STEAM.

A NEW WAY OF INTERACTING IN SCHOOLS AND MUSEUMS.

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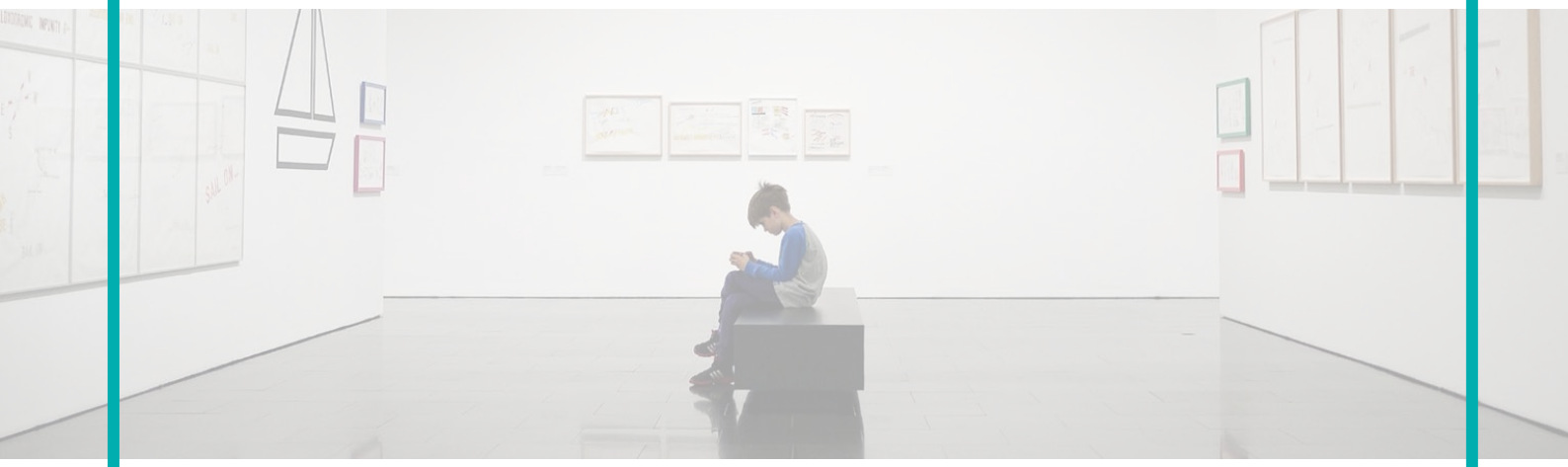


Abstract.

It has been proven that STEAM projects expose students to the creative process and teach them a new way to value science, technology, arts and mathematics. But do museum and educational experts really believe in STEAM? The aim of this paper is to show the state of the art in STEAM, and underscore this methodology's main strengths and weaknesses.

A systematic review of articles and museum websites was carried out before the research was begun. In a final stage, a survey was completed by a selection of ten experts and museum specialists who provided their points of view on the issue, in addition to their experience on various projects.

Our findings indicate that there is an academic interest in STEAM, but few relevant examples of real change in museums and schools, where STEAM should be more visible.

Keywords.

STEAM, museums, education, science, technology, arts, mathematics.

CONTENTS

1. A CONTEXT IN CONSTANT TRANSFORMATION

Beyond any doubt, we live in a society of pictures, of technology and immediacy. The social transformation that has come about in recent years, and still relentlessly advancing, must be coupled with a transversal educational model suited to integration into the complex reality surrounding us, and emphasizing teamwork and development of creative processes. At the same time, museums must turn their focus of attention to the visitor, their relationship with the space, and the experience generated through interaction. Therefore, master classes where students learn by rote, read aloud and underline passages in textbooks are things of the past. The same applies to cabinets of curiosities and the passive experience of visitors standing before works of art.

We are now in the era of the Museum 4.0. This means that visitor experiences are personalized, and that museums depart from the museum itself. Today's museum has no walls: it is possible to take virtual tours and visit collections from home. Presentiality, the museum as mausoleum, and art works as a means of aesthetic enjoyment all give way to the creation of multisensory experiences that generate a new type of emotional connection between user and museum, in which participation, either virtual or face-to-face, is the key.

On another note, educating students in STEAM (Science, Technology, Engineering, Art and Mathematics) competencies is a way of facing the future that lies ahead. It is possible to consider transversal competencies as fundamental components of educational success. These are competencies such as teamwork, critical thinking, active gazing, fluid communication, etc. In other words, aspects that contribute to our being able to adapt to the needs brought to bear by the 21st century, a liquid society that must learn to prepare future generations to face major challenges. To make this possible, it is necessary to develop innovation from an early age, and be capable of building a more competitive, innovative territory. Creativity and innovation unite to advance dynamic methodologies built around the technological. Therefore, today's learning process must become something integrative and meaningful.

a. Student experience as the focal point of an education system

Educational undertakings of the 21st century must turn students into the leading players of their own learning process. To achieve this aim, teachers have to be capable of seeking out new methods, tools and spaces that contribute to meaningful learning. This will require life-long, multidisciplinary training. It no longer makes much sense to speak in terms of syllabi or subjects. The future is in project-based learning, mutual collaboration among different areas, and placing students' interests in the centre of learning. This way, an educational project based on the inter-relation of concepts, subjects and knowledge that can be applied in real situations gives rise to a form of learning based on experimentation and the senses.

Portable Hands-On Museum - Mobile ED productions, Inc.

The STEAM model emerges in this context as a proposal that connects ideas and concepts to better understand subject matters, to face challenges put forth by society and contribute rapid, effective solutions. Real, tangible scenarios contribute to understanding concepts that are abstract or difficult to explain. Promoting creation and materializing certain ideas after conducting a reflexive, critical process turns learning into a more participatory process in which shared knowledge experiences that motivate and engage students are generated. Further, this methodological approach must be accompanied by the creation of physical and educational spaces in which these projects can be comfortably developed.

2. FROM STEM TO STEAM. A WAY OF LEARNING AND INTERACTING

The term STEM was mentioned for the first time in the National Science Foundation of the United States in the mid-1990's. It appeared as a response to the over-arching need to train students in the technological realm, with the purpose of developing professional profiles that were non-existent at that time, but would be acutely necessary in the near future.

In April 2015 the first International STEAM Conference was held at Barcelona's CosmoCaixa, bringing together some of the most relevant projects on the application of STEM and STEAM.[1] At that time, it was made clear that the creative-artistic factor was as necessary as any scientific-technological component. Thus, with addition of the letter A, "Arts" were integrated into the project. In fact, in 2011 South Korea decided to combine arts with the STEM methodology to encourage creativity of students and associate logical thinking with the development of creative processes.

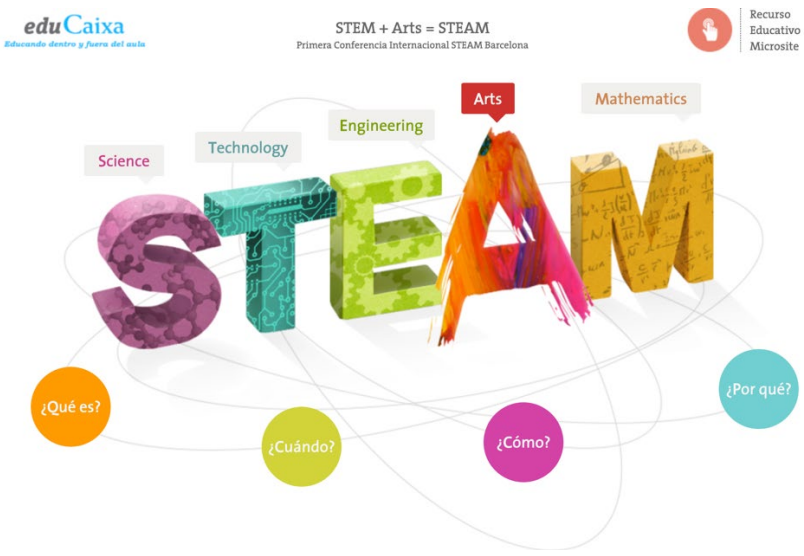


Illustration 1First international STEAM conference

Museums join in the design of active knowledge in the same way educational centres carry out project-based learning. So-called "museums without walls" began to back models of collective curation, a system according to which museum users were asked to vote on the works that would

[1] In 2019 the Fifth International STEAM Conference was held at CosmoCaixa > https://2019.steamconf.com/es/.

make up the next exhibition, or develop co-creation projects on social media platforms, and combine tactile and digital experiences in museography.

Awareness of the matter spread to universities, launching projects in which sciences and the arts were united. Proof of this was the scientific monologue and micro-theatre event entitled 'Guiones para la Ciencia (Scripts for Science)', first held in 2015, for secondary and pre-university school students from the autonomous community of Extremadura. The effort was led by the Servicio de Difusión de la Cultura Científica (Scientific Culture Diffusion Office) of the University of Extremadura, in conjunction with the Fundación Española para la Ciencia y la Tecnología (Spanish Foundation for Science and Technology), – Ministry of Economy, Industry and Competitiveness. The contest involved writing scripts on scientific experiments and/or discoveries that were then performed on-stage. In this way, the performing arts became a vehicle to bring science and technology closer to youth.

Around the same time, STEAM was progressively implemented in on-line learning environments. One example of this is the Museo Virtual ESIT, promoted by the UNIR (the Online University) in 2018, an interactive educational innovation project that is accessible through an interactive interface. Its main goal is to facilitate the publicity of projects carried out by design students, generating a virtual museum that became a platform of discussion and dialog.

Museo Virtual ESIT.

The next international event to further STEAM will take place in March 2020, with the 'Kyoto Steam – International Arts x Science Festival', a cultural program that connects arts with science and technology, to be held in Okazaki. The program has the support of the Kyoto City University of Arts, Kyoto Municipal Museum of Art, Kyoto Arts and Culture Foundation, Kyoto City Music Art Cultural Promoting Foundation, etc.

3. STEAM COMES TO MUSEUMS

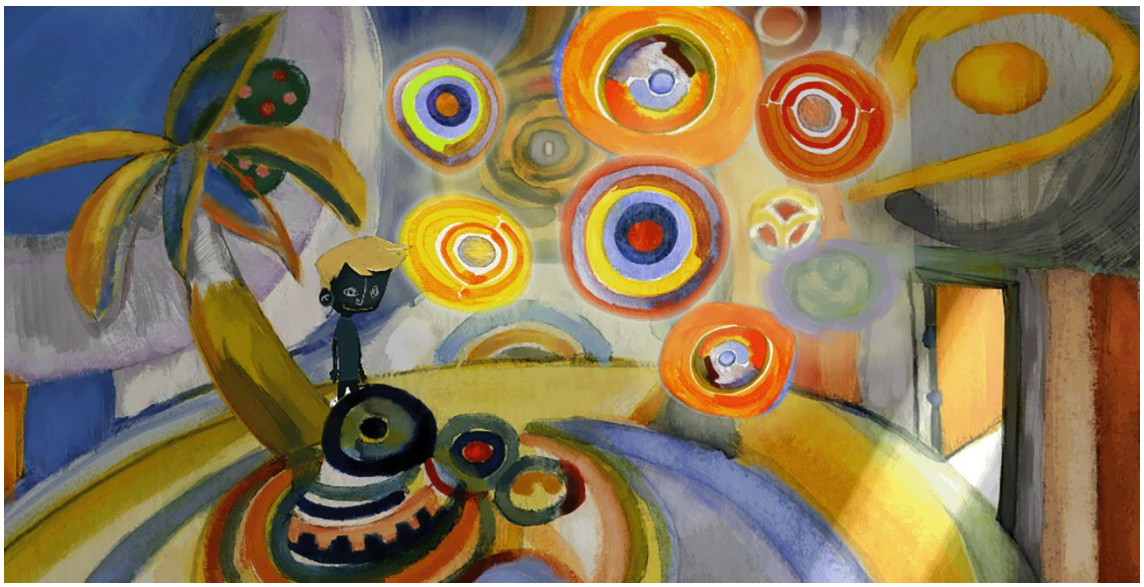
There are numerous museums that have already applied STEAM in their programs and spaces[2]. First, mention can be made of the Tinkering-zone of the Museo Nazionale della Scienza e della Tecnologia Leonardo da Vinci di Milano, a new permanent space opened in 2014 as an interactive laboratory devoted to production, engineering and design in order to develop an innovative educational program based on creativity. The space is geared to children eight years and up as well as adults, and is based on working in groups to explore and understand science and technology. The activities are proposed around the Inspiration Box, an area where the creations of visitors, artists or designers who have worked there are put on display. The entire project revolves around creative reuse and sustainability, but an effort is also made to generate a domestic, familiar atmosphere. All proposed activities are accessible without prior reservation. There is no fixed opening time.

Tinkering-zone of the Museo Nazionale della Scienza e della Tecnologia Leonardo da Vinci

[2] Innobasque and EDE Fundazioa developed in 2017 the Guía de recomendaciones para impulsar y fortalecer los proyectos STEAM en organizaciones de educación no formal (Recommendations guide for promotion and reinforcement of STEAM projects in non-formal education organizations)> https://www.innobasque.eus/uploads/attachment_files/steam_es-5c6293db8a40d.pdf.

Working under the slogan “Ideas You Can Touch”, Explora of Albuquerque, New Mexico offers an interdisciplinary activities program. One of the most innovative activities is the “Fun Friday Night”, a night-time proposal that has been on offer for adult users since 2018. Also noteworthy is ‘InterARTive: get creative’ featuring live music, and exhibitions of sculpture based on different media, including yarn and other materials, taking part in jewellery, henna and toy pet workshops, or experimenting with lights. Further, all these activities are facilitated by local artists and museum staff.

Another project worth mentioning is Nubla, begun in 2018 from the education department of the Thyssen-Bornemisza Museum of Madrid. Thanks to the support of a development company (Gammera Nest), another devoted to video games (Sony Spain) and the museum staff, a group of young people have been able to thoroughly familiarize themselves with the collections to contribute a personal interpretation of the art. This is a means of encounter, co-creation and learning that has given rise to a multidisciplinary team of artists, cultural managers, philosophers, programmers, designers, musicians, etc., who have created three games: Nubla 1, “El mundo de Nubla” (World of Nubla) and Nubla 2. The adventure began in 2016 with a workshop entitled Nubla Art Game, with a view to developing a critical, constructive outlook on artistic creation. Another outcome of that workshop was creation of a video game. Starting in 2018, the program “Open Tuesdays” was consolidated, featuring weekly meetings of young people from diverse backgrounds, to share and work together on production of the video game. At the end of that year, they began to offer guided visits to adults and young people (from 15 to 25) to discuss how the different works of the museum had influenced the creation of the video game. Nubla 2 was presented.



Nubla Art Game

STEAM has also been present at the Museu Marítim de Barcelona since 2019 thanks to the support of Lego Education Robotix. In this case, the museum proposes three activities for school groups ('Izad velas' [Raise Your Sails] for pre-schoolers, 'Matemáticas, un mundo de máquinas' [Mathematics, a World of Machines] for primary and 'La Mar de Ingenio' [Sea of Ingenuity] for secondary school students) in which their curiosity, the exchange of ideas, teamwork, creativity and experimentation are encouraged through a number of trial-and-error processes. These are proposals in which students are free to experiment and explore as they acquire new knowledge by cooperating in open tasks.

Lego Education Robotix at the Museu Marítim de Barcelona.

Another project that bridged the world of museums and schools in 2019 was the one promoted from the Museu de la Tècnica de Manresa (Technical Museum of Manresa) with the support of the Universitat Politècnica de Catalunya (Technical University of Catalonia), the Fundació Aigües de Manresa – Junta de la Sèquia (Aigües de Manresa Foundation - Canal Board) and BBVA Bank. The project is articulated around the 'Las matemáticas y la vida' (Mathematics and Life) exhibition and interacts with the museum's permanent exhibits. In fact, this exhibition was born ten years ago, and has toured through different towns and cities of Catalonia, with warm reception from the public. Renewal of the panels is slated for 2020. The exhibition is also accompanied by a program of multidisciplinary and interactive activities, conceived by the Technical University of Manresa, and aimed at a target group of users from three to 18 years of age. Notably, one of the first activities to be promoted by the program will be a Training Course on STEAM activity guidance, aimed at individuals interested in dissemination and education with the goal of promoting industrial vocations linked to creativity and everyday uses.

4. QUESTIONNAIRES

To discover the state of the art of STEAM in the museum realm, and with the goal of gaining awareness and training museum and other cultural professionals, as well as members of the sector's business community, a survey has been conducted among a selection of technical officers and experts from this field.

a. Methodology

Two types of questionnaires were designed for this evaluation: one focused on museum technical personnel and another for experts external to these institutions, often linked to the academic and university communities. Each questionnaire has been adapted to the language of the interviewee.

The following questions were asked:

Questionnaire 1 - Technical staff of museums
1. When did your institution begin working on STEAM projects?
2. Was it an original idea of your museum, or were you following the lead of others?
3. What other examples inspired you?
4. Are you developing STEAM projects autonomously, or in collaboration with other organizations or experts?
5. Could you list the institutions your museum cooperates with?
6. What type of public do your STEAM projects target?
7. In general, what has been the response received upon completion of this kind of project?
8. How do you evaluate the STEAM projects?

9. Does your work team receive any training on this subject matter?

10. What are the strong and weak points of the STEAM methodology?

Questionnaire 2 - STEAM Experts

1. When did you begin in the world of STEAM?

2. How did your interest in this kind of projects come about?

3. Have you ever received any training on STEAM methodology?

4. If so, what kind of training?

5. Why is it so necessary to promote STEAM projects in our society?

6. In general, do you think that schools and museums know the STEAM methodology?

7. How can these programs be disseminated among schools and cultural institutions?

8. Do you know of any STEAM project that you would like to highlight, developed in a museum or cultural institution?

9. What type of public are your STEAM projects applied to?

10. How do you evaluate the STEAM projects in terms of quality and efficiency?

11. What do you consider the main strength and main weakness of the STEAM methodology?

b. Professionals surveyed

A total of 42 experts were selected based on the development of STEAM projects, their involvement in the dissemination of this methodology and knowledge of its link with the museum

realm. Consideration has also been given to the incorporation of diverse geographies (Europe, Asia or Oceania, among others) as well as types of museums that are represented (art, technology, sciences, etc.). They were contacted by e-mail over a two-month period.

The survey was sent to a selection of professionals from the following museum, cultural and educational institutions.

Institutions contacted

Bay Area Discovery Museum (United States)

Big Van Ciencia (Spain)

CTIC (Spain)

Departamento de Ciencia de la Fundación Bancaria “La Caixa” (Spain)

Escola Projecte Barcelona (Spain)

ESERA (United Kingdom)

European Schoolnet (Belgium)

EuroScience (France)

Explora (United States)

Fundació Aigües de Manresa (Spain)

Fundació Jaume Bofill (Spain)

Fundació Pere Tarrés (Spain)

Fundación Thyssen (Spain)

Georges Lucas Educational Foundation (United States)

Ingenium Museum (Canada)

Innobasque and EDE Fundazioa (Spain)

International Arts × Science Festival (Japan)

MakerKids (Canada)

Mobile Ed (United States)

Museo de los niños Costa Rica (Costa Rica)

Children's Museum of Houston (United States)

Museo Nazionale della Scienza e della Tecnologia Leonardo da Vinci (Italy)

Museu de les Aigües (Spain)

Museu Marítim de Barcelona (Spain)

Museu Nacional de la Tècnica i de la Ciència de Catalunya (Spain)

Museum of American History (United States)

Museum of Science of Boston (United States)

Museum of the Riverina (Australia)

Museum Planning (United States)

Rijksmuseum (Netherlands)

Tate Gallery (United Kingdom)

The Willow School (United States)

UNIR (Spain)

University of Extremadura (Spain)

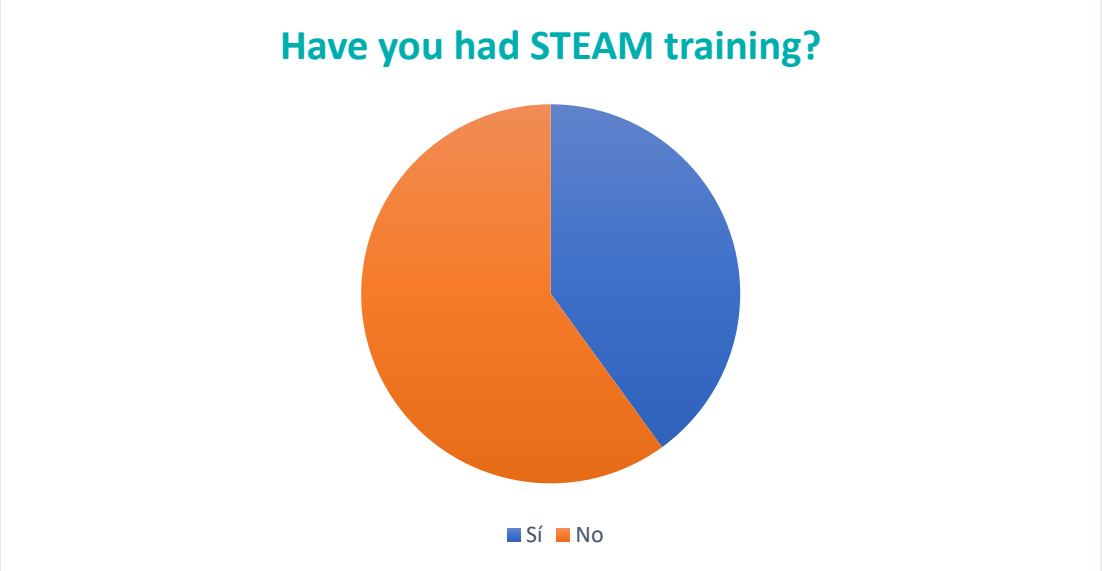
Of the 42 surveys individuals contacted, a total of nine responded to the survey: four museum employees and five external professionals associated with museum institutions:

- Big Van Ciencia (Barcelona, Spain).
- Departament de Didàctica de les Ciències Socials de la Universitat de Barcelona [Department of Social Science Teaching of the University of Barcelona] (Barcelona, Spain).
- European Schoolnet (Brussels, Belgium).
- Explora Museum (Albuquerque, United States).
- Georges Lucas Educational Foundation (United States).
- KYOTO STEAM – International Arts × Science Festival (Kyoto, Japan).
- Museu de les Aigües (Barcelona, Spain).
- Museu Marítim (Barcelona, Spain).
- Museum of the Riverina (Wagga Wagga, Australia).

c. Evaluation of results

In general, work was begun with STEAM projects between 2003 and 2018. The majority began between 2010 and 2018, while 30% began recently, as of 2017.

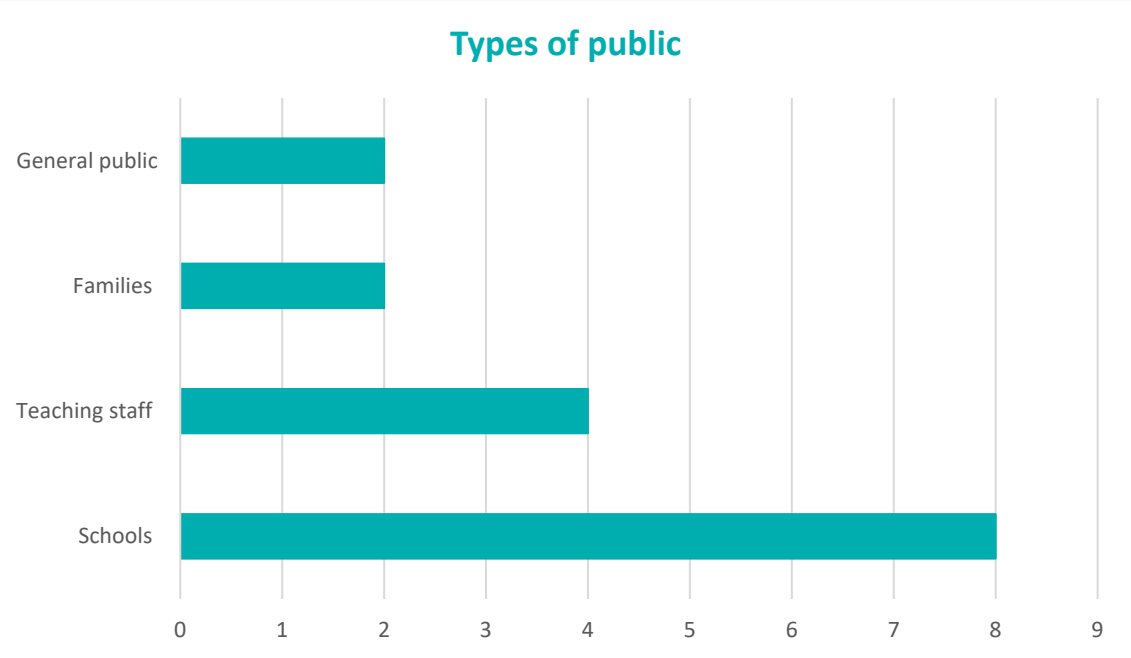
Their interest in STEAM either began out of professional curiosity, necessity (subsidies and grants) or application in their projects. None of the experts had received special training in STEAM, but all of the museum professionals had participated in specific training.



There was a widespread belief among the experts that schools and museums do not thoroughly know the STEAM methodology. Among the proposals to improve this knowledge they proposed:

- → Promoting public-private cooperation projects, thus opening spaces to innovation, in both educational centres and museums.
- → Providing financing through grants or subsidies that enable the development of unique projects with achievable goals.
- → Creating a network of institutions committed to this type of education to expedite the generation of shared projects.
- → Publicizing success stories for those professionals who are beginning to train in and familiarize themselves with the STEAM world.
- → Intensively promoting the training of teaching staff.
- → Using blogs, specialized websites and educational platforms to disseminate these practices.

Museums are accustomed to cooperating with other external entities, such as scientific and technological parks, universities, hospitals, primary and secondary schools and companies. In terms of target publics, respondents were unanimously in favour of gearing STEAM to school-age children. Families would be at a secondary level, though they are also included as targets of STEAM.



In general, all evaluated museum projects received positive feedback on the experience. For example, the EXPLORA museum uses STEAM methodology in all its activities (exhibitions, museum spaces, workshops, etc.), applying a minimal amount of text in the museological discourse for visitors to draw their own conclusions, and let their ideas flow. “Visitors

specialized in both art and sciences stated that a new world had been opened to them, offering new sources of inspiration, that never would have been possible if they had kept solely to their specialties."

As for the evaluation system, the most widespread among the museums was on the surveying system, either internal (managed by the museum itself) or external (through universities that publish their results in specialized journals). The third-party experts added that any effective evaluation would require:

- → application of an evaluation system through a number of criteria and standards associated with the learning goals.
- → Determine clear diagnostic measures to fully understand the students' comprehension process, establish indicators for, and document the entire process.
- → Improve the learning experience through an evaluation of the project and its contents.

Concerning the annual budget that museum organizations devote to these projects, two divergent paradigms were found: Explora or Kyoto Steam devote 100% of their budget to STEAM initiatives (given that the entire institution is based on this methodology), while other museums make small investments of up to 3,000 euros per year.

As a final element worth noting, following is a list of several strengths and weaknesses of the STEAM mentioned by those surveyed:

Strengths	Weaknesses
All those interviewed agreed on the transversality that makes it possible to bring disciplines closer together in a natural way.	The name “STEAM” is not very well-known, and in certain countries (such as Japan) the acronym is lost entirely due to linguistic reasons.
This is a much more realistic methodology, connected with real life, unlike more traditional education in which areas of knowledge are separated by subjects.	There is a high degree of “encroachment” and very basic, low-quality projects that affect the professionalism of the model.
Students are at the epicentre of many of the projects, something that facilitates connecting and reconnecting with this target group.	Content is still very important, and yet, oftentimes it is not given the same importance as is given to the methodology.
	Most of the projects consist of an approach to technology and art, but ignore mathematics. It is difficult to use in schools, as there is a high percentage of the teaching community who are not yet mentalized for such a change.
	Internal dynamics of institutions make it difficult to coordinate shared projects.

5. CONCLUSIONS

With this small study, it has been demonstrated that the need to rethink educational models and the museum institution itself has emerged from different places around the world to offer a response, not only to new generations, but the true needs of 21st century society. STEAM projects came about in this context in a natural way, to be integrated into the real workings of life, establishing interdisciplinary models that promote multilateral thinking, problem-solving and multiple viewpoints.

This new model contributes to the learning of the skills necessary for the job market, not just drive scientific-technological realms. Furthermore, the methodology proposed naturalizes science, bringing it closer to users and making it more comprehensible. This reinforces our understanding of the world we live in and boosts individuals' callings for science, technology and artistic pursuits. That is why STEAM projects open a world of possibilities, and get students and museum visitors to be more creative and curious.

On another note, it has been found that the impact of STEAM in our society is still very small. First, this is because despite being a necessity, changing internal dynamics is difficult. Second, because it is necessary to have training that promotes the development of quality projects, and encourages school and museum administrators to support this type of model. Third, because the development of such proposals must be accompanied by a significant financial endowment.

To conclude, this study has shown that many of the organizations involved in STEAM initiatives are carrying them out in a timid, mostly irrelevant way. This should lead us to a reflection process on how to turn this methodology into the focal point of schools and museums in the 21st century, and on how to make this model the functional axis of education and culture. Overall, interest in STEAM has been confirmed at the more theoretical and academic level. Yet, few relevant examples of significant change in schools and museums have been found. STEAM projects should have a higher profile, and more media impact. It is not a matter of small-scale activities or innovative models. It is about the need to adapt to our times, and understand our environment by questioning ourselves.