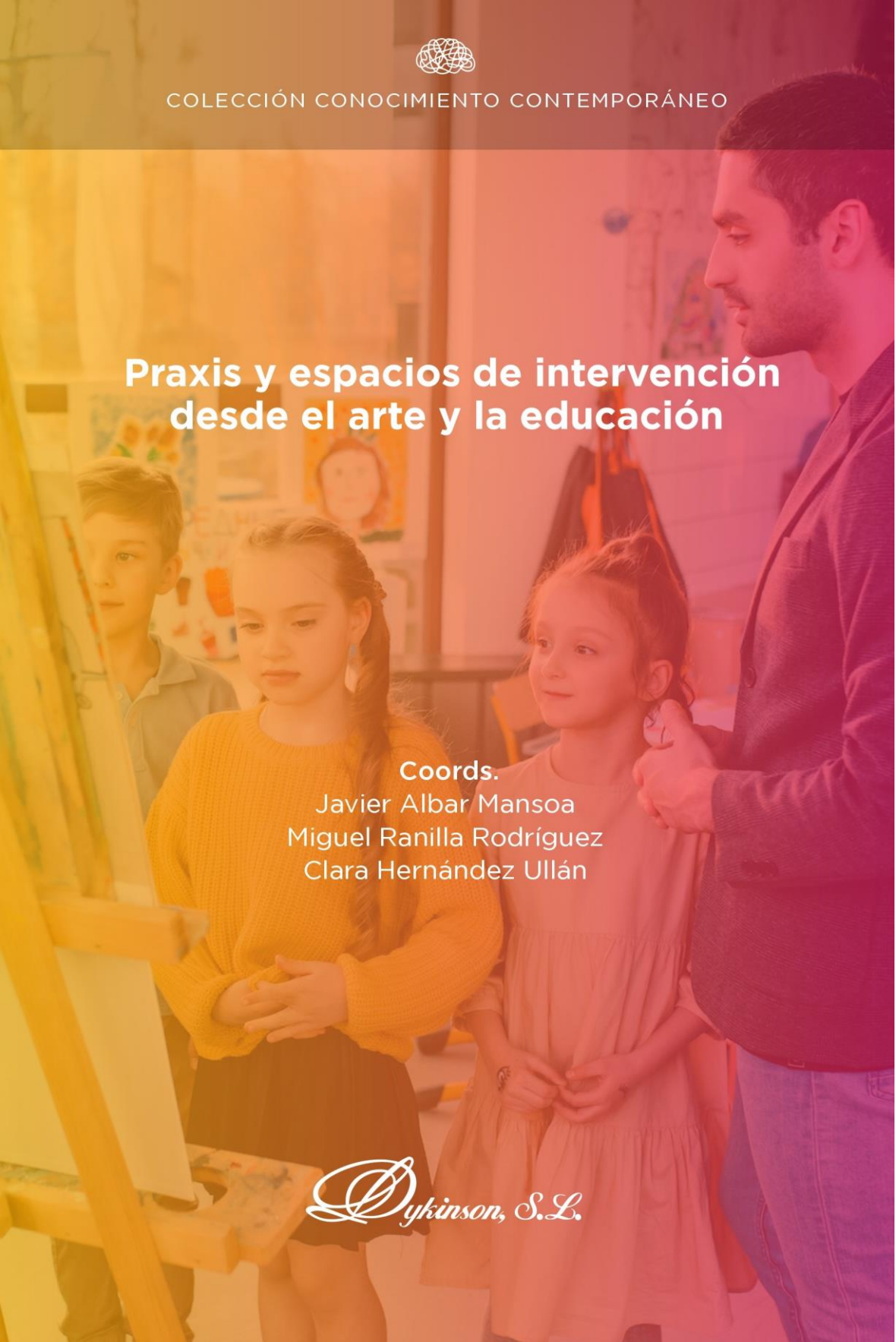

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BRIDGING ART AND *STEAM* EDUCATION: COLLABORATIVE ART INSTALLATIONS AS EDUCATIONAL TOOLS

JUAN CARLOS OLABE
Christian Brothers University
XABIER BASOGAIN
University of the Basque Country
MIGUEL ÁNGEL OLABE
University of the Basque Country

1. INTRODUCTION

This chapter explores the fusion of art with science, technology, engineering, and mathematics (STEM) to form STEAM education, a comprehensive educational approach that inspires creativity and critical thinking.

STEAM education integrates the creative thinking and expressive skills found in the arts with the problem-solving and analytical capabilities inherent in STEM fields. It fosters a holistic learning environment that encourages students to connect their learning in these critical areas together with arts practices, elements, and design principles. STEAM education is vital as it nurtures innovation, adaptability, and a diverse set of skills necessary for the 21st-century workforce (Bequette & Bequette, 2012; Quigley & Herro, 2016; Conradty & Bogner, 2019).

The LOMLOE, also known as the "Education Law", is a Spanish legislative initiative aimed at modernizing the education system. This reform targets key competencies like mathematics, science, technology, and engineering, which are crucial for developing practical problem-solving and critical thinking skills. By incorporating these areas, the law intends to foster creativity, innovation, and a comprehensive understanding of

the world, preparing students to thrive in an increasingly complex and technology-driven society (López, 2022).

Collaborative art installations represent an innovative educational approach in STEAM education. By allowing students to actively engage in the creation of large-scale art projects, they can effectively apply and integrate their knowledge across the STEAM disciplines. This hands-on, collaborative learning experience not only stimulates creativity and critical thinking but also demonstrates the interconnectedness of these diverse fields, highlighting the relevance of each in understanding and shaping our world (Conradty & Bogner, 2020; Henriksen et al., 2015).

2. THE ROLE OF COLLABORATIVE ART INSTALLATIONS IN EDUCATION

In this section, we explore the transformative role of collaborative art installations in STEAM education. By bridging art with scientific disciplines, these installations provide a dynamic, hands-on learning platform, fostering creativity, collaboration, and a deeper understanding of the interconnectedness of diverse fields of knowledge (Eger, 2011; Guyotte et al, 2015).

2.1. How art installations can be used as an educational tool

Art installations, especially when they're collaborative, offer unique opportunities to transform traditional learning experiences. They serve as a creative bridge between the abstract concepts often found in STEM fields and the tangible, expressive nature of art. This blend allows learners to engage with science, technology, engineering, and mathematics in a more approachable, relatable context.

The hands-on aspect of creating an art installation encourages students to apply theoretical knowledge practically. For instance, they may need to use mathematical principles to plan the layout of an installation or apply scientific understanding to select suitable materials. This direct application aids in consolidating and reinforcing the theoretical knowledge acquired in the classroom.

Art installations stimulate creativity and innovative thinking. By challenging students to represent complex concepts visually or three-dimensionally, they engage in creative problem-solving, a skill highly valued in many careers.

Collaborative art installations promote teamwork and communication skills. They require participants to work together, discuss ideas, delegate tasks, and compromise to achieve a common goal, mirroring real-world collaborative scenarios in professional settings.

Art installations have a public-facing aspect that can enhance students' sense of achievement and responsibility. Knowing that their work will be seen and interacted with by others can motivate students to strive for quality and accuracy, thus deepening their learning experience.

2.2. The value of collaboration in the learning process

Collaboration is an essential aspect of the learning process, particularly in the context of STEAM education. It simulates real-world situations where individuals must work together to solve complex problems, mirroring the multidisciplinary teamwork often found in professional environments, especially in science and technology industries.

In collaborative art installations, students must communicate effectively, share ideas, negotiate solutions, and coordinate efforts to accomplish a shared goal. This process enhances interpersonal skills, fostering empathy, respect, and an appreciation for diverse perspectives (Johnson & Johnson, 2009; Lou et al., 1996; Ross, Hogaboam-Gray & Rolheiser, 2002).

Collaboration also encourages problem-solving. When students work together, they are more likely to consider multiple approaches to a challenge, critically evaluate these options, and synthesize them into innovative solutions. This enhances their critical thinking skills and encourages innovative thought.

Collaboration creates a sense of shared responsibility and accountability. Each participant has a role to play in the success of the project, and this can lead to increased commitment, engagement, and effort.

Importantly, collaboration can also foster a deeper understanding of the material. When students explain their ideas to others or debate different approaches, they must articulate their understanding clearly. This process can reveal gaps in their knowledge, prompt questions, and lead to more profound learning.

3. THE COLLABORATIVE ART INSTALLATION PROJECTS

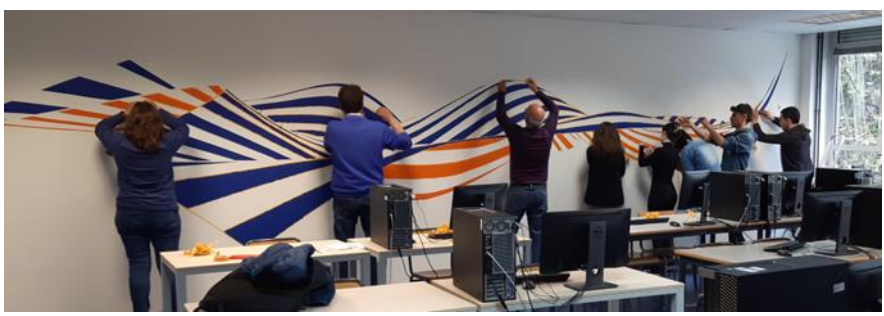
This section describes the specifics of the collaborative art installation projects, highlighting their design, execution, and the profound learning experiences they facilitated within the multidisciplinary context of STEAM education.

3.1. DESCRIPTION OF SEVERAL COLLABORATIVE ART INSTALLATIONS

The collaborative art installations designed and executed as part of this project were diverse in their approach, reflecting a range of STEAM disciplines. They were implemented across various educational levels, from elementary and secondary schools to universities and adult education centers, enabling a wide spectrum of learners to participate.

One of the installations involved acrylic painting on plaster walls (Figure 1).

FIGURE 1. *Wall on plaster painting of manifold surfaces exploring color and geometry*



Note: Adapted from the authors' website, 2022 (https://www.ehu.eus/es/web/gmm/wall-drawing-2022.sydney)

This project allowed participants to explore the interplay of color and texture, while also incorporating mathematical concepts of geometry and 2d representation of 3d surfaces.

Another installation used translucent vinyl on glass, providing a platform to investigate the science of light and color and the technology of materials science (Figure 2).

FIGURE 2. *Installation of translucent vinyl on glass to investigate the science of light*

Note: Adapted from the authors' website, 2022 (https://www.ehu.eus/es/web/gmm/glass-drawing-2022.boston-glass-drawing-2022.osaka)

A more complex project (Figure 3) involved painting on metal panels.

FIGURE 3. *Installation of acrylic paint on metal to explore a minimal language of color and 3d representation*

Note: Adapted from the authors' website, 2022
(https://www.ehu.eus/es/web/gmm/wall_drawing_2022.ankara)

This installation brought in aspects of engineering, such as understanding the properties of different metals, and the technology of different painting techniques suitable for metal surfaces.

The most ambitious installation was a 3D structure made of spruce. This project required a deep understanding of engineering principles for structural integrity, mathematical skills for precise measurements, and artistic vision to create a visually pleasing structure (Figure 4).

FIGURE 4. *3D structure to explore geometric perspectives and engineering principles for integrity.*

Note: Adapted from the authors' website, 2022 (https://www.ehu.eus/es/web/gmm/3dstructure2022.bremen)

These diverse installations, each uniquely blending art with various STEAM fields, provided students with a holistic, hands-on learning experience that went beyond traditional classroom teaching.

3.2. The rationale behind mediums and techniques used

The choice of mediums and techniques used in the collaborative art installations was carefully considered to ensure they served two main purposes: to enhance the educational experience and to create meaningful, engaging art pieces.

Each medium was selected to enable exploration of specific STEAM concepts. Translucent vinyl on glass made it possible to explore light diffusion and color mixing, integrating art with physics.

In the case of the 3D spruce structure, the medium choice allowed for a deeper dive into engineering principles. Participants could learn about the material properties of wood, the necessity of precise measurements in construction, and the importance of structural integrity in engineering designs.

The techniques used, such as painting, assembling, and modeling, were chosen to offer a hands-on, tactile learning experience. They required active engagement and problem-solving, which fostered a deeper understanding of the concepts being explored.

3.3. Information on the participants and settings

The collaborative art installations brought together a diverse array of participants, ranging from elementary and secondary school students to university students, faculty, and staff. This intentional inclusivity aimed to foster a broad exchange of ideas and perspectives, enriching the learning experience.

The involvement of younger students brought a fresh, unencumbered viewpoint to the projects. Their innate curiosity and willingness to experiment were valuable in driving creativity. Secondary school students contributed more advanced understanding of STEAM concepts, while university students brought a higher level of expertise and were often able to mentor the younger participants.

Faculty and staff involvement was crucial, providing guidance, ensuring safety, and facilitating the learning process. They served as role models, demonstrating the value of lifelong learning and the relevance of STEAM disciplines in everyday life.

The settings for these installations were carefully chosen to be easily accessible to the participants and the wider community. They were created in common areas within educational institutions, including elementary and secondary schools, universities, and a community center. This

placement not only facilitated frequent interaction with the installations, enhancing the learning experience, but also served to raise public awareness and appreciation of the integrative potential of STEAM education.

4. ART AS UNDERSTANDING: THE 20TH CENTURY EVOLUTION AND ITS IMPACT ON STEAM

This section describes the evolution of art in the 20th century, focusing on the emergence of art as a tool for understanding. We will explore how this shift influences and enhances the implementation of STEAM education, fostering a more holistic and interconnected learning experience (Gombrich, 1995; Arnheim, 1974; Danto, 1981; Elkins, 2003).

4.1. The transition of art as desire, beauty, and emotion, to art as understanding

The understanding of art has undergone significant transformation over the centuries. In early periods, art was primarily seen as a medium of desire, beauty, and emotion. Artists sought to create aesthetically pleasing works that evoked emotional responses and depicted objects of desire. Art served as a mirror, reflecting the artist's inner world or the beauty of the external world.

However, the 20th century witnessed a shift in this perception. While beauty and emotion remained important, art started to be viewed as a medium for understanding and communicating complex ideas. Artists began to use their work to question, challenge, and explore various facets of human existence and the physical world.

Abstract art, for instance, moved away from literal representation, encouraging viewers to interpret the artwork and discover meaning. Conceptual art placed more emphasis on the idea behind the work than its aesthetic value. These movements reflected the growing understanding of art as a vehicle for intellectual exploration and discourse.

This transition in the perception of art opened new avenues for integrating art with other disciplines like science, technology, engineering, and mathematics, leading to the development of STEAM education. Art as

understanding bridges the gap between these diverse fields, fostering a more holistic and interconnected learning experience.

4.2. How understanding of art has influenced STEAM education

The evolution of art towards a medium of understanding has profoundly influenced STEAM education and the design of the installations in this project. It has opened new possibilities for integrating art into science, technology, engineering, and mathematics, creating a more holistic and engaging learning experience.

In STEAM education, art serves as a tool to visualize and comprehend abstract concepts from other fields. For instance, an artistic representation of a mathematical pattern or a scientific phenomenon can provide a tangible, visual context that enhances understanding and retention. Art also fosters creativity and innovation, skills that are essential in all STEAM fields.

In the design of the installations, this understanding of art influenced the choice of mediums, techniques, and concepts. The installations were not merely about creating aesthetically pleasing works; they were designed to visually express and explore STEAM concepts. For example, the 3D spruce structure was not just an artistic sculpture; it was a practical exploration of engineering principles.

This perspective of art encouraged collaboration and active participation, as the process of creating and understanding art became a shared journey. Participants were not just passive viewers; they became active creators and interpreters, deepening their engagement with the STEAM disciplines.

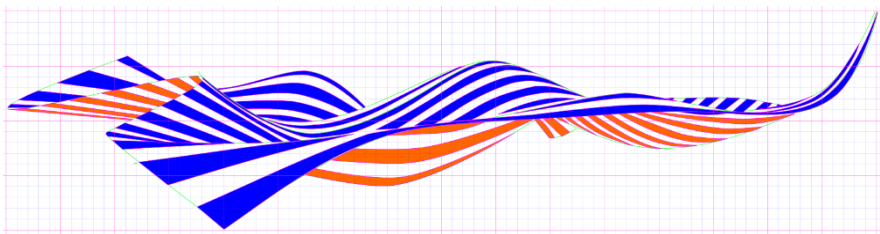
5. EXAMINATION OF SELECTED ARTWORKS

In this section, we will explore four selected artworks from the collaborative art installations. Each artwork embodies different elements of STEAM education, providing rich examples of how these disciplines can be creatively integrated and understood through the medium of art.

5.1. Description of four selected artworks

"Wall Drawing 2022 Sydney" is a powerful exploration of manifolds, which are three-dimensional surfaces appearing frequently in nature, as well as in the work of contemporary artists like Frank Gehry and Richard Serra. This artwork uses minimalist language, employing 56 rectangular stripes in two colors, blue and orange, to represent these curved surfaces. As a viewer's visual system processes the non-rectangular perception of these stripes, they are challenged to decipher the underlying curved surface. This work underscores the idea of discretization and integration, where individual elements (the colored stripes) form a complex structure (curved manifolds). The white color of the wall plays a crucial role, as it is mentally incorporated by the viewer into the image, subtly underlining the artwork's inherent language. See Figure 5.

FIGURE 5. *Wall Drawing 2022 Sydney; exploration of 3d manifolds in 2d space*

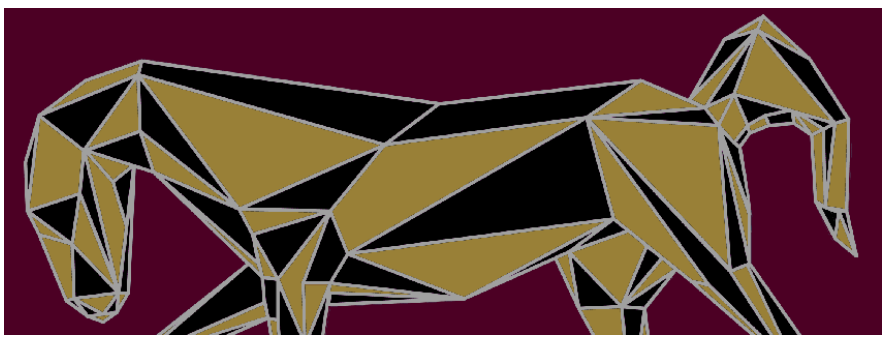


Note: Adapted from the authors' website, 2022 (https://www.ehu.eus/es/web/gmm/wall-drawing-2022.sydney)

This collaborative action aims to foster an Open-Space educational experience outside traditional classroom confines. The objectives are to develop cognitive primitives, motivate student collaboration, and overcome pedagogical hurdles by implementing visible art in the school community. It introduces fundamental STEAM concepts like top-down design and non-Euclidean geometries, while also motivating students to gain knowledge and tools necessary for designing and creating such installations. The approach seeks to transform learning content through direct intervention, promote self-regulated learning, and stimulate analysis of how different STEAM elements interrelate in an educational structure (Lippard, 1997; Bevan et al., 2015).

"Wall Drawing 2022 Ankara" is an artwork that explores the human visual system's hierarchical nature, from basic edge detection to complex image recognition. Using a minimalist language of straight lines, simple polygons, and two colors (black and gold), it allows viewers to perceive a 3D figure and a well-proportioned, recognizable animal. The artwork employs two artistic paradigms. First, it can be appreciated at both a local (micro) and global (macro) level, allowing for distinct cognitive and aesthetic experiences. Second, it demonstrates the differential and integral essence of images, breaking down a three-dimensional structure into primitive elements, then combining these to form a superior structure, reinforcing the idea that everything is a set of parts, and a set of parts make up a whole (Edmonds et al., 2009). See Figure 6.

FIGURE 6. *Installation to explore the human visual system's hierarchical nature*

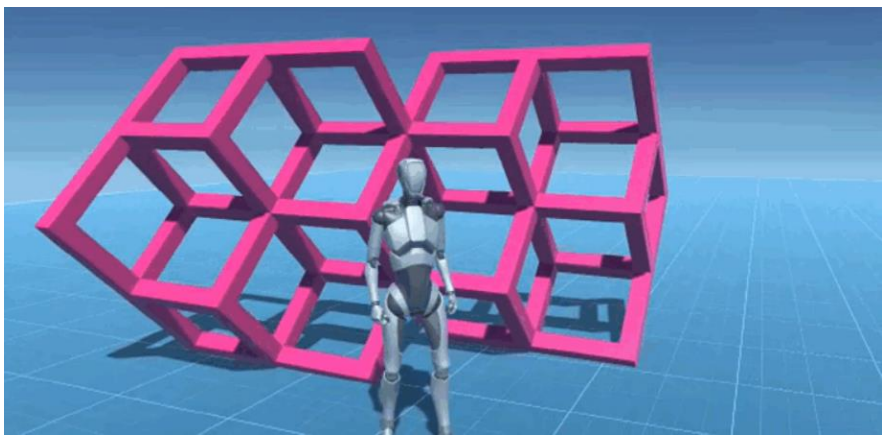


Note: Adapted from the authors' website, 2022
(https://www.ehu.eus/es/web/gmm/wall_drawing_2022.ankara)

"3D Structure 2022 Bremen" is a dynamic exploration of geometrical principles centered around the cube. This piece features two interconnected, incomplete super-cubes, each further divided into smaller cubes. The edges, positioned at a 45-degree angle to the floor, are designed with parallel lines of magenta, white, or black, granting the structure an element of transparency. As viewers walk around, their perspective shifts, presenting a panorama of shapes including rhombuses, triangles, diamonds, hexagons, squares, and rectangles. This dynamic play of symmetries from a static structure invites viewers to contemplate the nature of perception and understanding, fostering a dialogue between

the eye, the mind, and the structure itself (Livingstone, 2002; Zeki, 1999). See Figure 7.

FIGURE 7. *Installation to explore the dynamic geometrical principles centered around the cube*



Note: Adapted from the authors' website, 2022 (https://www.ehu.eus/es/web/gmm/3dstructure2022.bremen)

"Glass Drawing 2022 Boston" is a stained-glass installation that presents a profound exploration of visual experience, structural appreciation, and the essence of composition. The artwork offers viewers an experience of color saturation and purity not typically found in nature, achieved through meticulous elimination of light impurities and non-linear color generation. The artwork is appreciated at two levels – local and global. Locally, the viewer engages with contrasts of color and simple geometric shapes, while at a global level, they perceive structured components, identifying them through color and geometric patterns. The installation embodies the idea of differential and integral essence, demonstrating how a complex structure like a pergola can be broken down into primitive elements and how these elements combine to form the larger whole. This interactive experience imprints the viewer with the understanding that everything is both a sum of its parts and a constituent of a larger whole (Gage, 1999; Arnheim, 1974). See Figure 8.

FIGURE 8. *Installation to explore the essence of composition and visual interpretation*

Note: Adapted from the authors' website, 2022 (https://www.ehu.eus/es/web/gmm/glass-drawing-2022.boston-glass-drawing-2022.osaka)

5.2. Discussion of the basic concepts of art and STEM

Each of these artworks presents an interplay of Art and STEM concepts, serving as tangible demonstrations of theoretical ideas and principles.

"Wall Drawing 2022 Sydney" uses minimalist language to explore manifold surfaces, a concept from geometry, and thus mathematics, that is prevalent in nature and architecture. The artwork's differential and integral essence reflects the mathematical processes of differentiation and integration, illustrating how complex structures are built from simpler elements and how these elements combine to form a whole.

"Wall Drawing 2022.Ankara" leverages a basic geometric language to depict a realistic figure, encouraging viewers to perceive complex structures from simple shapes. It illustrates how the human visual system processes images, a concept central to neuroscience, a STEM field. Each artwork, in its unique way, intertwines artistic creativity and scientific principles, thereby exemplifying the essence of STEAM education.

"The 3D Structure 2022 Bremen" revolves around the simple geometrical structure, the cube. The concept of incomplete and inclined cubes and transparency introduces viewers to unique visual perspectives, prompting them to understand static structures from dynamic viewpoints. This promotes spatial reasoning, a key skill in STEM fields such as engineering and architecture.

"Glass Drawing 2022 Boston" represents an innovative educational activity that operates within an Open-Space environment. It utilizes a top-down design approach, demonstrating how complex systems, such as

non-Euclidian parametric surfaces, can be implemented with increasingly simpler subsystems, including windows, panes, and polygons.

5.3. CONNECTIONS BETWEEN THE DIFFERENT FIELDS IN STEAM

Each of the presented artworks remarkably exemplifies the intersection of the fields that constitute STEAM education. They underline the interdependence and synergy between these domains, demonstrating how each informs and enriches the others.

Starting with "Wall Drawing 2022.Sydney", the concept of manifold surfaces derived from geometry is visually expressed using artistic elements. This representation manifests how mathematical principles can be translated into visual arts, enriching the aesthetic experience while simultaneously providing a tangible understanding of complex geometrical concepts.

"Wall Drawing 2022.Ankara" combines the human visual system's principles with geometric constructs to depict a realistic figure, thereby fusing neuroscience, mathematics, and visual arts. This compelling combination encourages viewers to experience and appreciate the intricate interconnectedness of these fields.

"The 3D Structure 2022 Bremen" extends this theme, utilizing artistic creativity to express geometric concepts. Its design encourages viewers to engage with the artwork and thus with the underlying geometric principles in a dynamic, physical way, thereby connecting visual arts, mathematical concepts, and spatial reasoning.

The Collaborative Action project creates an environment where art, design, and various STEM fields converge. Students learn to apply mathematical concepts to real-world challenges, harnessing technology, and engineering principles in creating artistic installations.

"Glass Drawing 2022 Boston" presents an innovative combination of scientific principles and artistic expression that is characteristic of STEAM education. It emphasizes the importance of local and global perspectives in both art and science. The local level consists of an intricate arrangement of geometric shapes, while the global level reveals

more complex structures created by these shapes. It exemplifies the quintessential objectives of STEAM education: interdisciplinary exploration, integrated learning, and the creation of connections between traditionally distinct domains.

6. EDUCATIONAL STRUCTURE SUPPORTING COLLABORATIVE PIECES

This section describes the educational infrastructure required to facilitate collaborative art pieces. We explore the need for an integrated, interdisciplinary approach, addressing the role of educators, the design of learning environments, and the application of pedagogical strategies to maximize the benefits of STEAM education through collaborative art installations.

6.1. Overview of the teaching methods used in the project

The teaching methods used in the collaborative art projects were experiential, project-based, and student-centric. The instructors acted more as guides, promoting inquiry and discovery rather than direct instruction. This enabled students to actively explore and understand the concepts behind the art installations, fostering a deeper level of engagement and comprehension (Kolb, 2014; Thomas, 2000).

The project-based approach emphasized the process over the product. Students worked collaboratively, planning, and executing their art installations. This method honed their skills in problem-solving, teamwork, and critical thinking. It also provided a tangible, real-world context for the abstract concepts taught in STEAM subjects.

The teaching methods were student-centric, focusing on the students' interests, abilities, and learning styles. Differentiated instruction was employed to cater to a diverse range of learning needs and preferences. Students were encouraged to take ownership of their learning, with self-directed activities forming a significant part of the curriculum.

Technological tools were also integral to the teaching methods, enabling students to explore complex concepts and create their art installations.

Software for design and simulation, hardware for construction, and digital platforms for collaboration and communication were used extensively.

Continuous reflection and feedback were emphasized, with students encouraged to critically evaluate their work and learn from their mistakes. This iterative process of learning is fundamental in STEAM education and was a critical aspect of the teaching methods used.

6.2. Examination of the learning goals achieved

The learning goals achieved through these collaborative art projects were multiple, spanning various domains of the STEAM curriculum.

In the science realm, students developed a deeper understanding of principles such as parametric geometry and complex 3D structures. These concepts were instrumental in the design and execution of the art installations, promoting scientific inquiry and fostering critical thinking (Honey, Pearson, & Schweingruber, 2014; Bagiati & Evangelou, 2015).

The technology and engineering aspects were addressed using cutting-edge software and hardware tools. Students acquired hands-on experience in these areas, expanding their digital literacy and honing problem-solving skills. By applying technological and engineering principles to their projects, they grasped the interconnectedness of these domains in real-world contexts.

Art, the central theme, offered students a platform for creativity, innovation, and aesthetic appreciation. Students learned to use art as a medium for expression and communication. Moreover, by employing minimalist language in their designs, they delved into the study of form, pattern, and color, enhancing their visual literacy.

Mathematics was intricately woven into the projects as well. The design and construction of the installations necessitated a sound understanding of mathematical concepts like geometry, measurement, and proportionality.

The collaborative nature of these projects fostered key interpersonal skills such as teamwork, communication, and leadership. Through their

active participation, students developed a sense of responsibility, resilience, and resourcefulness. Moreover, by presenting their work to the wider community, they learned to articulate their ideas confidently and compellingly. In summary, the learning goals achieved extended beyond academic knowledge, nurturing important life skills and values in the students.

6.3. Discussion on the implications for STEAM education

The implications of these collaborative art projects for STEAM education are far-reaching and transformative.

These projects showcase the possibilities of hands-on, project-based learning. They demonstrate how complex theoretical concepts can be made tangible, understood, and appreciated through practical, engaging work. This experiential form of learning increases retention and comprehension and could significantly improve student engagement in STEAM subjects (Bequette & Bequette, 2012).

They exemplify the integration of art into the traditional STEM framework. This integration underlines the importance of creativity and design thinking in solving scientific problems and innovating in the tech industry. Recognizing and embracing the "A" in STEAM can make these fields more appealing and accessible to a broader range of students.

These projects promote interdisciplinary learning and problem-solving. The necessity of understanding and applying principles from various fields to create the installations reflects the realities of modern work environments, which increasingly require employees to possess cross-disciplinary knowledge and skills.

These projects could inspire a shift towards more collaborative and socially-engaged learning environments. They highlight the value of teamwork, communication, and social impact in education, skills which are vital for the future workforce.

7. CONCLUSION

This chapter has presented a journey through the intersection of art and STEAM education, exploring how collaborative art installations can serve as powerful teaching tools, fostering a more inclusive, engaging, and holistic learning environment.

The significance of these projects lies not only in their creative output but in the transformational learning experiences they provide. They transcend traditional classroom boundaries, encouraging students to grapple with complex concepts, collaborate, and problem-solve, thereby developing cognitive, social, and emotional competencies. Moreover, these projects highlight the vital role of art in STEAM, asserting its relevance and capacity to enhance scientific understanding and innovation.

The impact of these installations on students has been profound. They have witnessed a shift in perspective from passive recipients to active creators of knowledge. It's hoped that this empowering experience will lead to a deeper engagement with STEAM fields and potentially shape future educational and career paths.

Looking forward, we propose several avenues for future work. More extensive research into the long-term effects of these projects on student outcomes, a broader application of these methodologies in diverse educational settings, and the development of teacher-training programs to equip educators with the necessary skills to facilitate such projects are just a few possibilities.

Ultimately, this work presents a compelling case for the transformative potential of integrating art into STEAM education, marking an exciting departure from traditional pedagogical approaches, and opening a world of creative learning opportunities.

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