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Collaborative STEAM in Educational Centers: Artistic installations in public spaces

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Abstract: The STEAM initiatives promote the idea that art is a fundamental element in education and human expression. We study the possibility that a group of students from an educational center may be able to implement an artistic installation. We also study whether the installation could be aligned with educational policies that foster STEAM ideas and practices. Furthermore, we analyze whether these activities can be carried out collaboratively by students using public spaces designated by university administrators. To address these issues, we organized an artistic installation project at the School of Education of Bilbao, Spain. The installation was carried out by 63 sophomore students. The result of this project is the artwork entitled Glass Drawing 2021 Havana. The installation was created in a study hall with a large glass wall adjacent to the main entry of the school building. The dimensions of the work are 1830 cm by 238 cm, and it uses the technique of translucent vinyl on glass. The artwork Glass Drawing 2021 Havana shows that the students of an educational center can create a collaboratively STEAM art installation using the existing public spaces of the university.

Keywords: collaborative STEAM, artistic installations, public spaces, teacher education

1. INTRODUCTION

STEAM education has been on the educational agendas of OCED countries for more than 10 years. However, the integration of STEAM education in schools and universities has only succeeded in very few places, and in short lived projects (Barcelona, 2014; Freeman et al., 2019; van der Vlies, 2020). There are government programs and private initiatives that address the integration of STEAM from different perspectives. The former favor integration of STEAM subjects in the existing curriculum, and the latter pursue concrete experiences using technologies in classic problems reformulated in STEAM terms (Bahrum et al., 2017; Corlu et al., 2014; Khan and Rodrigues, 2017).

The most widely solution available to educational institutions to incorporate STEAM in the short term encourages the acquisition of technological infrastructures and materials, hardware and software, accompanied by the specialized training of teachers in the use of the new equipment (Mamani et al., 2021; RoboSTEAM, 2019; Shatunova et al., 2019).

Are there other alternatives to this situation? The proposal that we describe widens the spectrum of solutions for the integration of STEAM in the education of our young students. It proposes a concrete and sustainable paradigm that overcomes the limitations of the traditional proposals (Costantino, 2018; Guyotte et al., 2014; Guyotte et al., 2015; Graham, 2021; Kim & Kim, 2020; Liu et al., 2021; Olabe et al., 2020). In addition, the proposal presented here is designed to provide a solution that could be easily replicated in schools and universities, and that could be adapted to their educational needs and objectives, regardless of their economic means and their demographic characteristics. Integrating STEAM in school requires two initial tasks: a) developing a curriculum based on the real use of STEAM in industry (in a concrete and non-theoretical way); and b) the teaching of these concepts in an integrated way (and not as four isolated areas in separate courses.)

The role of STEAM in industry is easier to understand and study if we use a hierarchy that explains the relationship between the four areas of STEM. The root of this hierarchy is Engineering. The goal of engineering is to build solutions. To build these solutions we use the tools provided by the field of Technology. The technological tools are designed to optimize the transformation and control of systems based on the knowledge provided by the sciences (physics, chemistry, biology, geology, etc.) Finally, the knowledge provided by the sciences is studied, represented, and manipulated with the tools of mathematics (Olabe et. al, 2019). The STEAM paradigm was created as the result of adding Art to the four areas of STEM. Art adds components of creativity, innovation, and aesthetics which are fundamental in the education of our students. Creativity, innovation, and aesthetics are an intrinsic part of engineering (Huser, 2020; ViewSonic, 2021).

We describe the activities for the creation of an art installation in which the students explore ideas from the different fields of STEAM: in engineering, the concepts of discretization and the bottom-up implementation; in the field of technology, the mechanisms of formal languages; in the field of science, the effect of vinyl in the diffraction of photons; and in the field of mathematics, the emerging set of patterns and symmetries created by an incomplete open cube. For centuries, including the present time, the field of art was closely guarded by art institutions that maintained a set of standards and cannons. These standards and cannons valued manual skills that required years of training and restricted the arts to selected groups trained in these skills (Cahnmann-Taylor and Siegesmund, 2007; Isbell and Raines, 2012). In the 19th and 20th centuries, several art movements clashed with the art institutions and gradually introduce alternative concepts to the traditional definitions of art. To the three traditional cannons, art and desire, art and beauty, and art and emotion, they added art and understanding (Graham, 2005). In this philosophy of art and understanding, art is viewed as the environment to explore and express ideas using visual forms instead of natural language. The artist Sol Lewitt is an example of proponents of the philosophy of art and understanding (LeWitt, 1967; LeWitt et al., 1974; Pinke, 2004). Modern art is changing how the institutional world of art interacts with society. Modern art is present in our streets, in our museums, in our buildings. The presence of art in our streets appears in formats and materials as diverse as metal, stone, wood, paper, lights, water.

Having made the connection between art and the understanding of our world and having made the connection between art and the expression of ideas in visual forms, it is easy to see the connection of STEAM and art. STEAM represents an ever-increasing set of ideas about the world and nature. These ideas can be represented visually through art.

We can use the expression “STEAM Art” to identify the artworks and installations designed from their inception to explore and express STEAM ideas. The idea that gives rise to this artwork must contain one or more STEAM fundamental fields, either in its form, in its content, or in its execution (Perignat, and Katz-Buonincontro, 2019). Earlier, we described the general STEAM ideas contained in the art installation. In addition to these components, we highlight two pedagogical components present in the art installation: 1) the motivational value of performing collaborative work; and 2) the motivational value derived from building an artistic work in a public space where it will be shared with many citizens. These two components had a fundamental effect in the pedagogical and artistic success of this STEAM project.

Collaborative work is an element of great relevance in the professional work of industry. This fact should encourage teachers the use of collaborative work systematically in the school environment as well. Collaborative work favors communication, productivity, the exchange of ideas and knowledge, innovation, and the achievement of common goals. In addition, collaborative work promotes, in a special way, team resolution of complex problems, and the motivation to overcome difficulties. The ability to work in teams is theoretically considered an important transversal skill to be developed by students in the university environment (EHU, 2020; Sá and Serpa, 2018; Tsankov, 2017).

The implementation of a large-scale artistic installation in a public space has motivated students to work as a team and solve all the problems that appear in the execution of such a complex project. The school environment primarily develops mental skills through individual activities, for example: solving mathematical problems or writing a literary work. On the other hand, but less frequently, students carry out activities that involve some type of construction work, with paper, cardboard and other materials. In these activities, students experience great satisfaction in the creation of an artifact. Seymour Papert valued the theory of constructionism to facilitate the acquisition of knowledge. This theory is based on learning through the realization of artifacts. In this way the student learns while building (Papert and Harel, 1991). Based on the theory of constructionism, we present the collaborative construction of a STEAM art installation with the purpose of strengthening the STEAM knowledge of students.

The pedagogical movements Makerspace and Fab Lab (Fabrication Laboratory) are two examples that propose improving learning through collaborative work. These paradigms are characterized by the following features: a) They require a physical space equipped with technological components (3D printers, laser cutters, microcontrollers, etc.); b) Learning is done through a series of guided projects in the different technological areas supported by the lab equipment; and c) Learning is programmed in groups of two people (peer to peer.) These two pedagogical initiatives initially produced great optimism in the academic world, which responded with large financial investments to provide the space and equipment required. However, the objective that students would participate in the activities programmed in these laboratories has not been achieved in general. The laboratories are usually empty, and the equipment, tools and machines become obsolete over time (Konopasky and Sheridan, 2020; Rosa et al., 2017).

The artistic installation presented here develops a collaborative learning method that does not try to replace the Makerspace and Fab Lab models. Rather, it presents an alternative model. This alternative model presents two fundamental variations. First, it abandons the idea of creating a central space with technological equipment and adopts the principle that construction should take place where the students are. Second, it adopts the principle that the construction activity should not be determined by the equipment available in a lab. The source of the project must be a fundamental STEAM idea that students would explore and learn. The construction activity and the materials used will be selected in according to the STEAM idea.

Our first research question therefore asks whether students of an educational center can create a STEAM art installation, strengthening their knowledge of STEAM fundamental concepts. Our second research question asks whether it is possible to create a complex STEAM art installation in a public space developing the capacity for cooperation of the students of an educational center.

2. INTRODUCTION

The pedagogical project that we present is based on three methodological strategies (MS1,2,3). The methodological strategy MS1 is involved in the creation of the framework and infrastructure that will support the design, implementation, and evaluation of an art installation. MS1 provides the means and techniques to carry out a large-scale artistic work, which will be implemented collaboratively by a large group of participants. The methodological strategy MS2 is applied after the administrators of the educational center have approved the use of a space in the university for the implementation of the art installation and the participating students have been identified. MS2 designs and plans the activities according to the space and participants. Finally, the methodological strategy MS3 is used in the implementation of the art installation and the formal evaluation of artistic and academic goals.

2.1. MS1: methodological strategy for the creation of a pedagogical framework for the design of collaborative STEAM art installations

The academic initiatives of the last decade have shown that Makerspaces and Fab-Labs have not been very successful in accomplishing their goals. The academic world needs to continue the search for new alternatives. One such alternative consists in modifying the initial concept of Makerspace and substitute the centralized physical space in which is based with more flexible spaces (Spencer, 2016; Wong & Partridge, 2016).

The new model of Makerspace is intended to overcome the limitations of the traditional makerspace. We call this new model Open Space. This name, Open Space, refers to the fact that the collaborative activities will not be implemented in a predefined laboratory, but rather in an existing public space that does not require the traditional equipment of a laboratory. These Open Spaces are designed to allow the economic and environmental sustainability of the new makerspaces.

By extension, we call Open Space Group (OSG) the persons who organize and manage the implementation of artistic works in a school or university. The members of the OSG include teachers and administrators assigned to stimulate and manage STEAM projects through collaborative art installations in the school. The initial role of the OSG is to collect and evaluate the STEAM proposals. The project proposals to implement art installations are generally initiated by teachers and professors interested in involving their students in this type of activities. The OSG encourages teachers to submit proposals with the goal of supporting their pedagogical initiatives. The OSG includes members with art installation background that are tasked with integrating the ideas of the proposals into concrete projects.

We highlight the open nature of Open Spaces by emphasizing the goal of integrating any of the areas of STEAM, and not be limited to one specific area that is determined by the instrumentation and the equipment of a traditional makerspace. In addition, the word Open refers to the open philosophy that is present in: open to new formats, techniques and materials for the realization of the artistic work; open to collaboration with other schools.

An important characteristic of Open Spaces is their collaborative nature. Collaboration means teamwork among students and teachers. The organization and development of art installations requires intense collaboration of all participants. The collaboration is fostered in the classroom, during the study of the theoretical concepts of the project, and during the practical sessions when the art installation is implemented.

2.2. MS2: Design and planning of the activities for the implementation of collaborative art installations

A project begins when a teacher submits a STEAM art proposal. Later, the OSG approves its creation and provides institutional and administrative support, including the active participation of teachers and students. Once these steps have been completed, the strategy methodology MS2 will be tasked with the design of the specific activities that are required in the implementation of the art installation. The objectives of the methodological strategic MS2 include: 1) promote the collaboration among students in the implementation of an art installation; and 2) promote the students' understanding of STEAM ideas integrated in the project.

The success of the academic project lies in the optimal organization of these activities. The organization for both objectives is structured in five stages: 1.- Design, 2.- Material, 3.- Planning, 4.- Execution, and 5.- Evaluation.

Table 1 summarizes the methodological strategy MS2. The table describes the five stages for each of the objectives.

Table 1. Stages of the MS2 Methodological Strategy

	Goal 1: Creation of the artistic work	**Goal 2: Learning the STEAM fundamentals of the work**
Design	Design diagrams plans 3D perspectives details modules panel STEAM components	sessions: introduction execution of installation final synthesis
Material	vinyl, paints, Dibond accessories and complements vinyl cutting (cutter-plotter) assembly of racks	ppt presentations collaborative exercises (on the work)
Organization planning	stages of the work student groups work equipment materials for organization teams	calendar LMS platforms and Google classroom
Execution	initial preparations (panel markings) execution sessions in the physical space of the educational center by students final preparations (for delivery of work)	sessions in the classroom: introduction final exercises
Evaluation	Artistic work carried out	Portfolio

2.3. MS3: Management and execution of activities and evaluation of results

The methodological strategy MS3 is tasked with the successful execution of the activities programmed in MS2. This execution culminates in the implementation of the two objectives of the work: the implementation of an art installation, and the students´ understanding of the STEAM fundamentals integrated in the artwork.

MS3 is implemented throughout several work sessions with the students. The first of these sessions takes place in the classroom. This session is dedicated to describing the STEAM fundamentals of the work: the design and the materials of the work. There are also dedicated to reviewing the technical procedures that will be used in the implementation of the artwork. The students get familiar with the formal planning of construction and the problems that will appear along with the best strategies to overcome them.

The work teams are organized in groups of 3-4 students. The operation of collaborative work between team members and their relationship with other teams is explained. Finally, to finish this first session, the students visit the public space allocated in the university for the art installation.

The second session is dedicated to the execution of the work. If the work is very complex, several work sessions will be required. This session takes place in the assigned public space. Prior to the start of this session, the collaborating team of teachers prepares the materials for each team. The collaborating team of teachers starts the session indicating all the participants the tasks to be carried out. The students begin the execution of the work following the planned steps and procedures. They use the prepared materials and tools. The students work as a team: they make group decisions and carry out together the actions that will create the work. The team of teachers participates and collaborates with the students assisting them and supervising the execution.

After the execution sessions of the artwork, the last session is held. In this last session, the students work in teams to carry out a set of STEAM exercises related to the artistic work implemented. The teams complete a set of exercises using photographs that they have taken of the work implemented by them as well as the complete work. The exercises are integrated into an LMS platform, creating a digital portfolio of the work implemented by each team.

3. RESULTS

This section includes the results of the art installation titled Glass Drawing 2021 Havana. This artwork was installed in the School of Education of the University of the Basque Country, Spain. The work was implemented with the participation of second year students (63 people, 50 women and 13 men) during the month of November 2021.

The OSG allocated for this artwork a public space in the main building of the school: a study hall. This study hall is on the ground floor of the school, and it is located next to the main entrance. The classroom contains a large glass wall with views of the gardens surrounding the main building. The glass wall contains a total of 10 glass panels; each panel has dimensions of 185 cm wide and 245 cm high.

After the approval of the OSG of the work, the methodological strategy MS2 was launched. The teacher requesting the STEAM art installation and members of the OSG team elaborated the set of activities (see Table 1). The set of activities was designed for the realization of an art installation according to the characteristics of the assigned physical space, as well as the body of students in the course School Organization, taught by the requesting teacher.

The fundamental STEAM areas that the Glass Drawing 2021 Havana explores are the following: in engineering, they explore the concept of discretization (how a system is made of many small parts) and the bottom-up implementation (how a system is built by constructing small parts and are connected into larger components until the complete system is created.) In the field of technology, the students use the mechanisms of formal languages for the description and generation of structures (a group of edges creates a small cube, several small cubes create a cube structure, etc.) In the field of science, they explore the effect of vinyl in the diffraction of photons (what are the differences between transparent and translucid, and how the glow effect of the vinyl is created.) In the field of mathematics, the students analyze the hexagonal symmetry of the artwork and the large set of patterns and symmetries that are created with an apparent simple structure. Finally, in the field of art, they explore how the mind perceives three dimensional structures created with simple polygons, and the effect of color patterns in the perception of space.

The artwork designed has as its basic element an incomplete open cube (IOC). The IOC is a cube with empty faces (open) and with some of its edges removed (incomplete). The artistic language of the artwork uses juxtaposition as a mechanism for combining basic elements. The juxtaposition of two IOC cubes allows the creation of a higher-level element in the language. The method of progressive juxtaposition of cubes was used for the creation of new elements in the language. The complete design of the Glass Drawing 2021 Havana is shown in figure 1.

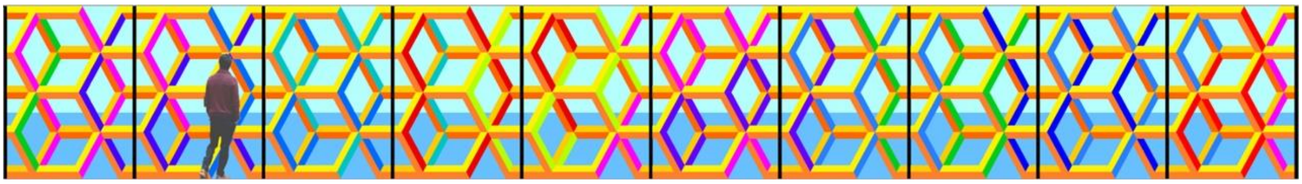

Figure 1. Design of the artwork Glass Drawing 2021 Havana.

The Glass Drawing 2021 Havana was designed using the existing structure of 10 glass panels in the study hall. The design features 10 large open cubes, which the viewer identifies by their hexagonal shapes with the top and bottom edges in contact with the ceiling and floor respectively. Each one of these large open cubes, in turn, is constructed by combining 8 smaller incomplete cubes. The three-dimensional edges of the cubes are colored with a palette of 15 colors.

A large IOC cube occupies two adjacent glass panels in the classroom. The IOC is perceived by the viewer as a 3D structure. The symmetries in the design cause the emergence of multiple hexagons and rhomboids. The distribution of the colors on the edges of the cubes creates in the mind of the observers the underlying three-dimensional structure of the artwork. Figure 2 illustrates one of the large incomplete open cubes.

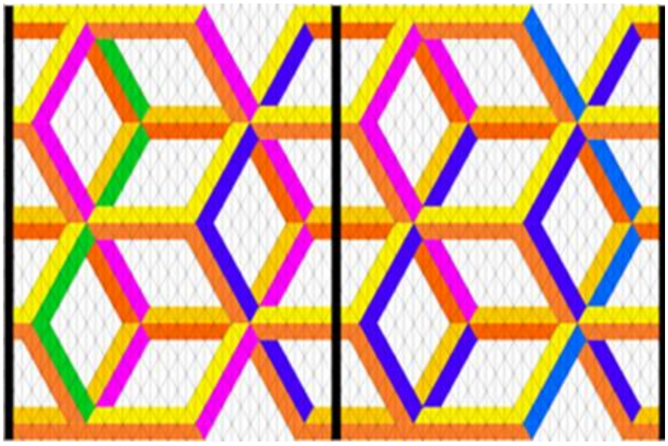

Figure 2. Design of a large IOC of the artwork Glass Drawing 2021 Havana.

Once MS2 was completed, the methodological strategy MS3 was launched. The first work session of MS3 was carried out in the regular classroom. The students participated in this session by learning the basic procedures for handling vinyl, exploring the STEAM fundamentals integrated in the artwork, and studying the sequence of steps they would be taken during the execution phase of the artwork.

The second work session was held in the study hall assigned for the artwork. Teamwork required that all team members participated actively, both in decision making processes and in the physical actions of placing the vinyl and evaluating their actions.

During the construction session, the members of each team work on parallel tasks (while a student places vinyl tiles in the glass panel, a second student removes water and bubbles trapped under a tile, and a third student selects from the library of tiles the tile scheduled to be place next.) They listen to the comments and requests from the other team members, make decision on how to proceed, supervise the team´s progress, etc.

Once the students complete the art installation, they meet with their professors in the regular classroom for review and evaluation. The students work in teams and they complete a set of practical exercises. These exercises reinforce the fundamental STEAM concepts of the artwork they have just completed. Each team takes photos of the glass panel they have implemented and complete a set of exercises where they include their photographs. The students access and complete the practical exercises of this session using the Google Classroom platform.

4. DISCUSSION

4.1. Open Space

During the last years there has been an interest in new pedagogical methods based on the collaborative construction of artifacts in environments called makerspaces. The pedagogical foundation of the makerspaces lies in the elimination of learning obstacles through collaborative work among peers and in the implementation of specific artifacts where theoretical concepts are learned.

These initiatives seemed to have great pedagogical potential. However, they have not produced the anticipated results. This failure occurred for two main reasons: 1) a large percentage of the makerspaces created were designed with a centralized model, located in a laboratory, and equipped with high-cost hardware. This model is neither easily reproducible nor sustainable. The equipment infrastructure soon becomes obsolete in our world of rapid technological change; 2) a large percentage of the makerspaces created were designed with a model that promotes and develops very particular STEM activities, such as robotics and the use of digital hardware, 3D printers, etc. This model is of interest only to a small group of students and is unable to explore the wide range of STEM concepts.

The model proposed here maintains the two fundamental pedagogical elements of student motivation: student cooperation, and the learning of theoretical concepts through the creation of specific artifacts. The new model is based on the elimination of the two great obstacles of traditional makerspaces: the centralized model of a laboratory with a great economic cost, and the emphasis on the area of robotics that limits the study of the many areas of STEM.

We call this model Open Space. This name refers to the fact that the activities are not carried out in a centralized laboratory, but rather in any existing public space that does not require any type of specific equipment.

The word Open in Open Space also refers to the content of the ideas transmitted in these projects. These ideas are not restricted to areas such as robotics but are open to any STEM idea (biology, chemistry, geometry, art, mathematics, etc.)

In this project we offer an example of exploring STEM ideas and art with the goal of promoting the artistic education of students working STEAM areas and foster the creation of art installations in schools and universities with STEAM programs.

This article also presents the idea of using public spaces for the realization of artistic works. Traditionally, school art activities are limited to the creation of small artifacts such as paintings and small sculptures. With the example presented, in which a glass wall of a study hall is used for the realization of an artistic work, we intend to foster the idea of using public spaces in school projects.

4.2. Impact on students

There are three innovative ideas that are derived from the experience lived by the students in the creation of the artwork Glass Drawing 2021 Havana.

The first innovative idea is that we have provided the students with a transformative experience. After they complete the art installation, the students now know these revealing ideas: a) that the construction of the art installation is possible; b) that the students themselves are capable of creating the artwork; and c) that the students themselves are now prepared to create their own experiences for the creation of new art installations.

The second innovative idea with impact on the students is that the installation they created is and artwork. In the philosophy of art there are numerous paradigms of art (Graham, 2005). The paradigms include art and pleasure, art and beauty, art and emotion, and art and understanding. In this last paradigm, art and understanding, the role of art in understanding centers around the exploration of knowledge and its representation in our minds as a vehicle for comprehending the world and nature.

The third innovative idea with impact on the students is the use of languages to represent ideas. An idea is a group of symbols and the procedures to manipulate them. From an initial set of symbols, we are able, through manipulation, to obtain a new set of symbols, which may form new ideas. The process of representing the symbols and later manipulating them, requires a language. Ideas are represented in languages. Therefore, the experience of learning new languages, and using them to represent ideas, and later transforming them in artworks, is fundamental in human development. In the artwork presented, the fundamental symbol is a cube, a very familiar object.

The study hall is situated next to a shallow pool that surrounds the building. The artwork was designed also to interact with the architecture of the building. The pool reflections extend the artwork from the glass panels to the water that encircles the building. The reflections extent to the wet walkways during rainy days.

In addition, the interior and exterior views of the installation show two different interpretations of a unique structure and the chromatic spectrum of the cubes.

The experience of learning the particular language of Glass Drawing 2021 Havana provides the students with the scaffolding to understand the inner structure of languages and their ability to represent and manipulate symbols. It also provides the students with an understanding of the role of languages in the process of learning existing ideas and creating new ideas with value.

5. CONCLUSIONS

This work offers a set of three strategic methodologies that contribute to the integration of STEM in schools and universities with the implementation of art installations. These three strategic methodologies are based on a pedagogical model that we have named Open Space. This model fosters the development of collaborative art activities in public spaces. It is designed to transmit fundamental ideas of all STEAM disciplines (engineering, computation, biology, chemistry, art, mathematics, etc.).

Sixty-three students from the School of Education of the University of the Basque Country, Spain, implemented a collaborative art installation. The art installation was created to include STEAM components in its design, in its execution, and in its final implementation. The artwork Glass Drawing 2021 Havana, created by these students, is the result of a project designed to answer the first research question (students of an educational center can create a STEAM art installation, strengthening their knowledge of STEAM fundamental concepts.) The results illustrated show the creation of an art installation project with the integration of STEAM fundamental ideas. The students demonstrated in this experience their ability to learn the techniques for the construction of art installations and their capacity to integrate the STEAM fundamental ideas.

The work Glass Drawing 2021 Havana was implemented collaboratively by 20 teams of 3-4 people, and it was created in a public space, a study hall, of the university. These two characteristics, collaboration and use of a public space, were incorporated into the project to answer the second research question (whether it is possible to create a complex STEAM art installation in a public space developing the capacity for cooperation of the students of an educational center.) The students that created the art installation are being recognized by their friends and professors for their ability to join forces in the creation of a large project that has become part of the university architecture.

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Supplementary Material: People interested in learning more about the theoretical aspects of this work, and the practical aspects of the implementation of the art installation (photographs, videos, concepts, links, participants, etc.) can find more information on this web page: https://www.ehu.eus/en/web/gmm/glass_drawing_2021.havana

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