SOME IDEAS FOR THE TRAINING OF STUDENT TEACHERS FOR STEAME EDUCATION

Dobrinka Boykina, Todorka Glushkova, Vanya Ivanova, Marta Teofilova, Boyan Zlatanov

Abstract. *In recent years, the STEM (Science, Technology, Engineering, and Mathematics) educational approach has gained popularity in Bulgaria, with more schools building STEM centers and adopting STEM interdisciplinary teaching and learning methods. Recently, STEM has evolved into STEAME, integrating Arts and Entrepreneurship into the framework. One of the main goals of this education is to stimulate and facilitate the development of essential skills such as critical thinking, deductive and inductive reasoning, logical reasoning, problem-solving, data manipulation, decision-making based on data analysis and interpretation, intellectual curiosity, and creativity. These vital skills can be developed through interdisciplinary project-based learning with mathematics at its core, as mathematical knowledge, skills, and competencies are applied across nearly all fields of human knowledge. This paper presents strategies and examples for training student teachers in mathematics, focusing on interdisciplinary teaching of STEAME school subjects.*

Key words: STEAME, STEM, Mathematics.

Introduction

The primary goal of STEAME (Science, Technology, Engineering, Arts, Mathematics, Entrepreneurship) education in schools is to prepare students for the challenges of the 21st century through an integrated approach to education that combines science, technology, engineering, arts, mathematics, and entrepreneurship. This educational approach has the necessary prerequisites to stimulate and facilitate the development of essential skills such as critical thinking, deductive and inductive reasoning, logical reasoning, problem-solving, data manipulation, decision-making based on data analysis and interpretation, intellectual curiosity, creativity, and more. Developing all these skills requires interdisciplinary, project-based education with mathematics at its core, as mathematical knowledge, skills, and competencies are applicable across nearly all areas of human knowledge.

This report presents some ideas and examples of approaches to training future teachers focused on the interdisciplinary teaching of STEAME school subjects.

Motivation and Related Works

STEAME education employs a multidisciplinary approach to teaching and learning, aiming to foster innovation, creativity, and practical problem-solving skills in students [1]. This approach arises from the increasing complexity of real-world challenges, where solutions often require a combination of technical knowledge, creativity, and business acumen. STEAME aims to bridge the gap between theoretical knowledge and practical applications by promoting skills such as critical thinking, teamwork, and adaptability. While traditional education requires in-depth knowledge of individual subjects, STEAME encourages connections between disciplines, reflecting real-world problems and solutions. Including the arts and entrepreneurship adds dimensions of creativity and strategic thinking, further encouraging innovation. Students are inspired to think outside the box and be proactive and creative by taking initiative and responsibility – essential traits for today's entrepreneurs and innovators.

STEAME aligns with global priorities such as the UN Sustainable Development Goals (SDGs), where multidisciplinary collaboration is key to addressing issues such as climate change, education, and economic inequality [2].

The educational community identifies as a key need for developing and implementing new approaches in STEAME learning such as project-based learning (PBL) [3], application of AI tools and technologies [4, 5], and creation of interactive resources. In this direction, a team from PU has successfully participated in the implementation of a series of international EU projects, including:

- STEAME TEACHER ACADEMY[1]
- FACILITATE-AI[2]

[1] STEAME TEACHER ACADEMY PROJECT – `https://steame-academy.eu/`
[2] FACILITATE-AI PROJECT – `https://facilitate-ai.eu/`

- BYOD-LEARNING[3]

Many schools worldwide, as well as in Bulgaria, have already adopted the STEAME principles, integrating subjects like robotics [6], design thinking, and business modeling into their curricula. Tools such as simulation software, coding platforms, and online collaboration environments are widely used to support STEAME learning. Project-based learning allows students from various schools to identify a problem (e.g. energy efficiency), design a solution (science, engineering, and technology), calculate feasibility (mathematics), creatively present the solution (arts), and economically justify their idea (entrepreneurship).

A key requirement for achieving the goals is the training and continuous improvement of the qualifications of current and future teachers. The motivation for professional development of current teachers is high, given the construction of modern high-tech STEM centers in schools, which will provide cutting-edge conditions for multidisciplinary, project-oriented learning. The authors have organized and conducted training sessions with teachers from Bulgaria and EU countries, such as:

- A two-day online educational seminar attended by 678 Bulgarian teachers from various academic disciplines, focusing on AI technologies in STEAME education. An international webinar with participation from teachers and pedagogical specialists from most European countries.
- The authors' primary emphasis, however, is on student-teachers. During their university education, these future teachers must adopt methods and approaches for organizing multidisciplinary project-based STEAME learning in schools. The article examines this group of future educators.

Some STEAME Methods and Approaches

Students' desire to use mobile devices encourages the integration of these tools in STEM education through an approach known as BYOD (Bring Your Own Device). The BYOD approach focuses on the use of video materials and digital tools outside the classroom at times convenient for students. Teachers provide students with engaging and interactive resources (e.g. videos) to review lessons before and after classes. This allows

[3] BYOD-LEARNING PROJECT – `https://byod-learning.eu/`

for more active and hands-on activities during classroom learning. These pre-class interactive learning materials can help in mastering knowledge and skills in:

- Distance/hybrid learning
- Introducing new topics in class
- Flipped classroom approaches

When the BYOD approach is applied in the "flipped classroom" framework, the higher levels of Bloom's taxonomy can be reached to a greater extent for didactic purposes (Fig. 1).

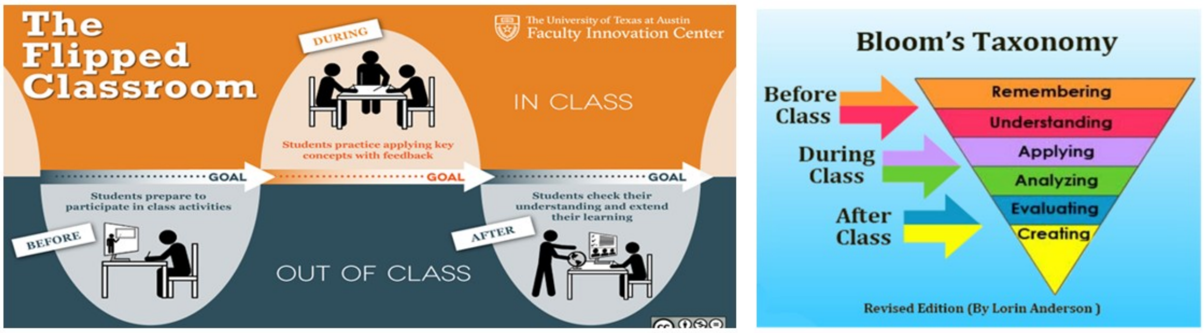

Figure 1. BYOD approach and Bloom's taxonomy

Mathematics plays a central role in STEAME education as mathematical knowledge, skills, and competences are integral to:

- Natural sciences (physics, biology, and chemistry)
- Informatics and ICT
- Economics and entrepreneurship
- Engineering and design

Even in Arts, one can appreciate the beauty of mathematics. For these reasons, it is of great importance to prepare mathematics teachers to teach in the STEAME environment. This requires teachers to:

- Apply mathematical knowledge to other disciplines,
- Construct mathematical models for problem-solving,
- Derive solutions to mathematical models using modern technologies,
- Analyze and interpret the obtained solutions in the context of real-world problems.

To understand their pivotal role in STEAME education, future math teachers must recognize that mathematics holds the key to solving problems in other areas of science and everyday life. An excellent starting point is the introductory mathematical disciplines students learn at university, such as "Higher Mathematics (part I)", which mostly covers Linear Algebra and Analytical Geometry. In Bulgaria, some of these topics are also taught in high schools as part of profiled mathematics preparation in Grades 11 and 12. However, they are absent from general preparation. For example, analytic geometry in the plane Oxy includes:

- Vector operations in coordinates
- Linear independence of vectors
- Vector basis
- Line equation
- Conic sections

This article presents some ideas for interdisciplinary STEM education based on mathematical concepts.

IT and computer science can improve and facilitate the process of teaching and learning mathematics and its applications in STEAME education. The application of digital technologies is multi-layered and multi-directional, including programming and software development, the use of AI technologies and robotics, as well as ICT tools for simulations, calculations, and presenting results. In this context, ICT technologies can be used in interdisciplinary education with mathematics.

- For algebraic calculations, a CAS can be used, such as Wolfram Mathematics, Maple, MATLAB, R, etc.
- For graphical representation of geometric figures, dynamic geometry software can be used, such as GeoGebra, Desmos, Geometer's Sketchpad, etc.
- For preparing educational materials and presentations with mathematical symbols and formulas, an appropriate environment, such as LaTeX or R (with additional packages for presentations and graphics), can be used.

The interaction between mathematics and physics (mechanics and robotics) is natural and forms the foundation for developing a wide variety of practical projects. Topics for training future teachers should include vector operations, the equation of a straight line; conic sections, etc.

School students learn about vectors and their application to mechanics in Grade 8 (linear operations: addition of vectors and multiplication by a scalar). In the profiled preparation, students explore the dot product of two vectors and how to compute it when the vectors are given by their coordinates. University students learn more about the dot product, as well as the cross and scalar triple product. Here are some examples of applying this knowledge to physics:

- The dot product can be used to calculate the work W done by a force $\vec{F}$ causing a material point to move linearly in the direction of the vector $\vec{s}$: $W = \vec{F} \,.\, \vec{s}$.
- In robotics, the vector and triple product can be used to calculate the torque of a force $\vec{F}$. Also, the equations of a straight and curved line of the second degree can greatly facilitate the programming of robotic movement.
- Students can use equations of straight lines and conic sections to study the optical properties of parabolic, ellipsoidal, and hyperbolic reflectors.

In searching for solutions to real-world problems, many applications of conic sections can be found (Fig. 2): suspension bridges, arches, satellite dishes, radio and optical telescopes, radar equipment, solar lenses, and searchlights.

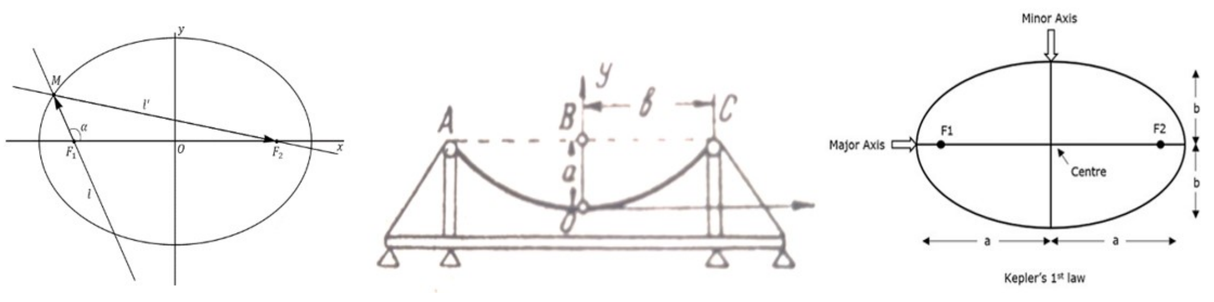

Figure 2. Application of equations of straight lines and conic sections to physics

For example, the suspension cable of a suspension bridge, such as the Golden Gate Bridge in San Francisco, has the shape of a parabolic arc. Conic sections are widely used in astronomy as they represent trajectories of celestial bodies – stars, planets, asteroids, comets, etc. According to

Kepler's First Law, each planet moves around the Sun in an elliptical orbit, with the Sun's center of gravity always located at one of the foci of the orbital ellipse, and so on.

The connection between mathematics, engineering, design, and art is an interesting and impressive side of STEAME education. For example, by generalizing the equation of an ellipse and a circle, French mathematician Gabriel Lamé created fascinating curves (Lamé curve or the so-called super-ellipse), which were used in the design of Sergels Torg square in Stockholm, Sweden. Another application of these curves, combing a square and a circle (the so-called "squircle"), is implemented in the central touchpad button in many Nokia smartphones. The "magic" super-formula of nature is a generalization of the equation of these curved lines (Fig. 3). The super-formula was proposed by the Belgian engineer, scientist, and mathematician Johan Gielis in 2003. In his book "Inventing the Circle: Geometry of Nature", Gielis described a mathematical formula involving simple trigonometry in polar coordinates that can be used to generate many complex shapes and curves occurring in nature.

Figure 3. Application of Math in Engineering, Design, and Art

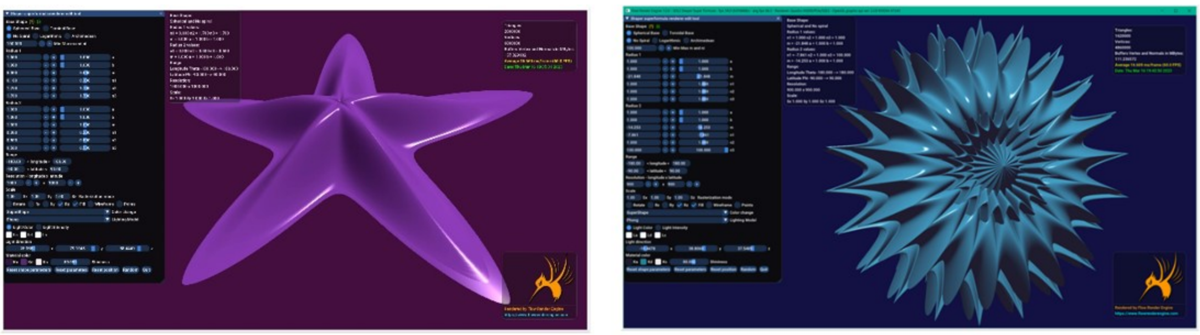

Figure 4. Applications of super-formula 3D generators in Art STEAME education

In 2017, Gielis presented a generalization of the super-formula to the 3D space via rotational surfaces, which he called a super-shape [7]. To visualize these 3D objects, appropriate software systems can be used, some of which are available online. When working in school STEAME interest clubs, the free web super-formula generator (`https://dynamicmathematicslearning.com/super-ellipse.html`) can be used, as well as the free super-shape 3D generator (`https://www.flowrenderengine.com/shaper-supershapes-generator.html`) (Fig. 4).

Financial mathematics, particularly in **entrepreneurship**, is another aspect. It is well known that major corporations have departments dedicated to cost optimization and financial policies. Entrepreneurs, unlike major corporations, lack such financial resources and must devise their own solutions for cost optimization and risk reduction. The fundamental techniques of financial mathematics can be useful in these activities. Nowadays, numerous powerful computer software systems are available that can perform the necessary computations. This eliminates the need for calculators. We concentrated on the use of algebraic computer systems rather than specialist financial calculators. This decision was made because, while an entrepreneur trains and attempts to describe the functions or procedures employed, he/she also learns financial concepts and models. Unlike financial calculators, algebraic computer systems may specify more sophisticated operations and display multiple models on the screen. We demonstrate, with examples from risk assessments of various investments, that the adoption of software technology does not resolve all issues. In such cases, the user must understand the model under consideration and reformulate the problem for the computer to solve.

Conclusions

Training students – future teachers is crucial for the success of STEAME education in schools. The key focus is on establishing cross-curricular connections with other STEAME subjects, which determines the need to direct the teaching content in university mathematics courses towards more applied aspects and topics. This article presented ideas for training future teachers in science, engineering, technology, art, design, and entrepreneurship. Future goals of the team include the creation of teaching materials for individual modules and topics, which will be part of a comprehensive and holistic qualification course. The international team has currently developed Learning and Creativity Plans of 52 topics to support student teachers in organizing project-based STEAME training. The developed materials and curricula are in the testing and verification stage.

Acknowledgments

This study is supported by the project FP23-FMI-002 "Intelligent software tools and applications in research in mathematics, informatics, and teaching pedagogy" at the "Paisii Hilendarski" University of Plovdiv.

References

[1] N. Al Hamad, O. Adewusi, C. Unachukwu, B. Osawaru, O. Chisom, A review on the innovative approaches to STEM education, *International Journal of Science and Research Archive*, 11 (1), 2024, 244–252, DOI: `https://doi.org/10.30574/ijsra.2024.11.1.0026`.

[2] F. Biermann, N. Kanie, R. Kim, Global governance by goal-setting: the novel approach of the UN Sustainable Development Goals, *Current Opinion in Environmental Sustainability*, 26, 2017, 26–31, ISSN: 1877-3435, `https://doi.org/10.1016/j.cosust.2017.01.010`.

[3] Y. Lee, B. Lee, Developing career-related skills through project-based learning, *Studies in Educational Evaluation*, 83, 2024, 101378, ISSN: 0191-491X, `https://doi.org/10.1016/j.stueduc.2024.101378`.

[4] O. Joseph, N. Uzondu, Integrating AI and Machine Learning in STEM education: Challenges and opportunities, *Computer Science & IT Research Journal*, 5 (8), 2024, 1732–1750, DOI: `https://doi.org/10.51594/csitrj.v5i8.1379`.

[5] J. Luzano, An Integrative Review of AI-Powered STEM Education, *International Journal of Academic Pedagogical Research*, 8 (4), 2024, 113–118, ISSN: 2643-9123.

[6] F. Ouyang, W. Xu, The effects of educational robotics in STEM education: A multilevel meta-analysis, *International Journal of STEM Education*, 11 (1), 7, 2024, DOI 10.1186/s40594-024-00469-4.

[7] J. Gielis, *The Geometrical Beauty of Plants*, Atlantis Press., 2017, ISBN: 978-94-6239-151-2, DOI 10.2991/978-94-6239-151-2.

Dobrinka Boykina[1], Todorka Glushkova[1,*], Vanya Ivanova[1],
Marta Teofilova[1], Boyan Zlatanov[1],
[1] Paisii Hilendarski University of Plovdiv,

Faculty of Mathematics and Informatics,
236 Bulgaria Blvd., 4027 Plovdiv, Bulgaria
Corresponding author: glushkova@uni-plovdiv.bg