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An approach for developing inclusive and engaging pedagogical content connected to physical objects for STEAM education

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ABSTRACT

In this work we present a methodology for introducing STEAM activities into high school which utilizes a multilayered approach. The developed materials help students to build up their STEAM abilities and teachers to have specific inclusive pedagogical sequences which they can use in their classes. First, we introduce the methodology of the project and then we present a case study of applying and evaluating a pedagogical sequence in school activities with senior high school students. The evaluation results are positive towards our practices, as students found the activities fun and engaging in connecting mathematics with the real world.

Keywords: STEAM education, pedagogical sequences, student engagement, mathematics, evaluation, Erasmus+, STEAMbuilders

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INTRODUCTION

STEAM stands for Science, Technology, Engineering, and the Arts, as well as Mathematics. Consequently, STEAM is STEM with the addition of the arts, including language arts, visual arts, humanities, dance, music, drama, design, and new media. In contrast to STEM, which focuses on scientific subjects, STEAM examines the same topics through creative problem-solving and analysis-based learning (Maeda, 2013; Perignat & Katz-Buonincontro, 2019). That is, various students collaborate to produce a visually appealing or artistic product based on their fundamental STEM knowledge. For example, the mathematics of the parabola is used in the creation of fine art imagery, demonstrating that STEAM is not a new concept and that artists such as Leonardo da Vinci have depicted the importance of combining science and art to make significant discoveries (Wade-Leeuwen, 2018).

As technological advancements reshape industries, STEAM education has gained prominence for its ability to cultivate essential skills such as critical thinking, adaptability, and interdisciplinary collaboration. The integration of the arts in STEM disciplines fosters a more comprehensive learning experience by encouraging students to approach problems with creativity and innovation. By merging artistic expression with scientific inquiry, students not only gain technical knowledge but also develop essential soft skills, such as communication, teamwork, and empathy—competencies that are increasingly valued in the modern workforce.

Various studies have revealed a large percentage of STEM college students (approximately 78 percent) decided to study STEM in high school or earlier, while almost one out of five STEM college students (21 percent) made their decision in middle school or earlier (Fayer et al., 2017; Microsoft, 2011). Still, only one in five STEM college students believe that their secondary education adequately prepared them with the knowledge required for STEM college courses. In addition, the study highlights a gender imbalance in employability within STEM fields, with women being underrepresented compared to men (UNESCO, 2017). Therefore, it is also essential to encourage more girls to pursue STEAM subjects (Guenaga et al., 2023; Liao et al., 2016). Addressing this gender gap requires a conscious effort to create inclusive learning environments that empower all students, regardless of gender, to explore STEAM fields. Through mentorship programs, hands-on workshops, and project-based learning, educators can inspire young learners to see themselves as future scientists, engineers, and innovators.

More than 65 percent of today's students will have careers that do not yet exist, according to trend analysts (World Economic Forum, 2016). Today, it is more important than ever to prepare our youth for the future and give them the confidence to create the world they want

This article is an output of the science project Erasmus+ 2020-1-FR01-KA201-080668 STEAMBuilders which is a collaboration between partners from France (Fermat Science), Belgium (LogoPsyCom), Cyprus (Citizens in Power), Slovenia (GoINNO), Spain (Trànsit Projectes), Greece (5th High School of Agrinio), and Denmark (Vesthimmerlands Museum) (https://steambuilders.eu/).

to live in. To this end, many schools are modifying their curricula and increasingly focusing on teaching students STEAM skills in a cross-curricular manner (Erduran et al., 2024). This approach not only enhances student engagement but also equips them with a diverse skill set that is applicable across a wide range of industries, from healthcare and architecture to entertainment and artificial intelligence.

Over the past years, STEAM and coding have emerged in both formal and non-formal educational settings, where they have provided a foundation for the development of a variety of educational activities (Harris & de Bruin, 2018). With STEAM content, we can assist educators in determining the most effective strategies for bringing their programs closer to students' realities. By integrating coding with artistic elements such as digital media creation, interactive storytelling, and game design, students gain a deeper appreciation of how technology can be leveraged for creative expression.

Although specific creations (e.g., Antonopoulos et al., 2018; Karachalios et al., 2021) are beneficial for providing STEM abilities, it is far more efficient to develop resources that will be easily applied, inclusive, and with "arts" fully integrated. The ability to blend technical proficiency with artistic innovation is crucial in an era where automation and artificial intelligence are transforming traditional job roles. Thus, educational institutions must prioritize the development of interdisciplinary curricula that balance analytical and creative thinking. This is the main focus of the specific work.

In the following sections, we report our approach and present a case study of the application of specific STEAM resources in an educational setting. By examining real-world implementations, we aim to highlight the best practices and provide insights into how STEAM education can be effectively incorporated into diverse learning environments. Through this work, we seek to reinforce the value of integrating the arts into STEM, ultimately fostering a generation of well-rounded, innovative thinkers equipped for the challenges of the future.

ENGAGING STUDENTS IN STEAM ACTIVITIES

Research suggests that incorporating interactive stories, multimedia narratives, and rich media into education fosters creativity, enhances conceptual understanding, and improves student motivation (Lazarinis & Konstantinidou, 2025). Storytelling has long been recognized as a powerful educational tool, and when combined with digital interactivity, it becomes an effective medium for engaging students in STEAM disciplines (Hunter-Doniger et al., 2018). Interactive storytelling allows students to become active participants in the learning process, making decisions and exploring various narrative pathways that align with STEAM concepts. Studies show that interactive storytelling enhances critical thinking and problem-solving skills by immersing students in real-world scenarios where they apply scientific and mathematical principles to navigate challenges (Gee, 2005; Lazarinis et at., 2020; Walters et al., 2018).

Multimedia stories further enrich STEAM education by incorporating text, images, animations, and sound to create an engaging learning environment. Research findings highlight that multimedia learning supports dual coding, allowing students to process information through both visual and verbal channels, leading to improved retention and understanding (Çeken & Taşkın, 2022). Digital storytelling in STEAM classrooms not only makes abstract concepts more tangible but also enables students to express their creativity by designing and producing their own multimedia content (Amirinejad & Rahimi, 2023). Students who engage with multimedia storytelling exhibit higher levels of motivation and interest in STEAM subjects compared to those using traditional text-based resources (Karahan et al., 2015).

Rich media, including augmented reality (AR), virtual reality (VR), and gamified experiences, provide immersive and interactive learning experiences that captivate students' attention and deepen their understanding of STEAM concepts. Jesionkowska et al. (2020) found that AR enhances spatial reasoning and comprehension in engineering and mathematics by allowing students to visualize complex structures in three dimensions. Similarly, Hamari et al. (2016) demonstrated that gamified environments incorporating storytelling elements increase student motivation and engagement by fostering a sense of challenge and achievement. Interactive videos and simulations provide opportunities for students to experiment with scientific concepts in a virtual setting, reinforcing theoretical knowledge through experiential learning (Dieck-Assad et al., 2020).

Interactive storytelling in mathematics fosters engagement by embedding mathematical tasks within compelling narratives. For example, Karaoglan Yilmaz et al. (2018) found that students exposed to mathematical storytelling demonstrated a more positive attitude toward mathematics compared to those taught through conventional methods. The integration of digital tools has further expanded the potential of interactive storytelling in mathematics. Multimedia platforms that incorporate animations, gamification, and adaptive feedback provide students with immersive learning experiences that reinforce mathematical concepts (Peláez & Solano, 2023).

Research shows that interactive storytelling and multimedia significantly enhance engagement, creativity, and understanding in STEAM education. While these tools improve motivation and support the integration of abstract concepts, existing studies often lack practical, physical world objects like in (Lavicza et al., 2022). Our endeavor advances this objective by providing a reproducible, multidisciplinary methodology rooted in practical application, with the intent of connecting theory and educational practice.

THE STEAMBuilders APPROACH

Our work, developed in an Erasmus+ project titled STEAMBuilders, employs a multilayered approach to enhance students' STEAM abilities while simultaneously providing teachers with well-structured, inclusive pedagogical sequences that can be seamlessly integrated into their classrooms. Through the collaboration of a diverse consortium of partners, each possessing expertise in various aspects of STEAM education and general pedagogy, we systematically developed, evaluated, refined, and implemented a collection of high-quality STEAM educational resources.

By promoting competence-based teaching and learning, our project contributes to raising the status of teaching professions, both by strengthening educational activities with ready to use materials developed methodologically. At the same time, we aimed to increase student engagement and achievement in STEM disciplines by integrating the STEAM approach with history and the humanities. By contextualizing STEM within historical narratives and cultural

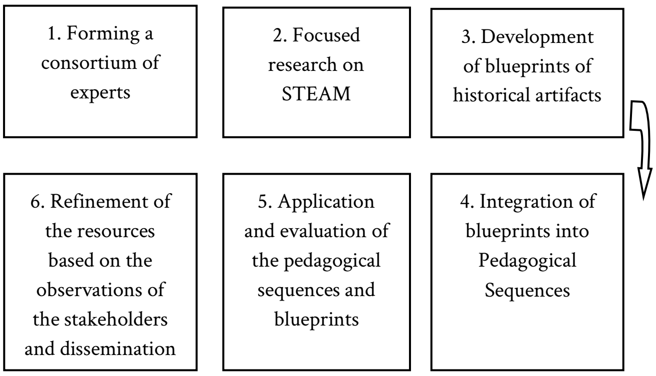

Figure 1. The STEAMBuilders phases (Source: Author)

developments, we seek to broaden students' understanding of these subjects, making them more accessible, engaging, and meaningful.

A central point of our project was the development of inclusive educational resources, ensuring that children requiring special educational support are adequately considered. Our materials were designed to be accessible to students with specific learning disabilities, students from disadvantaged socioeconomic backgrounds, migrant students, and girls, which is a group that is historically underrepresented in STEM fields. Through our commitment to inclusivity, we attempted to enhance the overall quality of education while fostering greater equity in learning opportunities.

The project followed a structured implementation approach, progressing through six key phases, as outlined in **Figure 1**.

Phase 1. Formation of a consortium of experts: At the outset, we established a consortium consisting of experts in education, inclusion, STEAM and STEM projects, as well as history specialists. Each partner brought unique expertise, ensuring a comprehensive and interdisciplinary approach. More importantly, all partners undertook dual roles–developing their own pedagogical resources while also critically evaluating the resources produced by other consortium members. This peer-review mechanism ensured high-quality educational materials that meet diverse learning needs.

Phase 2. Focused research on STEAM: During this phase, partners collaboratively researched STEAM projects and literature to create pedagogical booklets that emphasized the importance of STEAM education and provided practical guidance for its implementation in various educational settings. These booklets serve as basic resources for educators, offering structured strategies for integrating STEAM concepts into their teaching. The published booklets are available for reference (guide to pedagogical practices and STEAMBuilders IO2–https://steambuilders.eu/resources/).

Phase 3. Development of blueprints of historical artifacts: To provide students with hands-on, experiential learning opportunities, we developed detailed blueprints for the reconstruction of historical artefacts. These artefacts were carefully selected to represent different historical periods and diverse cultural contexts—ranging from Ancient Greece to the Renaissance—ensuring a broad and enriching learning experience. The selection process was collaborative, with consortium partners collectively voting on the artefacts to be included. Each blueprint incorporates relevant STEAM principles, such as mathematics, physics, and engineering, linking historical knowledge with modern scientific understanding.

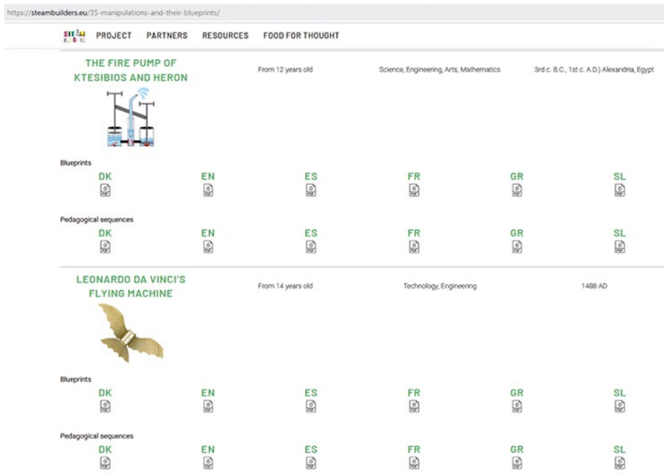

Figure 2. A sample of available resources (https://steambuilders.eu/35-manipulations-and-their-blueprints/)

Phase 4. Integration of blueprints into pedagogical sequences: Once the artefact blueprints had been developed, they were embedded into detailed pedagogical sequences that connect the artefacts with STEAM learning objectives. These sequences contextualize the artefacts within real-world classroom applications. For example, a pedagogical sequence explores how to use the sextant, an ancient navigational instrument, to illustrate Thales' theorem on similar triangles, thus enabling students to measure the height of a building. Each sequence includes historical insights, mathematical and scientific explanations, and is aligned with specific age groups and curriculum topics to ensure easy adoption by teachers. This cross-disciplinary integration enhances engagement by demonstrating the practical and historical relevance of STEAM concepts (**Figure 2**).

Phase 5. Application and evaluation: The resources were translated during the previous faces into six languages–English, French, Greek, Slovenian, Spanish, and Danish—to maximize accessibility and impact. The current evaluation phase was a crucial step in ensuring the effectiveness of the developed resources. More than 350 students participated in real classroom settings to test the applicability, clarity, and engagement level of the materials. The feedback collected from these practical implementations allows for data-driven refinement, ensuring that the resources are not only educationally robust but also student-friendly and effective in promoting STEAM learning.

Phase 6. Refinement of the material: In the final phase, all educational materials were refined based on classroom testing feedback. The materials have then been uploaded onto the STEAMBuilders project website and they have been made freely available to educators, students, and the broader learning community.

Throughout the project, partners evaluated and reviewed each other's work to ensure high-quality standards and successful learning outcomes. Additionally, inclusion experts systematically evaluate the materials to determine their suitability for students with mild learning disorders. This rigorous review process guarantees that the educational resources were inclusive, engaging, and pedagogically sound.

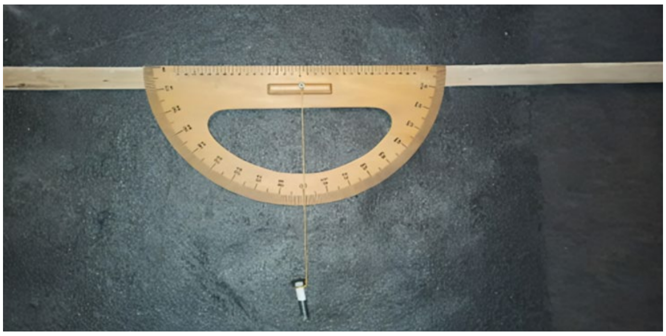

Figure 3. A simple sextant (Source: https://steambuilders.eu/wp-content/uploads/2022/09/Sextand_EN.pdf)

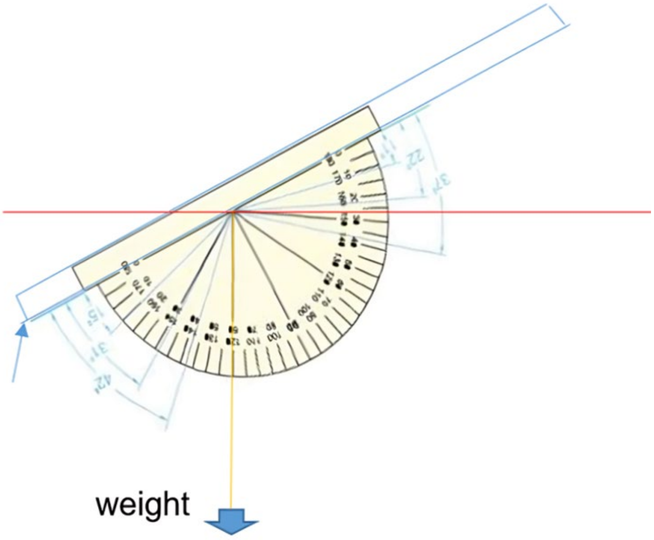

Figure 4. Usage of the sextant to measure the angles (Source: https://steambuilders.eu/wp-content/uploads/2022/09/Sextand_EN.pdf)

MEASURING HEIGHTS WITH SIMPLE INSTRUMENTS: AN EXAMPLE

Building A Simple Sextant: The Blueprint

A sextant is a navigational instrument used to measure the angle between celestial objects and the horizon, enabling accurate position calculations at sea. Building a simple sextant allows students to have hands-on experience with its key principles, including reflection, angular measurement, and sighting techniques. The blueprint outlines the materials, providing step-by-step assembly and usage instructions to construct and utilize a functional yet straightforward sextant, ideal for educational and experimental purposes.

Using simple materials such as

- a straight ruler, one meter (1 m) long,
- a wooden semi-circular protractor,
- a rope or a fishing line,
- a small weight, and
- a large screw and 5–6 nails

and step-by-step instructions students can build a simple sextant (see **Figure 3**). **Figure 4** shows how we can measure the angles using the sextant. The full instructions are found in: https://steambuilders.eu/wp-content/uploads/2022/09/Sextand_EN.pdf

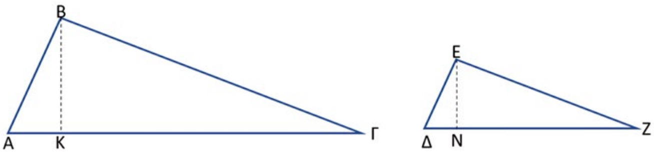

Figure 5. Examples of similar triangles (Source: https://steambuilders.eu/wp-content/uploads/2022/09/1_PedagogicalSequence_Sextant_FINAL.pdf)

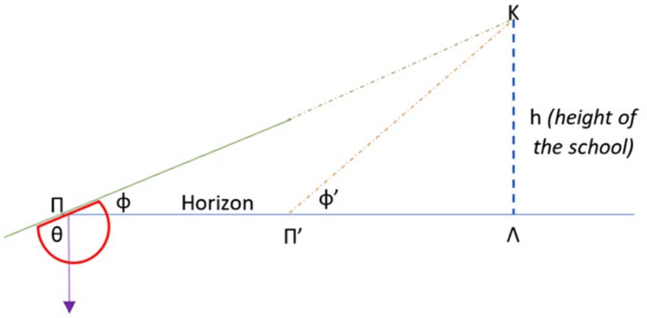

Figure 6. Using similar triangles to measure the height of a building (Source: https://steambuilders.eu/wp-content/uploads/2022/09/1_PedagogicalSequence_Sextant_FINAL.pdf)

Using the Sextant to Measure the Height of A School: The Pedagogical Sequence

To integrate the blueprint into the curricula, a pedagogical sequence enriched with historical facts was developed. The sequence has the following parts (https://steambuilders.eu/wp-content/uploads/2022/09/1_PedagogicalSequence_Sextant_FINAL.pdf):

Step 1. Who was Thales of Miletus?: During this step, students learn about Thales and his theorems.

Step 2. Similar triangles theorem: The theorem of similar triangles is explained to the students in the classroom (**Figure 5**). A brief explanation is given below:

Thales's theorem states that $\frac{AB}{\Delta E} = \frac{A\Gamma}{\Delta Z} = \frac{B\Gamma}{EZ} = \lambda$ and also $\frac{BK}{EN} = \lambda$ where BK, EN is the height of the triangles. That is, if we know that $A\Gamma = 10$ cm, then $\frac{A\Gamma}{\Delta Z} = 2$, so, ΔZ = 5 cm.

Step 3. Introduce and/or build the sextant: Students build a simple sextant, so they can be actively involved in the project.

Step 4. Presenting Xenagoras experiment: "Xenagoras (2nd century BC) was based on the theorems of Thales. He calculated the height of the peak of the Greek Western Olympus Mountain, named Flambouros. Xenagoras used a kind of 'diopter' to measure the altitude differences between this peak and the point of the ancient temple of Pythian Apollo where he was located." This historical note is important to help the students realize that all the current technologies are based on older innovations and that through history they can learn quite useful and exciting facts.

Step 5. Measuring the height of the school: The teacher explains theoretically how they can measure the height of a building (**Figure 6**).

Step 6. Evaluation of the activity: The last step involves the evaluation of the activity and perhaps the refinement of the learning material.

Table 1. Opinions of the students

Question	1 (Strongly disagree)	2 (Disagree)	3 (Neutral)	4 (Agree)	5 (Strongly agree)
The content of the activity is interesting.				2	40
The content of the activity is understandable.				3	39
The activity was able to keep me interested.					42
The practical activity helped me understand the mathematical topics better.					42
The activity allowed me to apply what I learned in a meaningful way.				1	41
I would recommend this activity to my peers.				2	40
I felt engaged and actively participated throughout the activity.				1	41
The activity was fun and enjoyable.				1	41

Evaluation of the Activity

The previously developed blueprint and pedagogical sequence have been utilized by two separate classes involving a total of 42 students. These students, aged 16 years old, were enrolled in a Greek senior high school, where they participated in a structured educational activity integrating mathematics, physics, and historical context through the hands-on construction and application of a sextant. The entire learning process spanned three teaching hours, during which students were actively engaged in both the creation of the instrument and the exploration of its practical applications.

To assess the effectiveness and perceived impact of this teaching approach, a short questionnaire was distributed to students upon completion of the activity. This survey included basic demographic questions but was intentionally designed to be short and easy to complete, minimizing potential survey fatigue and ensuring higher response accuracy. The primary objective of the questionnaire was to capture students' general impressions, attitudes, and engagement levels with this interdisciplinary approach to STEAM education.

Following the questionnaire, a discussion session was conducted, allowing students to openly express their views, beliefs, and experiences regarding the activity. This qualitative feedback was valuable in understanding how students perceived the integration of history and science within a practical, hands-on learning environment. The discussion also helped identify aspects of the lesson that resonated most with students, as well as areas where further refinement could enhance the learning experience.

Table 1 presents the most notable results from the questionnaire, highlighting key insights into student engagement and their receptiveness to this innovative learning method. The evaluation results indicate a highly positive reception of the activity among participants. Most respondents strongly agreed that the content was both interesting and understandable, with only a small number selecting "agree" or "neutral" and none expressing disagreement. All 42 participants agreed that the activity maintained their interest and supported their understanding of mathematical concepts, highlighting its effectiveness as a learning tool. Similarly, the vast majority felt they could meaningfully apply what they learned and would recommend the activity to their peers. Engagement and enjoyment were also rated very highly, with nearly all students reporting that they were actively involved throughout and found the experience fun. Overall, the responses demonstrate strong approval of the activity's design, delivery, and educational impact. The students' feedback further supports the effectiveness of experiential learning strategies, particularly those that combine historical context with practical STEM applications.

We also had a free text question, asking the participants to comment on our activity freely. All the comments were enthusiastic towards the didactic intervention. We provide some of the most characteristic comments:

> A. K.: I finally understood why we learn geometry.
>
> K. P.: That was really fun. It was like a game.
>
> P. P.: I really liked the learning today. I will go on and measure the height of my house.
>
> M. S.: Very interesting. I was impressed with Xenagoras and yes geometry can be fun.

Overall, the findings suggest that the sextant activity successfully fostered curiosity and interest in STEAM subjects, encouraging students to think critically and collaborate in problem-solving tasks. Future iterations of this lesson could potentially expand on these elements, incorporating additional interactive challenges and cross-disciplinary connections to further enrich the educational experience.

DISCUSSION

The reviewed literature underscores the growing recognition of STEAM education as a powerful framework for cultivating both technical and creative skills essential for the 21st century. Prior studies have demonstrated the value of integrating storytelling, multimedia, and hands-on learning in enhancing student engagement and deepening understanding across STEM disciplines. Additionally, the literature highlights the need to address gender imbalances and inclusivity in STEAM fields, particularly through early interventions and innovative teaching strategies. Despite these insights, a gap persists in the availability of ready-to-use, inclusive, and pedagogically structured resources that seamlessly embed historical context and artistic elements into STEM education.

By offering replicable blueprints, pedagogical sequences, and multilingual resources grounded in real classroom testing, this work contributes to a practical model for implementing STEAM education in ways that are engaging, equitable, and scalable. Physical models of geometric objects have been proposed in previous studies as well and have been found motivating for students to participate in and understand STEM topics (Lavicza et al., 2022). The classroom implementation of the STEAMBuilders approach illustrates how a historically grounded, hands-on learning activity, e.g., building and using a sextant, can effectively integrate science, mathematics, and cultural understanding (Park & Cho, 2022). The structured sequence of activities fostered collaboration, practical skill development, and direct engagement with mathematical concepts such as trigonometry and measurement (Gee & Whaley, 2016). The evaluation results from 42 students indicated positive outcomes: learners reported increased interest in mathematics, appreciation for interdisciplinary connections, and improved collaboration and problem-solving skills. These findings highlight the broader literature's emphasis on the potential of STEAM approaches while also exposing the continued need for accessible, adaptable, and inclusive materials that can be scaled across different educational contexts. This paper addresses that gap by not only validating the effectiveness of a STEAM activities in a real classroom but also by offering a replicable methodology, pedagogical structure, and student-centered design that can inform broader efforts in interdisciplinary education.

CONCLUSION

In this paper we presented the approach used in an educational project. Through collaboration, educational resources have been developed, refined and utilized in classes. The paper analyzed the methodology employed in the project and presented a case study of the application of a specific resource developed during the project. Evaluation of the materials by all the consortium partners and inspection from an inclusive point of view are two of the major dimensions of the project. By incorporating art into STEM education (STEM + A = STEAM), we are not only making the materials more accessible to more students but also providing them with the opportunity to engage in creativity and express themselves through their projects while tinkering, creating, sharing, and playing. The application of a pedagogical sequence into two student classes provided us with quite positive comments and helped all the students to participate. Most of the students realized some practical aspects of mathematics and managed to effectively use simple tools to make calculations. They also came to appreciate historical figures and their contributions to the development of technology. The project's approach can be easily replicated and all the material are online and can be reused. The availability of the resources in different languages is another contribution to the project. Overall, the collaborative development of free and assessed resources promotes STEAM education and supports the needs of both students and educators.

Moving forward, the next step is to adapt and scale the STEAMBuilders approach for broader classroom use across different age groups and cultural contexts. We also aim to develop additional interdisciplinary scenarios and digital resources, supporting teachers in implementing creative, inclusive STEAM learning on a larger scale

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Declaration of interest: The author declares no competing interest.

Data availability: Data generated or analyzed during this study are available from the author on request.

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