In R. M. Capraro, M. M. Capraro, & J. R. Morgan (Eds.), An introduction to STEM project-based learning: An integrated science, technology, engineering, and mathematics approach (2nd ed., pp. 1-5). Sense Publishers.

[5] Space Foundation. (2022). What is STEAM education and why is it important? Retrieved from https://www.spacefoundation.org/2022/06/22/what-is-steam-education-and-why-is-it-important/

[6] Arts Integration. (n.d.). What is STEAM education? Retrieved from https://artsintegration.com/what-is-steam-education-in-k-12-schools/

[7] Green Kid Crafts. (n.d.). 7 benefits of STEAM education for elementary school kids. Retrieved from https://www.greenkidcrafts.com/7-benefits-of-steam-education-for-elementary-school-kids/

[8] Space Foundation. (2023). Five benefits of teaching STEAM. Retrieved from https://www.spacefoundation.org/2023/03/15/five-benefits-of-teaching-steam/

[9] Connections Academy. (n.d.). What is a STEAM education and why is it gaining popularity? Retrieved from https://www.connectionsacademy.com/support/resources/article/what-is-a-STEAM-education/

[10] STEAME. (2019). STEAME: Guidelines for developing and implementing STEAME schools. Retrieved October 15, 2024, from https://steame.eu/

[11] STEAME GOES HYBRID. (2020). STEAME GOES HYBRID: Blueprint guidelines and policy recommendations. Retrieved October 15, 2024, from https://steame-hybrid.eu/

[12] Thales Cyprus. (2021). *STEAME students project*. Retrieved October 15, 2024, from https://thalescyprus.com/steame-students-project/

[13] STEAME Academy. (n.d.). STEAME Academy. Retrieved October 15, 2024, from https://steame-academy.eu/

[14] Koutouki, S., & Vassiliou, A. (2024). STEAM competence framework for educators. Encyclopedia MDPI. https://encyclopedia.pub/entry/56461

[15] 21stCentEd. (n.d.). Interdisciplinary approaches to STEM education: Bridging STEM with humanities. Retrieved from https://21stcented.com/interdisciplinary-approaches-to-stem-education-bridging-stem-with-humanities/

[16] Lin, H., & Wu, Y. (2024). A meta-analysis of interdisciplinary teaching abilities among STEM educators. International Journal of STEM Education, 11(1), 1-20. https://doi.org/10.1186/s40594-024-00500-8

[17] Oxford AQA. (2024, March 13). The benefits of embracing student-centred learning. Retrieved from https://www.oxfordaqa.com/news/the-benefits-of-embracing-student-centred-learning/

[18] Hummel B. (n.d.). What are 21st century skills? CEV. Retrieved October 15, 2024, from https://www.icevonline.com/blog/what-are-21st-century-skills

[19] Buckle J. (n.d.). A comprehensive guide to 21st century skills. Panorama Education. Retrieved October 15, 2024, from https://www.panoramaed.com/blog/comprehensive-guide-21st-century-skills

[19] Buczynski, S., & Co-authors. (n.d.). Why STEAM is so important to 21st-century education. University of San Diego. Retrieved October 15, 2024, from https://onlinedegrees.sandiego.edu/steam-education-in-schools/

[20] STEAME Academy. (2024). STEAME Teacher Facilitators Competence Framework [PDF]. https://steame-academy.eu/wp-content/uploads/2024/03/D2.4-STEAME-Teacher-Facilitators-Competence-Framework.pdf

Mediterranean Journal for
Research in Mathematics Education
Vol. 20, 2024

One Possible STEAME Approach on the Topic of Area of Squares and Rectangles in Fourth Grade of Primary School

Vojislav Andrik, Diofant School of Mathematics, voja.andric@gmail.com
Valentina Gogovska, UKIM, Faculty of Science and mathematics-Skopje, valentinagogovska@gmail.com; fax: 0038923228141

Abstract: *This paper outlines a methodical approach to teaching the "Area of Squares and Rectangles" lesson, tailored to the fourth grade, using the STEAME system. This traditional lesson was redesigned and implemented to align with STEAME principles, which emphasize interdisciplinary, hands-on learning. The aim of the research was to evaluate the accessibility and effectiveness of STEAME models for both students and teachers. The study involved seven classes of 10-11-year-olds, with a single STEAME-modeled lesson delivered per class. The research employed a variety of active teaching methods, including play-based and experimental learning, carried out through individual, pair, and group work. Student achievement was mainly assessed through knowledge tests and brief quizzes.*

Key words: *creative teaching methods in STEAME classroom, mathematical reasoning, real-world application of geometry, collaborative problem solving.*

Introduction

This paper describes an innovative approach to teaching the topic of "Area of Squares and Rectangles" in a fourth-grade classroom. It focuses on the STEAME (Science, Technology, Engineering, Arts, Mathematics, Entrepreneurship) model, which integrates interdisciplinary activities to make learning more engaging and practical. The lesson plan emphasizes hands-on learning, where students measure, compare, and explore surface areas through interactive tasks. The research, based on seven classes, assesses how well students and teachers adapt to the STEAME methodology, showing that this approach improves functional literacy and collaborative problem-solving skills. The findings, while positive, suggest that full implementation of STEAME in all lessons is impractical, but its principles can be applied selectively for impactful learning.

Measuring quantities is the initial step of every application of mathematics"-

Lebesgue Teaching Activities on Surface Area: Exploring Squares and Rectangles

The following teaching activities are designed to engage students in understanding the concept of surface area through practical, hands-on experiences:
1. Which is Larger? – This activity introduces one criterion for comparing shapes by size.

2. Give Me the Measurement, I'll Measure the Entire Figure – Students learn to measure the total surface area of different shapes.

3. What is a Square Centimeter? – A practical introduction to the unit of square centimeters, using a plastic model.

4. Surface Area of Squares and Rectangles – A focused activity where students calculate and compare the surface areas of squares and rectangles.

5. What is a Square Meter? – An activity designed to extend students' understanding from square centimeters to square meters.

6. Let's Measure Our Classroom – A real-world application where students measure the surface area of their classroom using square meters.

7. The Are – How Big is That Area? – A field activity that introduces students to larger units of area, like the area, used for measuring open spaces.

8. Art Content Incorporating creativity, students explore how art can intersect with mathematics by designing shapes with specific surface areas.

The Central Tool in Learning: The Plastic Square Centimeter

In this set of activities, the plastic model of one square centimeter serves as the main tool, helping students visualize and experiment with surface area. It encourages problem-solving and critical thinking, making the concept more tangible and interactive.

STEAME Model Approach: Surface Area of Squares and Rectangles

The fundamental principle in implementing the teaching topic of "Area of Squares and Rectangles" follows the STEAME (Science, Technology, Engineering, Arts, Mathematics, Entrepreneurship) model. This approach emphasizes *active learning*, where students engage in hands-on activities, collaborative problem-solving, and real-world applications of mathematical concepts.

Practical Implementation of STEAME in Surface Area Lessons

It is impossible to present all seven experimental lessons in a brief timeframe, so I have chosen to highlight select problems that demonstrate key elements of the STEAME (Science, Technology, Engineering, Arts, Mathematics, Entrepreneurship) teaching approach in this educational context. These problems showcase the interdisciplinary nature of learning while emphasizing hands-on activities and collaborative problem-solving.

Typical STEAME Problems in Surface Area Lessons

To facilitate the learning of surface area in squares and rectangles, the following types of problems are commonly introduced:

-Measuring and Comparing Shapes: Students use square centimeter and square decimeter models to measure various shapes and compare their sizes.

- Real-World Applications: Students apply their knowledge by measuring real surfaces such as their classroom or open spaces using appropriate tools.

- Creative Integration: In some activities, students incorporate art by designing shapes or patterns, connecting the mathematical concept of surface area with creativity.

Didactic Materials for Each Student

To ensure effective participation in these hands-on activities, each student is equipped with the following materials:

- Square grid
- Models of square centimeters
- Models of square decimeters
- Scissors and glue
- Crayons
- Calibrated ruler and triangle
- Various models of cardboard squares and rectangles

This personal STEAME kit ensures that each student can engage in individual and group tasks, promoting active learning.

Didactic Materials for the Classroom

For successful implementation of STEAME-based lessons, the classroom as a whole is provided with the following shared materials:
- A4 square grid paper (at least 30 sheets)
- Models of square centimeters (approximately 3000 pieces)
- Models of square decimeters (at least 250 pieces)
- Scissors (30 pairs)
- Crayons (multiple sets)
- Calibrated rulers and triangles (several)
- Models of cardboard squares, rectangles, and right-angled triangles
- Several cardboard shapes of various forms
- 10-meter and 5-meter measuring tapes
- Rope for field measurements

These materials allow for the exploration of both small-scale and large-scale surface areas, promoting real-world measurement activities inside and outside the classroom.

This approach provides students with an engaging, hands-on experience that bridges theoretical concepts with real-world applications. Through these STEAME problems, students not only learn mathematical concepts but also develop skills in critical thinking, creativity, and teamwork, preparing them for future interdisciplinary challenges. Each problem is designed to engage students in active experimentation, critical thinking, and collaboration, key elements of the STEAME framework.

Teaching Materials

1. Which is Larger?

1.1 On a square grid of cardboard, the following shapes are given. For each of the given shapes, mark and color the matching shape with the same color so that shape A corresponds to matching shape A1, shape B – B1, and so on.

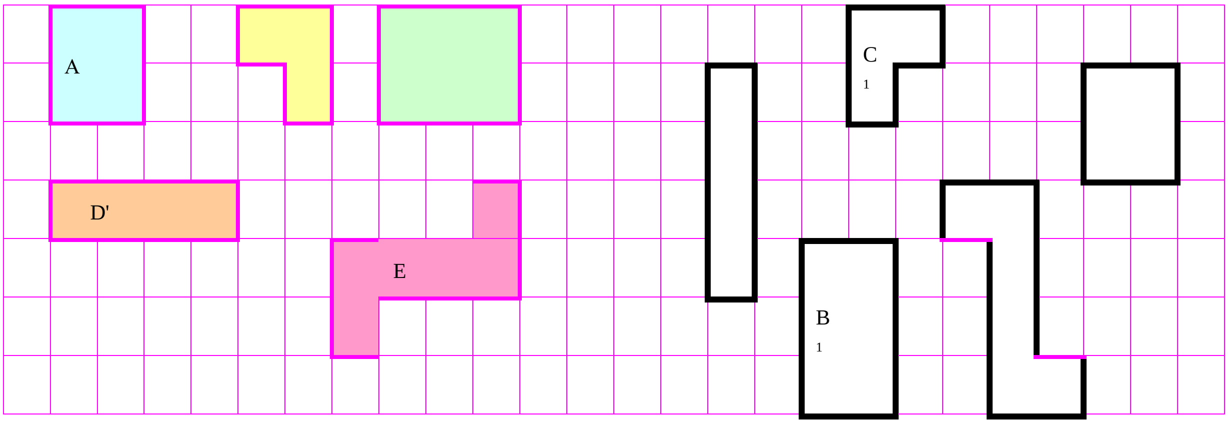


Figure1

1.2. Arrange the shapes A, B, C, D, and E in order according to their area, from the shape with the smallest area to the one with the largest.

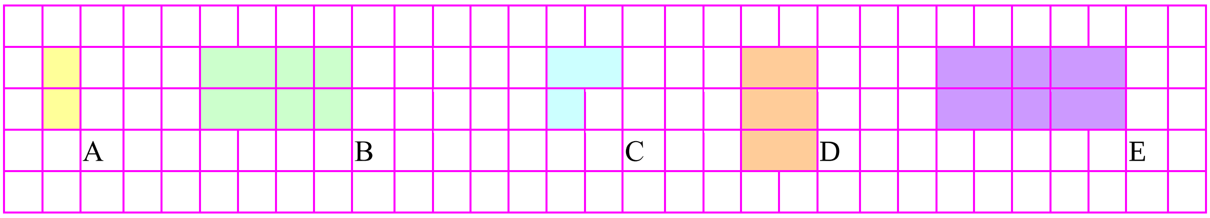


Figure 2

1.3. Using symbols □ and =, write the relationship between the areas of the given shapes.

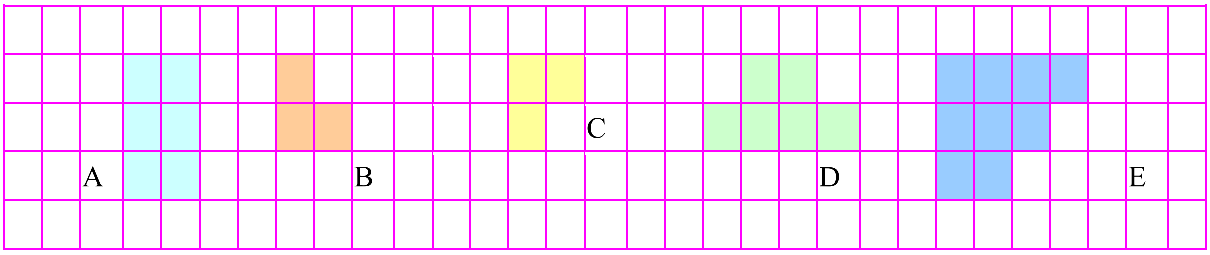


Figure 3

1.4. Using the models of the obtained squares, determine the areas of the following shapes:

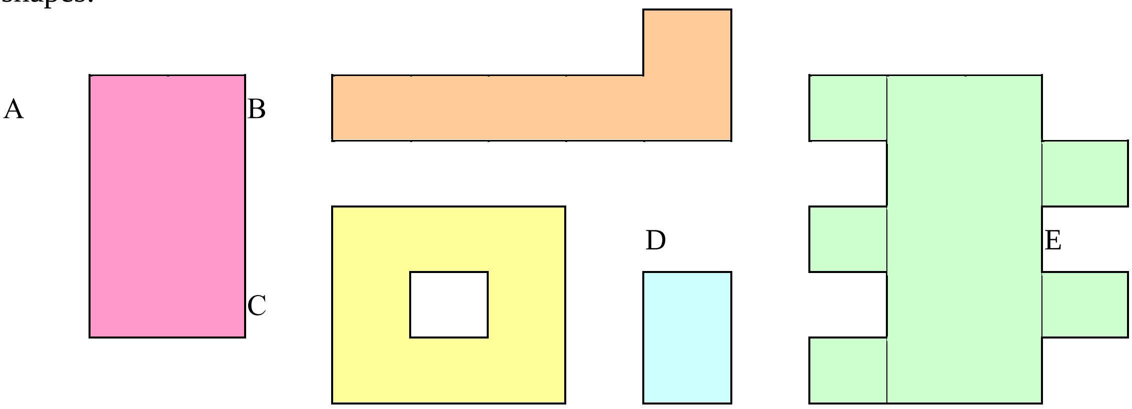


Figure 4

2. Give Me the Measurement – I'll Measure the Entire Figure

2.1. A stylized figure of a kangaroo is made up of equal squares. How many such squares have been used?

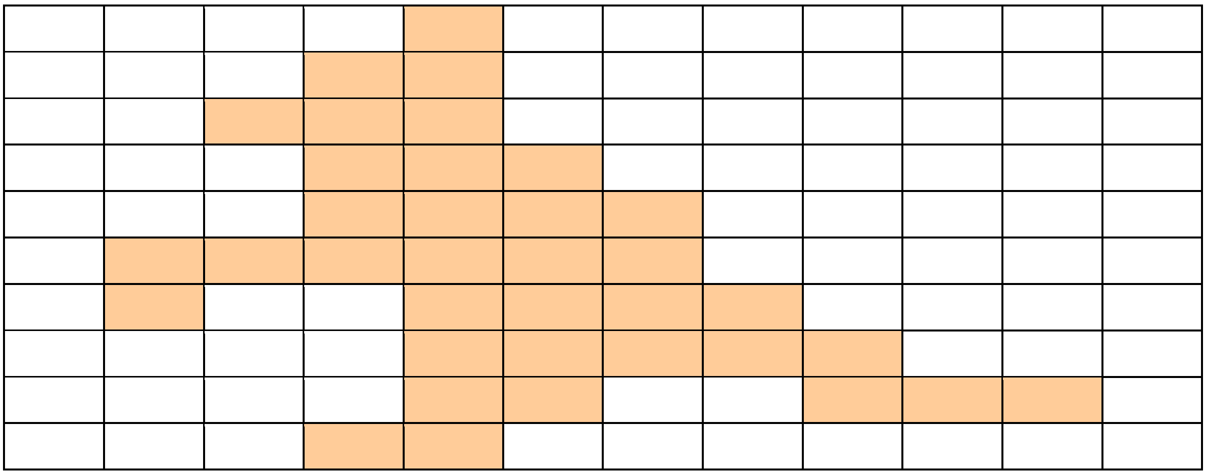


Figure 5

2.2 If is the unit of measurement for area, what is the area of the following figures? Which figure has the smallest, and which has the largest area?

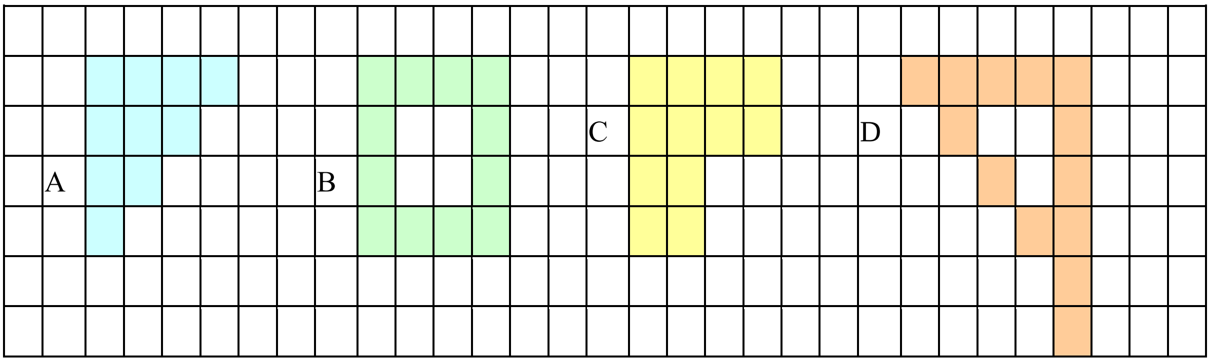


Figure 6

2.3. If is the unit of measurement for area, draw, on a square grid, figures of your choice with the following areas: a) 1; b) 2; c) 15; d) 6; e) 20;

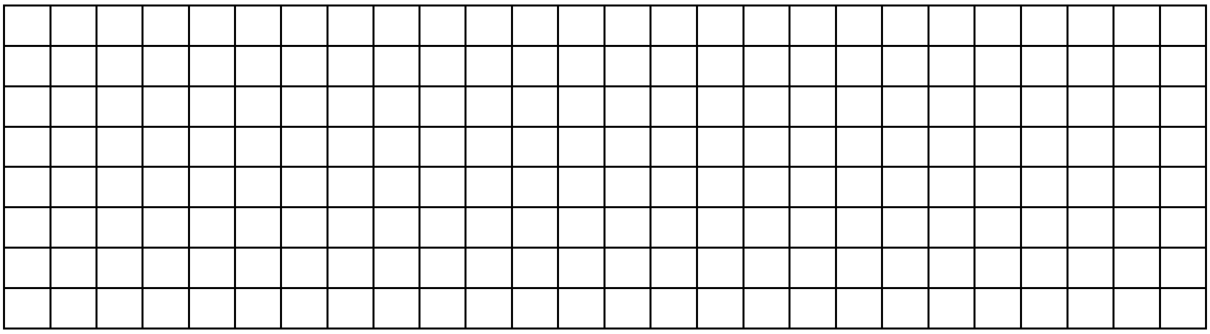


Figure 7

2.4. If is the unit of measurement for area, what is the area of the following figures?

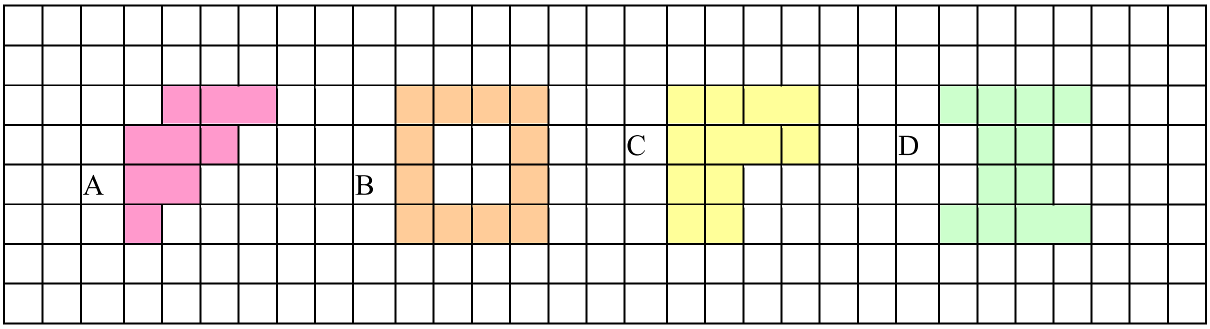


Figure 8

2.5. From the obtained square model, form letters in the word ПЕРА. What is the area of each letter in the word ПЕРА? Which “letter” has the smallest, and which has the largest area?

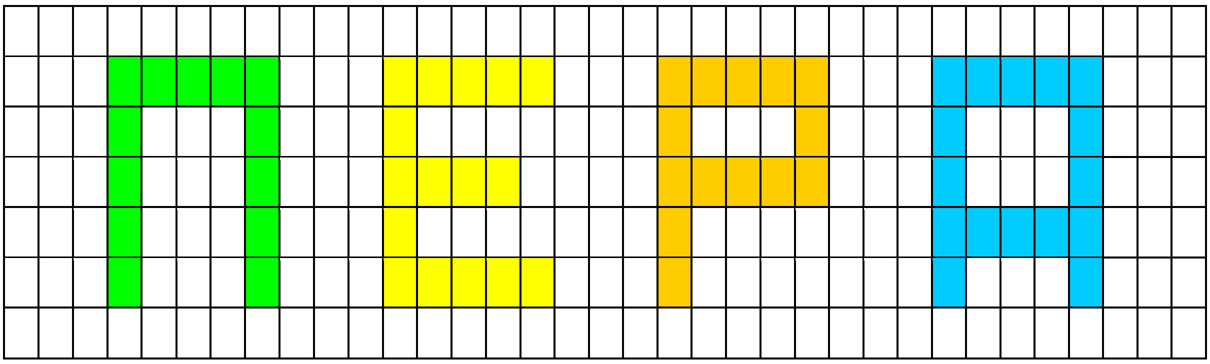


Figure 9

3. What is a Square Centimeter?

A square with a side of 1 cm (in front of you is a model of a square centimeter) is the unit for measuring area and is called a square centimeter, denoted as 1 cm^2.

3.1. Determine the area of figures A, B and C in cm^2 (square centimeters).

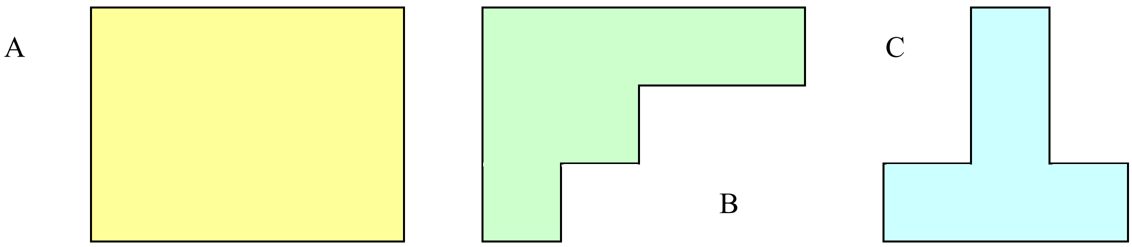


Figure 10

3.2. Determine the areas of the following rectangles in cm^2:

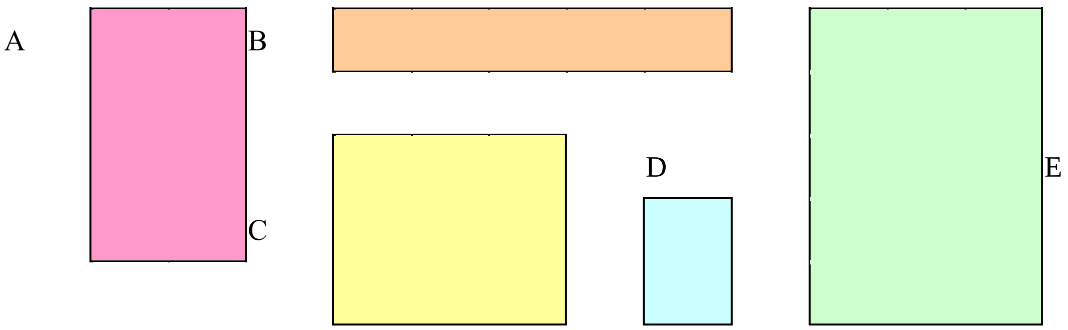


Figure 11

3.3 On a square grid with a side length of 1 cm, construct rectangles with the following areas:

a) 3cm^2; b) 6cm^2; c) 10cm^2; d) 18cm^2; e) 14cm^2.

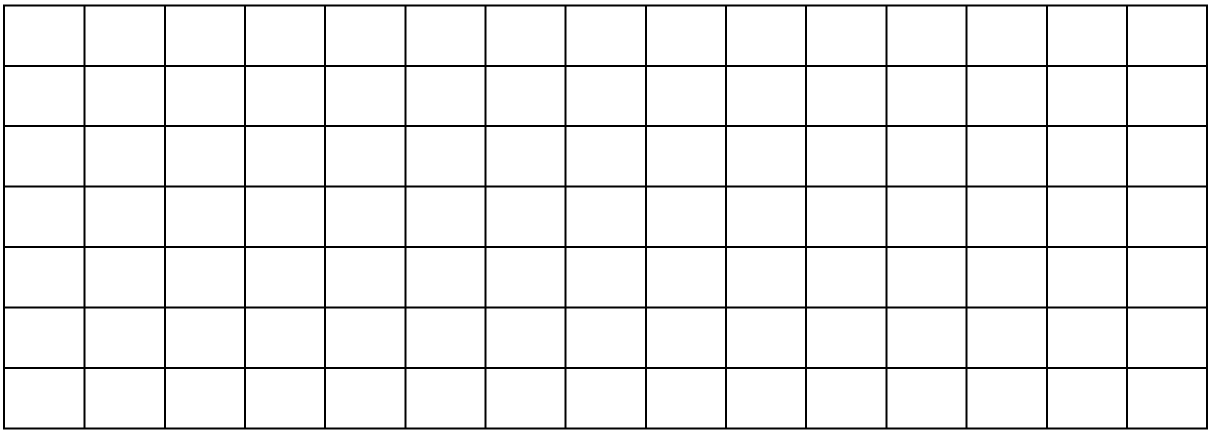


Figure 12

3.4. Determine the area of the following figures in cm^2:

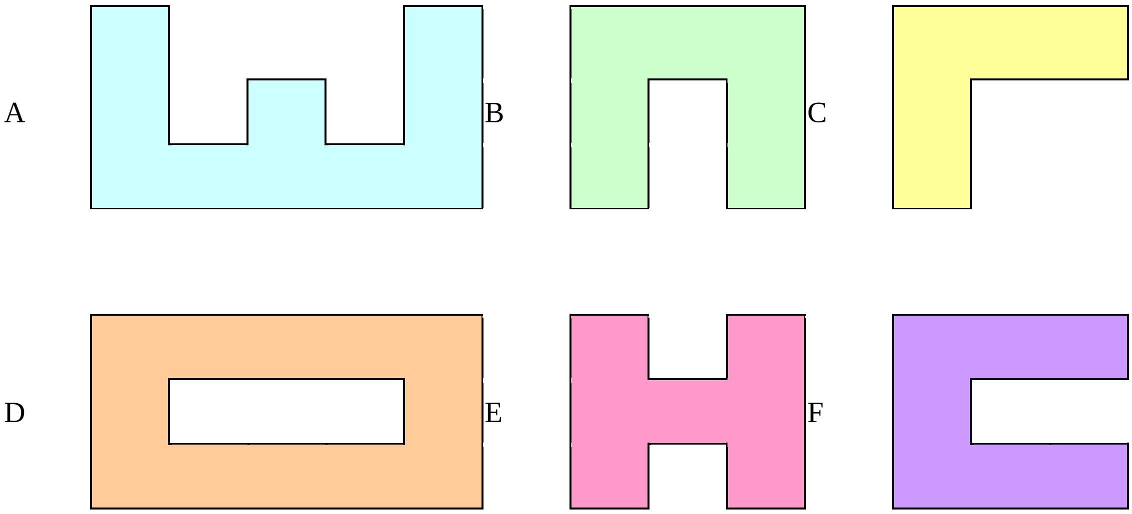


Figure 13

3.5. On a square grid with a side length of 1 cm, draw figures that are not rectangles but have an area of: a) 5 cm^2; b) 7cm^2; c) 8 cm^2; d) 12 cm^2; e) 13 cm^2.

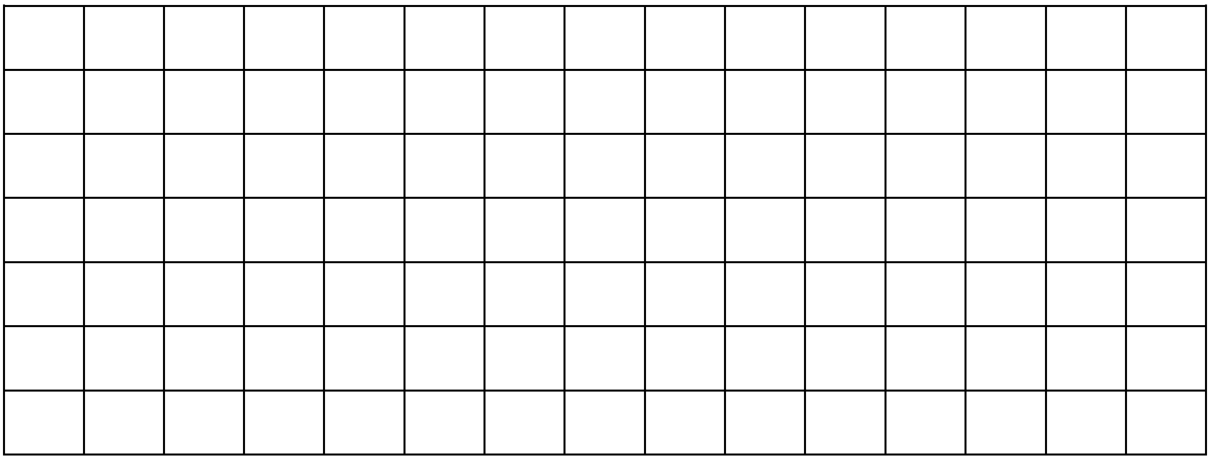


Figure 14

4. Surface Area of Squares and Rectangles

4.1. Using a model of square centimeters, form a square with a side length of 6 cm and count how many cm^2 the given model contains. Calculate the area of that square.

4.2. Using a model of square centimeters, form a rectangle with side lengths of 4 cm and 7 cm and count how many cm^2 the given model contains.

4.3. What is the problem with determining the area of a square with a side length of 45 cm or a rectangle with side lengths of 37 cm and 73 cm?

4.4. Can the process of calculating (counting) the area of squares and rectangles be shortened? How? Explain using the example from the previous problem.

4.5. What is the area of a square if the length of its side is *a* cm?

4.6. What is the area of a rectangle if the lengths of its sides are *a* cm and *b* cm?

4.7. Measure the side of the cardboard square you created and calculate its area.

4.8. Measure the sides of the cardboard rectangle you created and calculate its area.

5. What is a Square Meter?

5.1. If we call a square with a side length of 1 cm a square centimeter, what will we call a square with a side length of 1 dm?

5.2. How many square centimeters are there in a square decimeter?

5.3. Draw a square grid on a cardboard. Color 4 – 5 squares of 1 dm^2 in different colors, then cut them out with scissors.

5.4. Estimate between which values the surface area of your notebook is in square decimeters.

5.5. Measure the dimensions of your notebook. Calculate the surface area of your notebook in square centimeters and prove that your estimate was correct.

5.6. Each group, using square decimeter tiles of various colors, will create a square with dimensions of 10 dm x 10 dm on the assembled desks. What are the dimensions of the resulting square? Based on its similarity to square decimeters, what will this surface (figure) be called?

5.7. How many dm^2 are in a square meter?

5.8. How many cm^2 are in 1 m^2?

5.9. Is the surface area of your desk smaller or larger than 1 m^2?

6. Let's Measure Our Classroom

6.1. Draw a square meter on the classroom board. Divide the obtained square meter into square decimeters. Divide one of them into square centimeters.

6.2. Measure the dimensions of your desk, calculate its surface area, and express the area in square centimeters, square decimeters and square meters.

6.3. As a group, measure the dimensions of the classroom boards, door, windows, cupboard, etc., and calculate their surface areas in square meters, square decimeters, and square centimeters.

6.4. Measure the dimensions of the classroom and calculate its surface area in square meters, square decimeters, and square centimeters. Which of the obtained results is the most accurate?

7. The Are – How Big Is That Area?

(Field measurement – the lesson takes place on the school sports field for mini-football or handball)

7.1. In the schoolyard, use a rope and a meter tape to create a square with a side of 10 m. Mark the area of one is with chalk.

7.2. Measure the dimensions of the mini-football (handball) field. What is its perimeter, and what is its surface area? How can you calculate the positions of the goalposts if the goal is 3 m wide? How can you mark the center of the field?

7.3. In the schoolyard, create and mark a field for the game “Dodgeball” with dimensions 10 m x 20 m. How can you achieve a rectangular shape? Calculate the surface area of the field in ares and square meters.

7.4. The tied rope is 20 m long. Create the largest possible square or rectangular area.

7.5. The assigned rectangular area is 64 m^2. How can you organize the rectangular space so that the least amount of money is spent on fencing it?

8. Art Activities

8.1. On a piece of cardboard, draw a square decimeter (a square with sides of 10 cm). Divide the resulting square into square decimeters and color them so that you get 25 square centimeters of red, blue, white and green. Cut the colored square into square centimeters.

8.2. Using the small squares, you’ve cut out, assemble the Serbian flag with dimensions of 10 cm by 6 cm, making sure that each color occupies an equal area. What is the surface area of the flag you have created? How many square centimeters does each color cover? Can you use the same squares to assemble:

a) the French flag; b) the Dutch flag; c) the Russian flag?

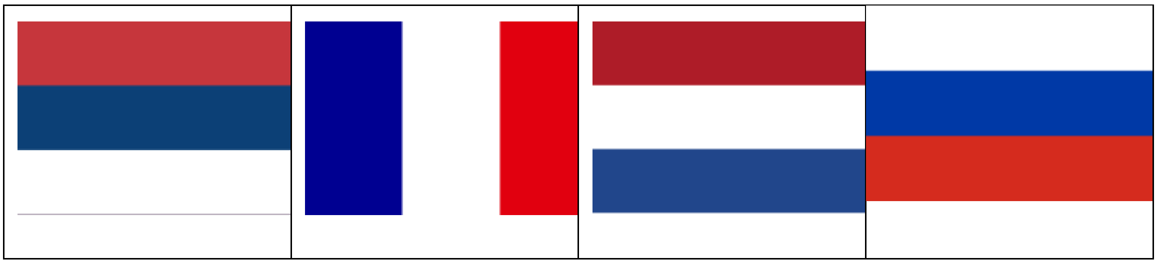


Figure 15

8.3. Can flags of other countries (such as the Italian or Hungarian flag) be made from the available small squares?

8.4. What is the surface area of the white, red, blue and green “squares” in the following “rug” mosaic?

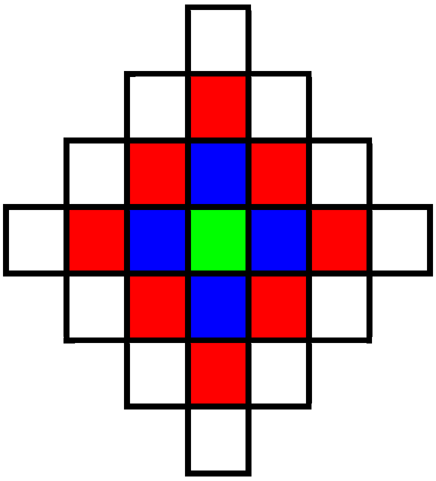


Figure 16

8.5. Using the available squares, create your own mosaic:

a) with the smallest possible surface area; b) with the largest possible surface area.

9. Possible Tasks for Homework and Additional Work After School

9.1. You have 40 squares, each with an area of 1 cm^2. Create a square with the largest possible surface area from the small squares.

9.2. You have 20 squares, each with an area of 1 cm^2. Create a rectangle with the largest possible perimeter from the small squares.

9.3. From a square with an area of 25 cm^2, two squares were made by cutting and assembling (with no leftover material). What are the perimeters of these squares?

9.4. Is it possible to obtain 13 smaller squares by cutting a square with an area of 36 cm^2?

9.5. A cardboard square with a side of 13 cm was cut into a new square with a side of 12 cm. can the leftover material be used to create: a) one square; b) two squares whose side lengths are natural numbers?

9.6. A football field has a length of 110 m and a width of 65 m. grass needs to be planted on the field. It is known that 3 kg of grass is needed for 5 m^2 of surface area, and 1 kg of grass seed costs 173 dinars. How much money is needed to buy the seed to cover the football field?

9.7. A piece of cardboard with an area of 150 cm^2 was cut and assembled to form a square with the largest possible surface area, whose side length is a natural number. What are the perimeter and area of the resulting square?

9.8. Shepherd Mile rented a meadow with an area of 9 ares and wants to fence it off to keep his lambs safe. One meter of fencing costs 1,200 dinars. How should Mile choose the dimensions of his rectangular plot so that he spends the least amount of money on fencing? How much money will he need?

9.9. Teacher Ljilja took her students to the countryside. The owner of the meadow where they planned to create a Dodgeball game field told Ljilja that she could enclose a rectangular space with a perimeter of 80 m. How should teacher Ljilja choose the dimensions of the space to get the largest possible area for the game?

9.10. The heating company charges for heating based on the amount of heat energy delivered. In Mira's hair salon, which measures 6 m by 4 m, there is underfloor heating that costs 5,112 dinars per month. What is the cost of heating per square meter of heated space?

9.11. Dragan needs to tile his disco, which has a length of 20 m and a width of 10 m. In the store, he saw three types of rectangular tiles: 20 cm x 20 cm, 25 cm x 25 cm, and 10 cm x 25 cm. The first tiles cost 200 dinars, the second 300 dinars, and the third 100 dinars. Since all tiles are of the same quality, Dragan decided to choose the cheapest option for tiling. Which tiles did Dragan choose? How many tiles are needed? What is the cost of tiling?

9.12. Engineer Zoran has been tasked with creating a mosaic on a floor with dimensions of 11 m x 10 m, using tiles in the shape of the Cyrillic letter Г. The tile consists of three identical squares with a side of 20 cm. Will Zoran be able to complete the task (without cutting the tiles)?

9.13. A given square is divided into four smaller squares by two lines, and each smaller square has a perimeter of 24 cm. What is the area of the original square?

9.14. A square with a side of 16 cm is divided by two lines into four congruent triangles. What is the area of each of these triangles?

9.15. The perimeter of a square is numerically equal to its area. What are the perimeter and area of this square, measured in meters and square meters?

9.16. The area of a square is 8 times larger than its perimeter. What are the perimeter and area of the square, measured in meters and square meters?

9.17. If the sides of a square are tripled, how many times does the perimeter increase, and how many times does the area increase?

9.18. If the side of a square is increased by 3 cm, its area increases by 57 cm^2. What is the perimeter of the original square?

9.19. The sides of two squares differ by 1 cm, and the difference in their areas is 63 cm^2. Determine the perimeters and areas of these squares.

9.20. The sum of the perimeters of two squares is 200 cm, and the difference in their areas is 100 cm^2. What are the perimeters and areas of these squares?

9.21. From cardboard squares with sides of 3 cm and 4 cm, a new square was made by cutting and assembling without any leftover cardboard. What are the perimeter and area of the new square?

9.22. The sides of a rectangle differ by 2 cm. If each side of the rectangle is increased by 3 cm, the area of the rectangle increases by 105 cm^2. Calculate the perimeter and area of the original rectangle.

9.23. A square and a rectangle have equal areas. The sum of the sides of the rectangle is 13 cm, and the difference between them is 5 cm. Which shape has the larger perimeter: the square or the rectangle?

9.24. Covering a floor requires 200 rectangular tiles with dimensions of 22 cm x 11 cm. How many square tiles with dimensions of 20 cm x 20 cm are needed to cover the same floor?

9.25. From a cardboard square with a side of 10 cm, a square with a side of 6 cm was cut. Can the leftover cardboard be used to create a new square without any leftover material? What are the side length and perimeter of the new square?

9.26. Can a cardboard square with a side of 6 cm be cut into 12 smaller squares whose side lengths are natural numbers, without any leftover material?

9.27. The sides of rectangle ABCD are AB = 6 cm and BC = 4 cm. Point E is on side AB, and point M is on side CD. Determine the length of line segment EM if the perimeter of quadrilateral AEMD is 14 cm and the perimeter of quadrilateral BEMS is 16 cm.

9.28. A rectangle with a perimeter of 96 cm is divided by one line into two congruent squares. How much larger is the perimeter of the rectangle than the perimeters of the squares.

9.29. If one side of a given square is extended by 8 cm and the other is reduced by 6 cm, a rectangle is formed whose area is equal to the area of the given square. Determine the perimeter of both the square and the rectangle.

Instruments for Researching the Effects of Experimental Teaching

To measure the impact of the experimental STEAME teaching approach, the following assessment tools were used: Test 41, Test 71, Five-Minute Quizzes (which, despite their name, lasted 7-8 minutes).

TEST 41

TEST 71

Surface Area of Squares and Rectangles

1. The lengths of the sides of a rectangle are 13 cm and 24 cm. Calculate the area of the rectangle.
The area of the rectangle is __________ cm^2.

2. The perimeter of a square is 88 cm. What is its area? (circle the correct answer.)
A) 400 cm^2 B) 354 cm^2 C) 484 cm^2 D) 476 cm E) 476 cm^2

3. The side lengths (dimensions) of a rectangle are natural numbers, and the area of the rectangle is 7 cm^2. What is the perimeter of the rectangle?

The perimeter of the rectangle is ___________ cm.

4. What is the area of the figure in the following image? (Circle the correct answer):

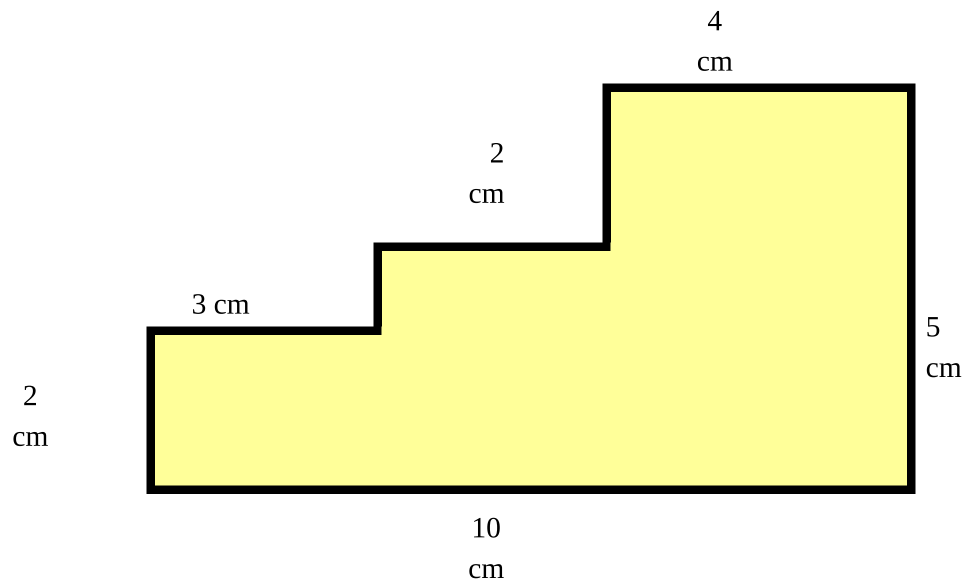


Figure 17

A) 20 cm^2 B) 28 cm^2 C) 28 cm D) 35 cm^2 E) 32 cm^2.

5. A rectangular bathroom with a length of 3 m and a width of 2 m needs to be tiled with square ceramic tiles, each with a side of 25 cm. How much money is needed to purchase the tiles, if one tile costs 100 dinars?

The amount of money needed for purchasing the tiles is __________ dinars.

Five-Minute Quiz 1

Given a square with a side of 5 cm and a rectangle with a length of 4 cm and a width of 6 cm, compare their perimeters and areas.

Five-Minute Quiz 2

The area of a square is 36 cm2. What is the area of a square that has a side twice as long?

Five-Minute Quiz 3

Using scissors, crayons and a square grid, color and cut out:
a) A square (yellow) with an area of 16 cm^2;
b) A rectangle (blue) with an area of 14 cm^2;
c) A triangle (red) with an area of 12 cm^2.

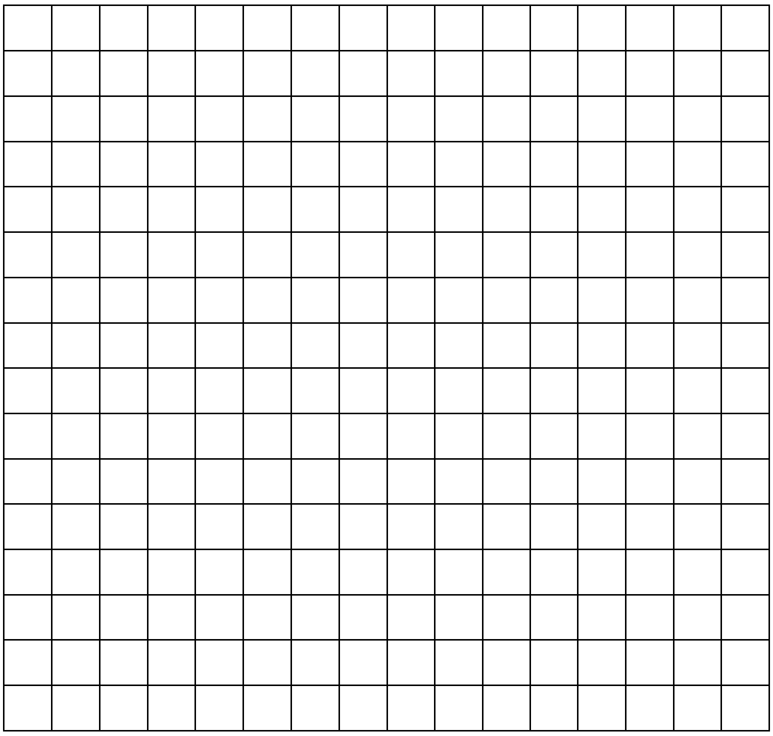


Figure 18

Research Results

The research was conducted on two different grades—IV and VI and involved several tests and quizzes. The results of the five-minute quizzes and the tests are summarized below:

Five-Minute Quiz Results (Percentage of Correct Answers)

	IV Grade	VII Grade	Combined Results
1	65%	80%	91%
2	72%	85%	
3	37%	50%	75%
4	49%	61%	
5	9%	18%	8%

Table 1

Test Results

Number of students who solved all tasks on the test:
- IV grade: 2 out of 158 (1.26%)
- VII grade: 16 out of 121 (13.22%)

Number of students who solved zero tasks on the test:
- IV grade: 24 out of 158 (15.18%)
- VII grade: 8 out of 121 (6.61%)

The research findings suggest that while experimental STEAME teaching has positive outcomes, there is always room for improvement.

Key conclusions include:

1. Positive Impact of STEAME: I am confident that the STEAME approach can significantly enhance various aspects of learning, including functional literacy.
2. Realistic Implementation Expectations: While STEAME, active learning, and project-based approaches are beneficial, it is unrealistic to expect these methods to be fully applied in every single lesson throughout the academic year. A balance must be maintained.
3. Principled Lesson Design: It is enough if teachers keep the core principles of STEAME in mind when designing lessons, rather than trying to implement the entire approach in every class.
4. Contribution to Future Teaching: This study is a small contribution to the broader effort of familiarizing educators with STEAME and encouraging its more frequent use.

Further Development of the Model

To continue improving the STEAME teaching model, the following steps are proposed:
1. Enhancing the model: Continuous refinement of all elements of the model.
2. STEAME Materials: Development of STEAME materials for practical lessons.
3. New Concepts: Introducing square millimeters, hectares, square kilometers, and associated problems into future lessons.
4. Expanded Curriculum: Creating additional lessons for extended classroom use.
5. STEAME Homework: Designing STEAME-based homework assignments to reinforce learning.
6. Ongoing Testing: Further testing and refining the model in real teaching environments.

Plans for Future Use of the Model

Looking ahead, the improved STEAME model will be further shared and utilized in various ways:
- Presenting the Model: Sharing the improved model at professional gatherings, conferences, and educational forums.
- Teacher Training: Educating teachers in professional development centers about the benefits and application of the STEAME approach.
- Publication: Creating and publishing a guidebook titled *"STEAME Variations on the Topic: Surface Areas of Squares and Rectangles,"* which will offer practical resources for educators.

References

Bequette, J. W., & Bequette, M. B. (2012). A Place for Art and Design

Clements, D. H. (2003). Teaching and Learning Geometry. In J. Kilpatrick, W. G. Martin, & D. Schifter (Eds.), A Research Companion to Principles and Standards for School Mathematics.

E. Sevimli, E. Unal, Is the STEM Approach Useful in Teaching Mathematics? Evaluating the Views of Mathematics Teachers, European Journal of STEM Education, 7(1) (2022), pp. 1-11.

F. Rezvanifard et al., Advancing engineering students' conceptual understanding through puzzle-based learning: a case study with exact differential equations, Teaching Mathematics and its Applications: An International Journal of the IMA, 42(2023), pp. 126-149.

https://www.e-ucebnici.mon.gov.mk/pdf/Matematika_6_mk.pdf К. Rasimi, V. Gogovska , S. Ristovska
K.A.P. da Silva, A.H. Borssoi, E.C. Ferruzzi, Integration of STEM Education in Differential and Integral Calculus classes: Aspects Evidenced in a Mathematical Modeling Activity, Acta Scientiae, 24(7) (2022), pp. 116-145.

M. Miteva, B. Zlatanovska, M. Kocaleva, Some Examples for Teaching Mathematics in STEM Context, STEM Education Notes, 1(2) (2022), pp. 31-39.

M. SANDERS: STEM, STEM education, STEMmania, The Technology Teacher, Dec./Jan.- 2009, 20–26.

N. Diana et al., Analysis of Teacher Difficulties in Implementing STEM Approach in Learning: a study literature, Journal of Physics: Conference Series, 1806 (2021).

Sousa, D. A., & Pilecki, T. (2013). From STEM to STEAM: Using Brain-Compatible Strategies to Integrate the Arts.

The 37 Greatest Math Quotes of All Time — Mashup Math

Thomas, J. W. (2000). A Review of Research on Project-Based Learning.

Yakman, G. (2008). STEAM Education: An Overview of Creating a Model of Integrative Education.

Mediterranean Journal for
Research in Mathematics Education
Vol. 20, 2024

Evolving Education and STEM: the STEAME Example

Kostis C. Koutsopoulos, Professor, National Technical University of Athens - NTUA, (Athens), Greece. V. P. EUROGEO, Belgium.

Yannis Kotsanis, PhD, Electrical and Computer Engineer of NTUA,
Head of Research and Innovation Department, Doukas School (Athens), Greece.

Abstract: *This paper highlights the need to accept that major changes have taken place in the way society perceives and practice education, which, however, impact and is impacted by technology, in the form of the constantly improving AI, and both enhance the also evolving STEM education (teaching and learning), which in turn determine students' performance. That is, the paper suggests that STEM education has transformed the traditional science teaching and learning into an evolving approach and a teacher–STEM–student a dynamic process. Moreover, it presents a new STEM framework where by achieving the integration and development of curriculum subjects such as environment, economy, arts etc. into a single integrated approach is advocating a didactic method that ensures the transversality of the learning process, utilizing all disciplines that are considered fundamental in the development of individuals in today's societal and working environments.*

Key words: *STEM education, STEAM, STEAME, Shifts in STEM education, Science education evolution, Education framework, Atificial Intellingence in STEM education*

Introduction

Educational stakeholders consider STEM to be the education approach in the fields of science, technology, engineering, and mathematics. It includes teaching and learning activities in all grade levels (from preschool to post-doctorate) and in both educational settings (i.e., classrooms and afterschool programs etc.). In addition, it is an educational approach that encourages critical thinking, problem solving creativity, innovation, collaboration, and teamwork. As the International Science Teaching Foundation (2024) has suggested "this favors the development of a student profile that is flexible, determined, and motivated that allows the student to apply their learning to new situations and relevant contexts". As a result, it is an effective tool for preparing students for the present and future working conditions as well as an efficient vehicle to promote science-oriented careers from an early age. That is, any STEM approach allows students to gain academic skills alongside with science and interpersonal capabilities, which leads at collaborating with one another while mastering the skills needed to innovate and find solutions for real-world problems.

But in accomplishing these goals, it has to achieve the integration and development of subjects such as science, economy, environment, arts etc. into a single interdisciplinary approach. It advocates, thus, a didactic approach that ensures the transversality of the learning process utilizing all disciplines that are considered fundamental in the development of individuals in today's societal and working environments. That is, in the present age of evolving societal beliefs, AI improvements and STEM changes, the role of education in general, and science education in particular, is crucial. It enables students and particularly the youngest, to acquire the skills and competencies necessary in accessing, deal with, constructing, formulating, utilizing, and sharing information and knowledge. Moreover, STEM education should be considered that by linking prosperity with knowledge-intensive jobs underlines the need for a STEM-educated workforce equipped with knowledge, skills and literacies to achieve innovation. (Britannica, 2024).

Given that AI has being integrated into each component of STEM and has gained a significant influence in education a few important points need to be mentioned:

- The integration of AI and STEM in education has been helped by their parallel changes in the last few years. This inevitable integration has created the basis for innovative approaches to teaching and learning.
- In STEAM education, the help of AI in the study of different curriculum subjects leads into adapting content and learning, which in addition fits each student's capabilities and enhance personalized learning (Kim & Kim, 2023).
- The new forms of STEM that include different expressions of art (i.e., music, poetry etc.), with the help of AI enhance creativity, but also help students bridge the gap between pure science subjects and art, emphasizes interdisciplinary learning and promoting a holistic understanding of complex systems and problems.
- As will see next (Fig 1) AI is helping the latest forms of STEM to achieve integrated competences.
- AI contribution to STEM education, in the form of software development and hardware optimization, enhances its application potential.

According to the above, we can redefine the four subject components of STEM (Koutsopoulos 2019).

Science: Various sciences fall withing this component of STEM, including biology, medicine, physics, chemistry, earth science etc. which help us to better understand the world around us.

Technology: Technology, in the form of AI, is the result of scientific advancements that have been put into practice, involving not only developing the means to solve societal problems, but also to improve students' knowledge, skills and competences.

Engineering: Engineering is the bridge between science and technology, which transforms theoretical knowledge into practical applications. It is the process through which technological concepts are realized and refined. Engineering encompasses various fields that their systems are enhanced. But from an educational point of view, it helps devising ways to solve problem and help address future challenges created to mitigate them.

Mathematics: In STEM, mathematics is the necessary key to operate. It is the basic tool in any research and development that improve human conditions. By providing an efficient way to understand the laws of nature and the natural phenomena, as well as solve practical problems in all disciplines, including education, it makes things easy to deal with them and understand them.

Importance of STEM Education and its impact on teaching and learning

The education institutions (ASU, iDTech, FPU, Study in the USA, Embassy Education) and the literature, probably including and this paper, the effort to emphasize STEM's importance in education, overstressed that STEM is mainly about setting students up for a job market that society needs. However, STEM is about teaching students how to consider issues in a systematic way allowing them to analyze data and construct-formulate effective solutions, which are skills needed in any productive economic area and in any country. The reasons and consequently STEM's importance is that with these skills the future workers (students) can address problems utilizing their thinking abilities and mainly creating new innovative approaches in achieving their objectives.

Moreover, following is a list exemplifying STEM's importance, compiled by examining several educational institutions programs:

- Builds talents in problem-solving, collaboration and innovation.
- Provides a base of specialized knowledge useful in many professional roles.
- Teaches critical thinking skills and instills a passion for innovation.
- Assists in the problem-solving and exploratory learning that fuel success across a variety of tasks and disciplines.
- Helps students navigate an increasingly complex tech-driven world.
- Teaches students skills that can lead to innovations the world needs to sustain the modern economy.
- Raises social awareness and communicates global issues to the general public.

In terms of STEM impacts, the characteristics of STEM education that play a determining role are: first, the hands-on instruction and the real-word issues application. In other words, STEM is an educational effort that goes beyond the traditional academic approach, in order to give students, the skills and tools to solve on their own real-world problems. For example, instead of simply learning about the approaches and techniques that go into building a highway, STEM teaches students about all the factors involved (not only engineering, but ecovomic, environmental, political etc.) and then lets them apply the knowledge of all of these to build their own highway. Second, despite the emphasis on science, students have to consider all curriculum subjects. The U.S. Department of Education suggested that students should "have the chance to become the innovators, educators, researchers, and leaders who can solve the most pressing challenges facing our nation and our world, both today and tomorrow", which can be done only withing a holistic approach. Third, STEM curricula is a different way of learning because it encourages students to use all subjects in addition to science. This integrated approach teaches students how to engage all disciplines, rather than focusing on a single subject, even if it is in science. STEM students learn to think creatively, acquire knowledge, and master every discipline in order to come up with an answer.

The previous discussion shows that STEM has profound implications for teaching and learning. However, these impacts are influenced by the evolving role of society in determining the literacies students required to navigate the science landscape. Thus, the use of STEM in education is raising fundamental questions about the nature, structure and components of teaching and learning in order to determine students' capacity to determine how and when to make judicious use of STEM in their science education. In sum, there are significant implications of STEM for education.

Indeed, the tremendous Increase of accessibility to information as well as the means of communication have brought major changes in the way society perceives and practice education, which impact present day technology in the form of AI and both in turn enhance STEM performance. On the other hand, STEM application is not only finding answers to a given problem, but also about questioning and understanding concepts. It is in essence an inquiry-based or project-based and as such is analogous with critical thinking (Ghanbari, 2015).

In sum, the evolutions in society that influence STEM changes clearly demonstrate the potential of STEM in enabling new forms of science teaching and learning and enhancing teacher science tasks. In other words, STEM has transformed traditional science teaching and learning into an evolving approach and a teacher–STEM–student a dynamic process. As a result, these STEM changes or paradigm shifts requires a re-examination of the roles and impacts of the ever-evolving society and science education on teaching and learning, which in turn determine students' literacies. In other words, it is imperative to determine what STEM actually represent (its evolving nature have provided several forms), and how can it be used into the educational process.

Navigating the shifts in teaching and learning

Wellman (in Truss, 2010) has written that "At this point we appear to have a 19th century curriculum... and 21st century students facing an undefined future". In other words, he believes that the world has changed in ways, which we are not able to understand and mainly to prepare students to face these changes. At the onset and in opposition to his thesis this paper suggests that STEM education, which has emerged as expressing the scientific disciplines in the 21st century can offer skills like problem-solving and critical thinking as well as the ability to create and communicate successfully with the scientific community. This is based on the fact that the fundamental sciences educational approaches, in the form of STEM, are constantly evolving developing new, efficient and effective educational environments that help students to face the complex and challenging present and future conditions, which can and should be achieved.

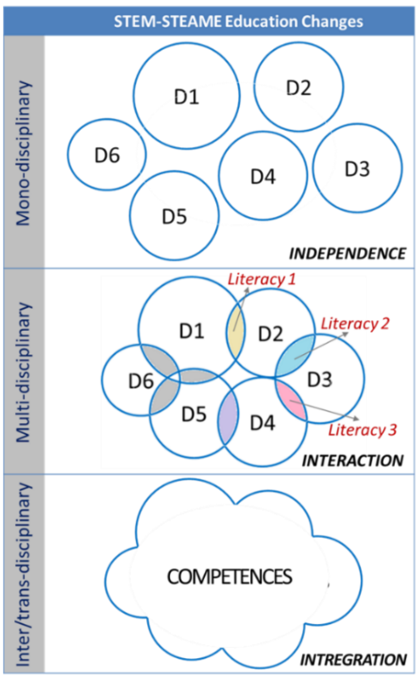
Indeed, in examining the world educational system one can fortunately discern a constant evolution or what Kuhn (1970) has termed paradigm shifts of basic educational aspects addressing the issues raised by Wellman and others (Koutsopoulos & Kotsanis, 2014). The most import of them are:

- **Society**: The way education is perceived and practiced has evolved into considerable changes. More specifically, society after WWII had ignored education focusing on economic/development issues. Later on, a new alternative was established where society accepted that education should satisfy principal human requirements and therefore the concept of education came back to the center of societal concerns and activities. Nowadays, society's response to education has further evolved into a holistic approach, which accepts that education should be related in a dialectical harmony with all the other factors of education. That is, given that society's changes are the determining force in all the other observed educational paradigm shifts or are the results of changes in societal perceptions and beliefs. It leads to the condition that society has a symbiotic relationship with education in that education is the transmission of society's norms and values that education process has to serve. Therefore, we are in the era of a holistic education.

- **Technology/AI**: There have been four educational paradigm changes differentiating technology application in teaching and learning (Koutsopoulos & Kotsanis, 2023): first, the appearance and use of Personal Computers has enhanced students' performance as was clearly established by the OECD (2017); second, the capabilities provided by the Internet allowed students to communicate, create, disseminate, store, and manage information, providing a step-wise evolution in education. Internet access has increased the flow of diverse information and expanded the space for knowledge and information as well as effecting societal changes; third, Mobile Devises (i.e., laptops, personal computers and mobile phones) have become successful learning and teaching tools in and out of the classrooms; and fourth, Artificial Intelligence, the latest form of technology tools, is transforming the way we live, work, and from the prospective of this paper learn science by changing the science education. In general, AI has fundamentally changed teaching and learning indicating that AI has come to stay, generally in education and particularly in science teaching and learning, and thus we are now in the AI educational era.

- **STEM Education**: At its inception STEM was defined as an interdisciplinary approach of Science, Technology, Engineering and Mathematics, aiming towards a cross-disciplinary approach to education, in order to improve students' problem solving and critical analysis skills in these four scientific areas. However, because teaching and learning of these areas by necessity follow changes in the way education is considered and practiced, which in turn are based on the way societal values are reconstructed and are considered as societal goals. These have resulted in new educational approaches to educate students in science for the existing and future conditions. As a result, over time an evolution of changes has taken place in STEM responding to societal and educational adjustments. In considering STEM and science education the following three changes have occurred (Koutsopoulos, 2019): first, for a long time the STEM consideration of education was fragmented, leading the separate disciplines of science, technology, engineering and mathematics to be individually considered as the only ones that could provide the methodology and knowledge to deal with these individual science dimension, or an **independence** of science disciplines approach; second, in the last few decades the application of teaching and learning of STEM imposed a condition requiring to be approached from various perspectives and concerns (Anderson, 2019; Godwin & Kaplan, 2008). That is, science education was treated as if it is the integrated sum of all the different components of the multi-faced cultural, political, social, environmental and economic reality or an **interaction** of science disciplines approach, providing literacies as a result of their combined contribution; third, recently an **integration** approach is considered as needed in science education. An interdicsiplinary approach that has to be simultaneously cultural, technical/technological, social, political etc., in dialectic harmony and respecting all aspects of teaching and learning an integral part of which are all curriculum disciplines, creating integrating competences (Fig. 1, Koutsopoulos 2019). In other words, it should draw on the various perspectives that express relations and interdependencies of all the curiculum subjects that are more than the original areas of STEM (i.e., arts and crafts, reading and writing, visual thinking, modeling etc.) as access points for guiding student to inquiry, dialogue, and mainly problem solving and critical thinking. In sum, it is evident that in science education all disciplines are teaching and learning factors and that science teahing and learning represents the era of an evolving system of STEM-family education (i.e., STEM, STEMM, STEAM, STEAME etc.).

Fig.1: STEM and STEAME Education changes



In addition, STEM education as well as specially STEAME projects are characterised by the use of:

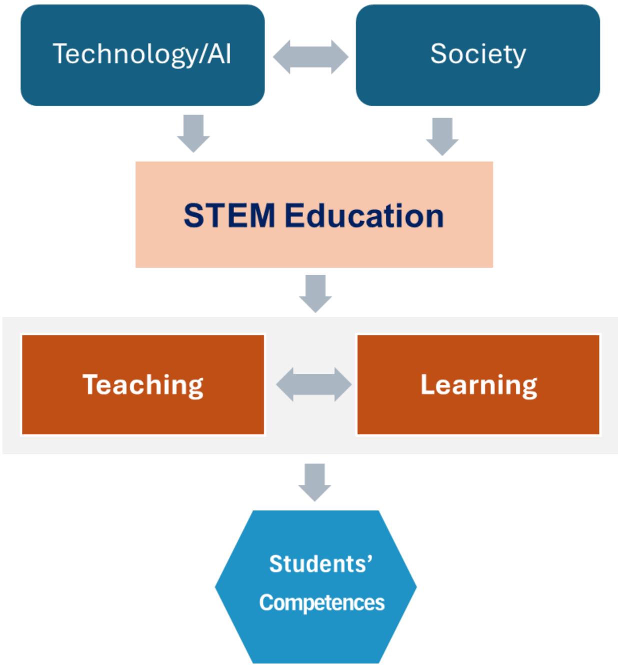
- **Project-based Learning**: Project-Based Learning (PBL), a major componet of STEM, is a methodology utilized by students in order to acquire content knowledge and skills by engaging and responding to specific questions, problems, or challenges. It based on the principle that effective learning system should be base on the acquisition of content material within a meaningful tasks framework, but mainly focusing on students' direct involvement. As a result, it can be characterized not only as project-based, but mainly as student-centered and student-led learning. The Project- based learning methodology cannot and should not be considered comparable or identical to the traditional 'doing a project'. In the first case the method is student-driven, where the project is the structured and is related to real learning. That is, is focused on the process and not on the product, which in turn allows effective learning. In the second case students usually offered all the information they need, which unfortunately they have to memorize it and the assigned problem leads simply to demonstrate how to apply the given information. In sum, PBL has changed teaching and learning, which indicates that the traditional "doing a project" is abandoned and we are now in the PBL educational era.

- **Inquire-based learning**: The previous arguments (PBL vs doing a project) can be made and with the Inquiry-based STEM learning, which is related to students' hands-on educational approach as an effective way to solve problems (Deák, 2021). This approach basically mirrors the way that scientists, engineers, artists, mathematicians, innovators etc. approach the real world and as a result is much more than merely hands-on learning. Consequently inquiry-based science should not to be confused or compared with 'hands-on' science and thus we are in the inquire-based era.

Evolving Education and STEM framework

A basic educational concern in the 21st century is that the major goal of the educational system is to teach the future work force to function in a highly technical environment that is constantly evolving. Given that STEM expresses the science component of education is having profound implications for teaching and learning. However, these implications are **society and technology/AI dependent** because how society perceives, practices education and creates the framework for the literacies (knowledge, skills and competences) accepted by society, that affects and is affected by technology/AI, determine STEM education. In other words, there are significant implications of societal and technology/AI conditions to STEM education (**teaching and learning**), which in turn have an impact on **Students' achievements** as shown in the framework shown in fig. 2 and explained next.

Fig.2: STEM Education Framework



Society: Society has a symbiotic relationship with education in that education is the transmission of society's norms and values. However, the way education is perceived and practiced is inevitably linked to the societal beliefs and approaches, which in turn leads into formulating students' literacies by accepting relationships, interdependencies and interactions in their knowledge, skills and competences. This is because society is related in a dialectic harmony with education and both represent the two sides of the same coin. As a result, the major role of society in the determination of the evolving STEM is in the following:

- Perception of science education
- Practice of science education
- Literacy formulation (Knowledge, Skills, Competences)

Technology/AI: Technology and in particular its modern expression, AI, plays an important role in STEM. Even at its most basic form, AI is distinct from any previous type of digital technological tool, because of its capacity to mimic human behavior. As a result, due to this feature AI tools tend to replace human decision-making with the utilization of predictions based on the analysis of past cases data, as opposed to the previous generations of ICT tools, which focused on facilitating routine tasks. In addition, as the UNESCO (2024a, 2024b) has articulated AI in education follows an approach that establishes fundamental ethical and practice principles to help the educational activities of all stakeholders. As a result, the human-centered role of AI in the determination of STEM is in the following:

- Mimic human behavior.

- Replace human decision making.
- Establishes ethical and practice principles.

In addition, it is appropriate to mention that technology/AI's role will:

- Continue to have an Impact on Education
- Continue to be an integral part of education
- Moore's law will continue to operate (technology' power will increase and its price degrease exponentially)
- Metcalfe's law will continue to operate (the power of a network will increase by the square of the number of users).
- Technology fusion will continue to operate (the distinction between computers, photos, publishing, TV/video, and telecommunications will be blurring).

STEM Education: Nowadays STEM is considered as the interaction of cultural, technical/technological, social, political etc. educational subjects. As the STEM Education in Europe: A Comparative Analysis Report (Haesen et al., 2018), has elaborated, STEM involves mathematics, which reflects the symmetry and shapes in education, art and engineering to justify the way each particular educational subject is adapted to its surrounding, humanities that lead students to ecological awareness etc. Moreover, STEM is focused in problem solving "were students and teachers co-operate as co-researchers", requiring from teachers, who by the way make the difference in the learning process, to find the appropriate problems that students have an interest in them, but mainly been able to meet the goals of these problems, which should be within their capabilities. Finally, STEM should be focused on attitudes and skills, such as communication skills and creativity, but mainly in critical thinking by connecting content, attitude and skills. As a result, the human-centered role of AI in the determination of STEM is in the following:

- S: Support creativity and communication.
- T: Treat all scientific subjects.
- E: Establish problem solving approach.
- M: Manipulate critical thinking

Learning: Learning utilizing AI has to accomplish at least three major goals: First, the basic mechanist way of simply transmitting knowledge contained within individual disciplines and which is usually downgraded (i.e., the teacher instructs how water evaporates in physics and chemistry and water is one of the physical elements); second, searching for knowledge by creating literacies out of related disciplines (i.e., students in order to be familiar with phenomena and processes in physic, the necessary literacy they have to be also familiar is certain mathematical principles); and third, to formulate competences by instituting knowledge, which have to include cultural, technical, social, political etc. aspects as well as and skills (the triptych knowledge, skills, and competences). As a result, the learning process of the impact of society and AI is mainly concentrated in the following:

- Transmitting Knowledge
- Searching for knowledge.
- Constructing-Creating Knowledge.

These coincide with UNESCO's position that use the terms *acquire*, *deepen* and *create* as they relate to AI competences as shown in Table.1

Table 1: UNESCO AI Competency Framework for Teachers high-level structure (UNESCO, 2024a).

Aspects	**Progression**		
	Acquire	***Deepen***	***Create***
1. Human-centered mindset	Human agency	Human accountability	Social responsibility
2.Ethics of AI	Ethical principles	Safe and responsible use	Co-creating ethical rules
3. AI foundations and applications	Basic AI techniques and applications	Application skills	Creating with AI
4. AI pedagogy	AI-assisted teaching	AI–pedagogy integration	AI-enhanced pedagogical transformation
5. AI for professional development	AI enabling lifelong professional learning	AI to enhance organizational learning	AI to support professional transformation

Teaching: Teaching STEM using AI leads into a non-linear teaching process or a disproportionality between cause (teaching changes) and effect (learning results). In addition, there are forces, which express the competing effects of teaching change and the expected resistance to these changes (i.e., the resistance of educational stakeholders in accepting the teaching changes). Finally, and fortunately, there exist system-internal drivers of change that lead towards stabilizing the new teaching approaches (i.e., the increasing number of teachers' ICT literacy). As a result, the teaching process as a result of the impact of society and AI is mainly concentrated in the following:

- Non-linearity of technology application.
- Resistance to Technology changes.
- Internal drivers enhancing change.

In terms of teaching the spiral curriculum approach should be mentioned because it is a very appropriate tool in achieving effective and efficient science education. The basic features of the spiral curriculum are:

- The student revisits a topic, theme or subject several times throughout their school career using various learning pathways and methods for instruction.
- The complexity of the topic or theme increases with each revisit.
- New learning has a relationship with old learning and is put in context with the old information.

In turn, this process provides the following benefits:

- The information is reinforced and solidified each time the student revisits the subject matter.
- The Spiral Curriculum allows for a logical progression from simplistic ideas to increasingly complex ideas.
- Students are encouraged to transfer their previous knowledge to meet later course objectives.

Students' Achievements/Competences: Students' response to STEM education is resulting from the teaching and learning approaches under the influence of AI and societal concerns. That response is defined in terms of three levels of progression of competency development, which represent the levels students with the help of teachers can achieve in all the competency aspects in relation to AI competency (Table 2). This teaching and learning progression, is focused and emphasizes desired outcomes at each level of AI aspect rather than creating inflexible, predefined steps that students (assisted by teachers) must go through. The first progression levels define the essential set of basic AI competencies required; the second, specifies the intermediate competencies that are needed to achieve a meaningful integration of AI; and the third one is concerned with advanced competencies required for the creative utilization of AI systems (Casal-Otero et al. 2023). As a result, the major competences that students with the help of teachers are required to acquire in STEM application are the following:

- Understand.
- Apply.
- Create.

Table 2: Revised Bloom's Taxonomy and AI literacy. (Ng, DTK et al. 2021)

Level	*Description*
1. Know	*Use information in new situations:* Copy, reproduce, recall & define AI concepts
2. Understand	*Explain ideas or concepts:* Describe, explain, interpret & demonstrate the meaning of AI
3. Apply	Use information in new situations: Execute, implement, use & apply AI apps in different contexts
4. Analyse	*Draw connections among ideas:* Organize, compare, decompose & abstract an AI problem
5. Evaluate	*Justify a stand or decision:* Appraise, predict, detect & justify decisions with AI apps
6. Create	*Produce new or original work:* Design, assemble, construct, build & develop AI applications

In addition to the three pillars regarding competences (understand, apply, and create, within a spiral learning sequence) it also aims to encourage the following aspects of their competences

- The first additional aspect concerns a learner-centered attitude towards the benefits and risks of AI (Long et al. 2020).
- the second aspect encompasses the social skills to navigate, understand, practice and contribute to the adaptation of a set of principles to regulate human behavior within the AI framework.
- The third aspect should incorporate AI techniques and applications to achieve a view of AI operational skills, tools and authentic tasks.

- The integrated last aspect and more advanced should include AI system design, which include skills that determine the problem scoping, architecture building, training, testing and optimization of AI systems, in order to gain deeper understanding of AI systems.

The STEAME example

A current form of the evolving STEM Education is the European STEAME program (since 2109, *STEAME.eu*), which is an educational initiative designed to integrate Entrepreneurship into the previous STEM form, known as STEAME (Science, Technology, Engineering, Arts, Mathematics and Entrepreneurship) framework (Makrides, 2023). The STEAME program is based on the STEM paradigm shifts and their framework presented earlier, which shows the validity and usefulness of applying them.

In addition, however and for the benefit of European educational stakeholders, a detailed presentation of the origins, objectives, implementation strategies, benefits, challenges, and impact of the STEAME program in the European educational landscape is presented next.

Origins and Rationale of STEAME: The STEAME program emerged from a growing recognition of the need for education systems that can adapt to the rapidly changing socio-economic landscape. The traditional STEAM framework emphasizes interdisciplinary learning by combining scientific and artistic disciplines to foster creativity, critical thinking, and problem-solving skills. However, as the digital economy expands and new business models evolve, there is an increasing need for students who should develop entrepreneurial skills.

Entrepreneurship was added to the STEAM framework to create STEAME, aiming to prepare students not only with technical and creative skills, but also with the ability to innovate, create business opportunities and adapt to complex, fast-changing environments. This extension is particularly relevant in Europe, where there is a strong push towards fostering innovation, competitiveness, and economic growth through education (Makrides, 2023).

Objectives of the STEAME Program

The STEAME program seeks to achieve several key objectives such as:

- Interdisciplinary Learning: To blend STEM subjects with the arts and entrepreneurship, encouraging students to think creatively and apply their knowledge in diverse contexts.
- Innovation and Creativity: To promote a culture of innovation by encouraging students to take risks, experiment and learn from failures in a controlled environment.
- Entrepreneurial Mindset: To instill an entrepreneurial spirit among students, equipping them with skills like: leadership, financial literacy, marketing, and business development.
- Real-World Problem Solving: To engage students in solving real-world problems through project-based learning and collaboration with industry partners.

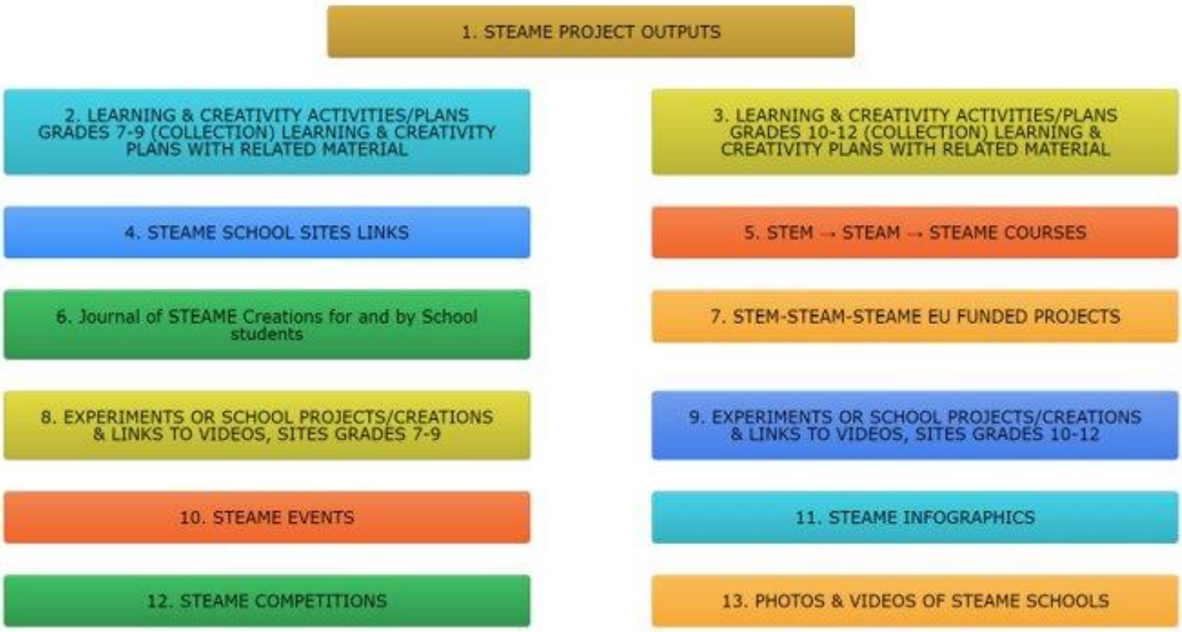
- Inclusivity and Accessibility: To make high-quality STEAME education accessible to a diverse range of students, including those from underrepresented communities.
- Future-Readiness: To prepare students for the future job market, which increasingly values interdisciplinary skills, adaptability, and innovation.

Implementation Strategies: The STEAME program is implemented through various strategies that vary across different European countries, tailored to the specific educational policies and needs of each region. Key implementation strategies include:

Curriculum Integration:
- Modular Approach: Introducing entrepreneurship as a module within existing STEAM courses, allowing for flexibility in learning and an interdisciplinary approach.
- Project-Based Learning (PBL): Encouraging students to undertake projects that require them to apply knowledge from various STEAM disciplines while incorporating business and entrepreneurship principles. Projects often simulate real-world challenges, where students create startups, develop business plans, or design innovative products.

Teacher Training and Resources (fig 3):
- Professional Development: Providing training and resources for teachers to effectively deliver STEAME content. This includes workshops on entrepreneurship education, project management, and interdisciplinary teaching methods.
- Collaborative Networks: Establishing networks and communities of practice where educators can share resources, experiences, and best practices related to STEAME education.

Fig 3: The STEAME Observatory: Repository of Resources (Makrides, 2023, STEAME.eu)



Use of Technology and Digital Tools

- Digital Learning Platforms: Utilizing online platforms and tools to facilitate collaborative learning, entrepreneurship simulation, and access to global resources.
- STEM and Business Simulations: Integrating technology-driven simulations that allow students to experiment with business ideas in a risk-free environment.

Industry and Community Partnerships:

- Industry Collaboration: Partnering with businesses and startups to provide mentorship, internships, and real-world case studies for students.
- Community Engagement: Involving local communities and organizations in the educational process to create a support system for student projects and initiatives.

Benefits of the STEAME Program

The integration of entrepreneurship into STEAM education brings several benefits:

- Enhanced Interdisciplinary Learning: By bridging STEM with arts and entrepreneurship, STEAME encourages students to see the connections between different fields. This holistic approach promotes deeper understanding and retention of knowledge.
- Development of Key Competencies: Students gain a range of skills including critical thinking, problem-solving, creativity, collaboration, communication, and leadership. The addition of entrepreneurship fosters skills like financial literacy, market analysis, and strategic planning.
- Preparation for the Future Job Market: With the job market increasingly valuing adaptable, innovative, and entrepreneurial talent, STEAME equips students with the competencies needed to thrive in various careers, whether in traditional industries or in creating their own startups.
- Increased Student Engagement and Motivation: STEAME education often involves hands-on, project-based learning that makes education more engaging and relevant to students. This approach can increase student motivation, especially for those who may not be engaged by traditional teaching methods.
- Promotion of a Growth Mindset: By encouraging experimentation and learning from failure, STEAME fosters a growth mindset, which is crucial for personal and professional development in a rapidly changing world.

Challenges of the STEAME Program

While the STEAME program offers many advantages, there are also significant challenges:

- Resource Limitations: Implementing STEAME requires significant resources, including trained teachers, access to technology, and funding for projects and materials. Many schools, particularly in underfunded regions, may struggle to provide these resources.
- Teacher Training and Preparedness: Teachers may need additional training to effectively deliver STEAME education. There is often a gap between the skills required to teach traditional subjects and those needed for interdisciplinary, entrepreneurial education.

- Assessment Difficulties: Assessing interdisciplinary and project-based learning can be complex. Traditional assessment methods may not adequately measure the skills developed through STEAME education, such as creativity, collaboration, and entrepreneurial thinking.
- Resistance to Change: There may be resistance from educators, parents, and policymakers who are accustomed to traditional educational models. Shifting to a STEAME framework requires a change in mindset and acceptance of new educational paradigms.
- Ensuring Equity and Inclusion: Ensuring that all students have equal access to high-quality STEAME education is a challenge, especially in diverse educational contexts across Europe. Efforts must be made to avoid exacerbating educational inequalities.

Impact of the STEAME Program

The impact of the STEAME program is being observed across various dimensions:

- Student Outcomes: Early evidence suggests that students engaged in STEAME education demonstrate improved problem-solving abilities, creativity, and a greater interest in STEM and entrepreneurial careers. They also tend to perform better in teamwork and leadership roles.
- Educational Practices: The program is driving a shift in educational practices towards more collaborative, interdisciplinary, and student-centered learning approaches. This shift is gradually becoming more prominent in European education systems.
- Community and Economic Impact: By fostering a culture of innovation and entrepreneurship from a young age, the STEAME program has the potential to contribute to local and regional economic development. Students who are equipped with entrepreneurial skills may be more likely to start their own businesses or innovate within existing companies.
- Policy Development: The success of the STEAME program has influenced educational policy across Europe, with several countries considering or implementing similar frameworks to foster innovation and entrepreneurship in their education systems.

The European STEAME program represents a forward-thinking approach to education, blending the strengths of STEM and the arts with the dynamism of entrepreneurship. While there are challenges in its implementation, the potential benefits for students, educators, and society at large are significant. By equipping young people with a diverse set of skills and a mindset geared towards innovation and problem-solving, STEAME education is preparing the next generation for a future that values creativity, adaptability, and entrepreneurial spirit.

As the program continues to evolve, it will be important to address its challenges, ensure equitable access, and continue to refine assessment and teaching methods to fully realize its potential. The STEAME initiative holds great promise for transforming education and fostering a culture of innovation and entrepreneurship across Europe.

Conclusions

The major conclusion of this paper is that nowadays major changes have taken place in the way society perceives and practice education, which, however, impact technology, in the form of the constantly improving AI, and both in turn enhance the also evolving STEM education and its performance that has the following characteristics:

- STEM has transformed traditional science teaching and learning into an evolving approach and a teacher–STEM–student a dynamic process.
- STEM is an educational approach that encourages critical thinking, problem solving creativity, innovation, collaboration and teamwork.
- STEM enables students to acquire the skills and competencies necessary in accessing, deal with, constructing, formulating, utilizing and sharing information and knowledge.
- STEM is an educational effort that goes beyond the traditional academic approach.
- STEM application is not only finding answers to a given problem, but also about questioning and understanding concepts.
- STEM education includes teaching and learning activities in all grade levels (from preschool to post-doctorate) and in both educational settings (i.e., classrooms and afterschool programs etc.)
- STEM evolution (the appearance of new forms) changes the role of education in general, and science education in particular.
- STEM is achieving the integration and development of curriculum subjects such as science, economy, arts etc. into a single interdisciplinary approach.
- STEM advocates a didactic approach that ensures the transversality of the learning process utilizing all disciplines that are considered fundamental in the development of individuals in today’s societal and working environments.

Finally, the paper presents the latest form of STEM, the STEAME program, which has incorporated the roles and characteristics examined. This presentation includes the origins, objectives, implementation strategies, benefits, challenges, and impact of the STEAME program in the European educational landscape.

References

Anderson, J. (2020). Key concepts in ELT: Reflection**.** *ELT Journal*. 74(4)**.** DOI: 10.1093/elt/ccaa039. Accessed 12 Oct. 2024 2024.

Casal-Otero, L et al. (2023). "AI literacy in K-12: a systematic literature review" *International Journal of STEM Education. 10(1).* DOI: 10.1186/s40594-023-00418-7 Accessed 12 Oct. 2024 2024.

Deák, Csaba, Baibhaw Kumar, István Szabó, Gábor Nagy, and Szabolcs Szentesi. (2021). "Evolution of New Approaches in Pedagogy and STEM with Inquiry-Based Learning and Post-Pandemic Scenarios" *Education Sciences* 11, no. 7: 319. https://doi.org/10.3390/educsci11070319. Accessed 12 Oct. 2024 2024.

Ghanbari, **S**. (2015)." Learning across disciplines: A collective case study of two university programs that integrate the arts with STEM". *International Journal of Education & the Arts*, 16 (8): 29-36.

Godwin, L., & Kaplan, S.(2008). Designing ee-Learning Environments: Lessons from an Online Workshop Education. *Computer Science Innovate: Journal of Online Education...* https://www.semanticscholar.org/paper. Accessed 12 Oct. 2024 2024.

Haesen, S., & Van de Put. (2018). "STEAM Education in Europe: A Comparative Analysis Report". EU funded project report. *EuroSTEAM*. ISBN 9789090311968. Accessed 12 Oct. 2024 2024.

Kim, B.-H., & Kim, J. (2016). Development and validationof evaluation indicators for teaching competency in STEAM education in Korea. *Eurasia journal of mathematics, science &technology education*, 12(7), 1909-1924.

Kim, J., McFee, M., Fang ,Q., Abdin O., & Kim, P. (2023). Computational and artificial intelligence-based methods for antibody development. *Trends Pharmacol Sci*. 44(3):175-189. DOI: 10.1016/j.tips.2022.12.005.. Accessed 12 Oct. 2024 2024.

Kotsanis Y. (2018). Models of Competences for the Real and Digital World. *Handbook of Research on Educational Design and Cloud Computing in Modern Classroom Settings*, edited by K.C. Koutsopoulos, et al., IGI Global, 2018, pp. 52-80. https://doi.org/10.4018/978-1-5225-3053-4.ch004

Koutsopoulos, C.K., & Kotsanis Y. (2014). School on Cloud: Towards a paradigm shift. *Themes in Science and Technology Education*. 2014 7(1):47-62. http://earthlab.uoi.gr/theste/index.php/theste/article/view/147

Koutsopoulos, C.K., & Kotsanis Y. (2023).

Koutsopoulos, K. (2019). "STEM Revisited: A Paradigm Shift in Teaching and Learning in the Science Related Disciplines". *Journal of Education, Society and Behavioural Science.30(3): 1-10; ISSN: 2456-981X*. Accessed 12 Oct. 2024 2024.

Kuhn, T.S. (1970). The Structure of Scientific Revolutions. Second edition. Chicago. University of Chicago Press.

Long, D. & Magerko, B. et al. (2020). What is AI Literacy? Competencies and Design Considerations. CHI '20: Proceedings of the 2020 CHI Conference on Human Factors in

Computing Systems. p 1 – 16. https://doi.org/10.1145/3313831.3376727. Accessed 12 Oct. 2024 2024.

G., Makrides. (2023). Η μάθηση στο μέλλον: Εκπαίδευση STEAME στη Σχολική και Τριτοβάθμια, Πανελλήνιο Συνέδριο Μαθηματικής Παιδείας

Ng, DTK et al. (2021). Conceptualizing AI literacy: An exploratory review, AI literacy in K-12: a systematic literature review.

OECD. 2017. *Education at a glance 2017*. OECD indicators. Paris: OECD Publishing.

Study in the USA. (2022) "Why is stem important? the impact of STEM education on society" https://www.studyusa.com/en/a/2157/why-is-stem-important-the-impact-of-stem-education-on-society. Accessed 12 Oct. 2024 2024.

The International Science Teaching Foundation. (2024). *STEM in Education*. Accessed 12 Oct. 2024 2024, Available Science Teaching.org

Truss, D. (2010). On Being an Agent of Change (self edition).

UNESCO. 2024a. *AI Competency Framework for Students*. United Nations Educational, Scientific and Cultural Organization, Paris. https://doi.org/10.54675/JKJB9835 Accessed 12 Oct. 2024.

UNESCO. 2024b. *AI Competency Framework for Teachers*. United Nations Educational, Scientific and Cultural Organization, Paris. https://doi.org/10.54675/ZJTE2084 19 Oct. 2024.

STEAME References and Deliverables:

- STEAME Website: https://steame.eu
- STEAME School of the Future Presentation
- O1. Guidelines for dynamic and adaptive STEAME curricula, IO1 Reference Files
- O2. Guidelines for STEAME Activities in Schools for two age groups
- O2. Handbook for Learning & Creativity Plans - EN
- O3. Guidelines for STEAME School Organizational Structure
- STEAME Repository: https://steame.eu/steame-observatory
- STEAME hybrid https://steame-hybrid.eu/
- Blueprint-Guidelines-for-Hybrid-STEAME_activities.pdf
- STEAME hybrid STEAME L&C Plans
- STEAME ACADEMY https://steame-academy.eu/
- STEAME ACADEMY D2.1 Comparative report analysis of the 16 projects
- STEAME ACADEMY D2.2 STEAME Teacher Facilitators Learning Outcomes set
- STEAME ACADEMY D2.3 Focus Group Validation Consolidated Report
- STEAME ACADEMY D2.4 STEAME Teacher Facilitators Competence Framework