handbook STEAM

Science
Technology
Engineering
Arts
Mathematics

STEAM PROCESS

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STEAM: WHY?

"Art and Science both aim at understanding the universe."
(*Fabiola Gianotti, particle physicist, general director at CERN*)

STEAM is the research and education field that integrates Arts into scientific disciplines (Science, Technology, Engineering, Mathematics)[1].

The goal of the STEAM approach is not to teach scientists to "play the artist" or artists to "play the scientist", but to **unite artists and scientists**, their research and their visions, **to understand - and change - the world**.

[1] For more information on the STEAM theoretical framework, download the STEAMProcess framework

STEAM: WHY?

“We are facing new global challenges: climate change, pollution, digitalization and a demographic explosion. All the signs point the same way: we must rethink and replan. And Europe can and must play a leading role in this. But I want this to be more than an environmental or economic project: it needs to be a new cultural project for Europe. This is why we will launch a new European Bauhaus movement - a collaborative design and creative space, where architects, artists, students, scientists, engineers and designers work together to make this vision a reality.”
(*Ursula Von der Leyen, President of European Commission*)

This handbook offers a series of activities dedicated to both artists and scientists: why? Because, following the path indicated by the new movement launched by the President of the European Commission Ursula Von der Leyen, “to build a future that is **beautiful, sustainable and inclusive**, it is necessary to create a space of encounter situated at the crossroads between art, culture, science and technology”.

The complex problems of the contemporary world require complex solutions: combining art and science means stratifying the research processes, stimulating creativity, innovation and critical thinking.

STEAM: WHY?

What are the concrete **advantages** of a STEAM approach?

1) DEVELOPING NEW SKILLS > in the annual report of the World Economic Forum The Future of Jobs, two trends can be observed.

On one hand, the job demand for the scientific-technological field is growing - especially Data Analysts and Scientists, AI and Machine Learning Specialists, Big Data Specialists.

On the other hand, if you look at the most important skills for an employer, hard skills decrease to the advantage of soft skills: of the top 15 places, 11 are occupied by skills related to creative thinking, problem solving and creativity.

↗ Increasing demand

1	Data Analysts and Scientists
2	AI and Machine Learning Specialists
3	Big Data Specialists
4	Digital Marketing and Strategy Specialists
5	Process Automation Specialists
6	Business Development Professionals
7	Digital Transformation Specialists
8	Information Security Analysts
9	Software and Applications Developers
10	Internet of Things Specialists
11	Project Managers
12	Business Services and Administration Managers
13	Database and Network Professionals
14	Robotics Engineers
15	Strategic Advisors
16	Management and Organization Analysts
17	FinTech Engineers
18	Mechanics and Machinery Repairers
19	Organizational Development Specialists
20	Risk Management Specialists

Source

Future of Jobs Survey 2020, World Economic Forum.

Top 15 skills for 2025

1	Analytical thinking and innovation
2	Active learning and learning strategies
3	Complex problem-solving
4	Critical thinking and analysis
5	Creativity, originality and initiative
6	Leadership and social influence
7	Technology use, monitoring and control
8	Technology design and programming
9	Resilience, stress tolerance and flexibility
10	Reasoning, problem-solving and ideation
11	Emotional intelligence
12	Troubleshooting and user experience
13	Service orientation
14	Systems analysis and evaluation
15	Persuasion and negotiation

Source

Future of Jobs Survey 2020, World Economic Forum.

STEAM: WHY?

For scientists, the STEAM practice helps integrate technical skills with the most requested soft skills. Does this mean that scientists are not capable of critical thinking and problem solving? Obviously not: the scientific and artistic research processes have many points of contact. Putting them together means stratifying the way of knowing things and communicating them externally, integrating scientific skills with the artistic ability to think out of the box and create an empathic connection with audiences. As Dr. Kristin Cook, associate dean of Bellarmine's Annsley Frazier Thornton School of Education and science educator, explains: "Incorporating the A in STEAM—art—brings in personal expression, empathy, meaning-making and the purpose of what you're learning. It's the humanizing piece of transdisciplinary and interdisciplinary instruction."

For artists, the STEAM practice helps to integrate new technologies (e.g. Artificial Intelligence) into their works and to acquire the knowledge to address significant issues for their research (e.g. climate change).

2) SEIZING NEW OPPORTUNITIES > starting from the New European Bauhaus prizes themselves, **there are more and more fundings that require a transversal and multidisciplinary approach**, in which professionals from the world of art and culture and from that of science and technology collaborate to create innovative projects that are also able to guarantee public engagement, making science more accessible to the public.

BE INSPIRED: discover STARTS, the initiative of the European Commission which supports collaborations between artists, scientists, engineers and researchers to develop more creative, inclusive, and sustainable technologies.

STEAM: WHAT?

What are the **characteristics** of STEAM?
There is no universal answer, but by comparing research and good practices we can say that the STEAM approach is:

1. HYBRID

In the words of Ursula Von der Leyen, the STEAM field stands “at the crossroads” between architecture, art, design, science, engineering and new technologies. The STEAM approach is by its nature multidisciplinary and trans-sectorial.
Whether it is an educational program or a research group formed to respond to a concrete challenge, **it is important that a STEAM process contemplates the contribution of heterogeneous skills, experiences and knowledges**, in order to address the same topic from multiple points of view.

2. HOLISTIC

A STEAM practice is not simply the sum of two parts - art and science, but something new that is independent of the individual components, and enriches them.
For this, **it is important that a STEAM approach is based on trust and respect** and that neither party pretends to have everything to teach and nothing to learn: “The overarching goal is the process of creating something new together - and the resulting exchange and reshaping of ideas.” (Fernanda Oyarzún, Scientific sculptor and marine biologist at the Coastal Social-Ecological Millennium Institute, SECOS)

STEAM: WHAT?

3. PROJECT BASED

A STEAM practice is, in fact, a practice. You cannot teach a scientist how to look at an object, a theme, a problem, from an artistic point of view - or an artist how to look at it from a scientific point of view - from a desk: both must experience the other's point of view.

For this, **it is important that a STEAM approach is experiential rather than theoretical**: artists and scientists must "get their hands on it" and work each with the other's materials to achieve a tangible goal.

4. PROCESS BASED

"The journey is more important than the destination", goes a famous adage. A STEAM practice is all about the journey: every step, every mistake, every discovery of the process are themselves a goal that has its own importance and meaning. Often **it is the same objectives that change during the process**, and the final result is very different from what was expected at the beginning.

For this reason, it is important that a STEAM approach dedicates the necessary time and space to the process, without accelerating towards the result, and that a moment of reflection is dedicated to each phase of the process.

BE INSPIRED: read the experience of artists and researchers on how to shape a productive collaboration between art and science.

STEAM: HOW?

Since the goal of a STEAM practice is to integrate art and science, **for it to be effective it is necessary for artists and scientists to experiment together.**
HOW TO DO IT?

Several universities and research centers, as well as educational and cultural organizations, organize **artist residencies** during which artists selected on the basis of a call or a free proposal develop a project in collaboration with students and / or researchers.

BE INSPIRED: discover Arts At CERN, the program of artist residencies, exhibitions and events at CERN.

Several educational organizations, both in the field of formal and non-formal education, organize **workshops or study programs based on the multidisciplinary approach between art and science**, starting from kindergartens up to higher education.

BE INSPIRED: discover the MA Art and Science at Central Saint Martins – University of the Arts London, the higher education course where "artists and scientists contribute to a greater understanding of what it is to be human and how we relate to the world around us".

STEAM: HOW?

The **STEAM PROCESS methodology** is based on three phases[2]:

1. **INSIGHT** & instinct **>** the **AWARENESS** phase, which is focused on **personal skills**: reflection, awareness of meaning, openness, critical thinking

2. **PROCESS** & test drives **>** the CURIOSITY phase, which is focused on **creativity**: social intelligence, seeing the forest from the trees, teamworking, disruption

3. **OUTPUT** & strategic tools **>** the COMMUNICATION phase, which is focused on **social impact**: producing scenarios, raising awareness, storytelling, inspiring

This handbook offers an activity for each of the three phases:

1. **INSIGHT** & instinct **> (RE)CREATE ART**

2. **PROCESS** & test drives **> USELESS MACHINES**

3. **OUTPUT** & strategic tools **> ARTSCIENCE PROJECT**

[2] See the STEAMProcess framework

STEAM: HOW?

Before starting...

- The activities proposed in this handbook are focused on strengthening the skills that characterize each of the methodology's phases: the Awareness area of skills, the Curiosity area, the Imagination area. **The three activities constitute an ideal path**: in the first, it is more artistic knowledge which guides the scientists; in the second, artists and scientists collaborate fifty-fifty, each starting from their own skills; in the third, it is more scientific knowledge which guides the artists. **At the same time, each activity can be carried out autonomously**, since each of them goes through all three phases, constituting a path that goes from conception to prototyping to the creation of an art object. For this reason, you can choose to carry out only one of the activities, or to carry them out on a non-continuous basis (for example "spreading" them over the course of an academic year).

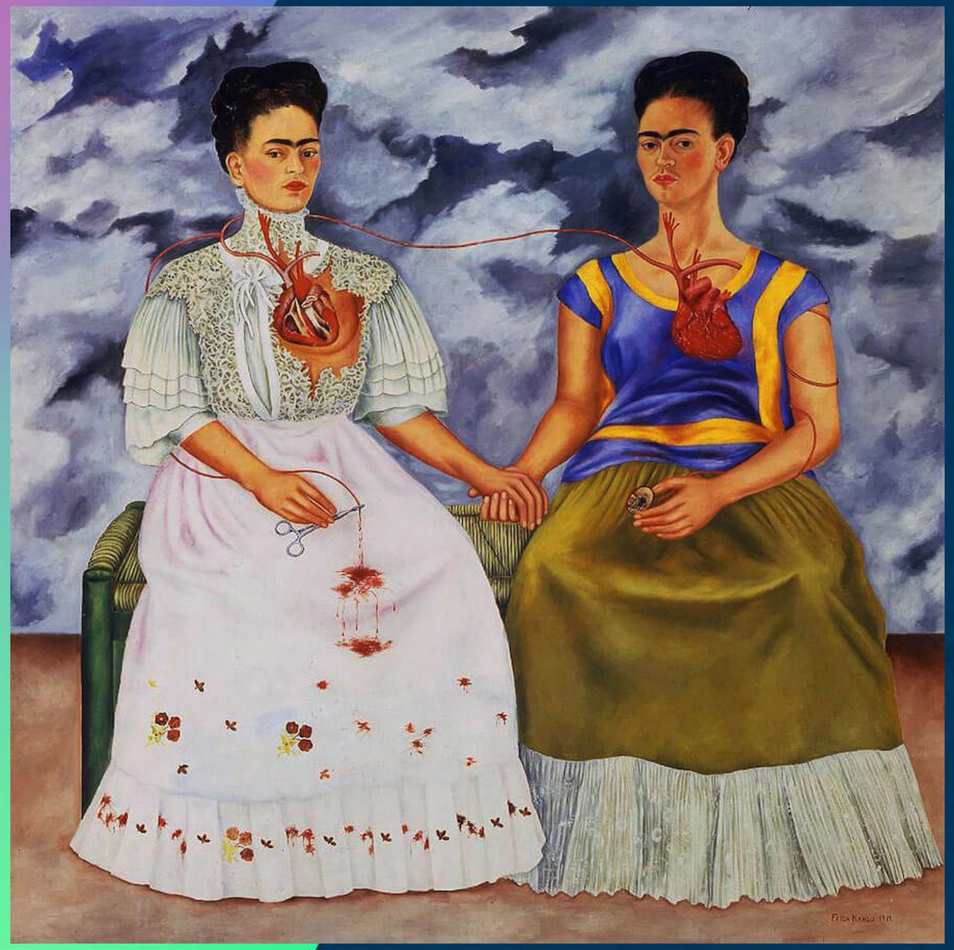
- **Each activity can last a few hours or even a day or two**, depending on the complexity of the output that you choose to produce: whatever the duration of the activity, the important thing is to **give the right space to the process**, stopping to reflect on each phase and reconstructing what was done and how it got there.

- Regarding the relevance of the process, it is important that the final output is proportionate to the duration and objectives of the activity. **The output does not need to be an artwork worthy of being exhibited in a museum**: even a prototype can be considered a satisfactory outcome, the important thing is that it is the result of a shared path that actively involves all participants.

- It is important to **have a good amount of heterogeneous materials available**, starting with the daily working materials and tools of artists and scientists, to which the most disparate objects and materials can be added, from electrical circuits to markers.

Activity 1

STEAM: INSIGHT > (RE)CREATE ART: WHY?



The Two Fridas, 1939 by Frida Kahlo

"Art is that of which one does not understand the meaning, but one understands to have a meaning."
(*Anonymous*)

To understand the phenomena that surround us it is important to ask ourselves about their meaning. It is this investigation in which the only rule is to never stop asking questions that allows us to reach the profound meaning of a phenomenon: not the only possible one, but the most significant for us, the one that arouses our interest and gives meaning to our research.

This activity aims to stimulate attention to insight as a research tool to multiply points of view and open new scenarios.

Activity 1

STEAM: INSIGHT > (RE)CREATE ART: HOW?

1) Find the meaning

Choose any work of art, from a descriptive work to an abstract one, from painting to sculpture to installation. It is not important which artwork you choose: the time you dedicate to find the meaning of that work is important. Attention! We are not talking about the absolute or objective meaning: that exists only in the mind of the artists, and sometimes it is not so clear even for them, or it changes over time. **What you have to find is your meaning, what that artwork tickles in you.**
HOW TO DO IT? Here is a technique conceived by the art historian Erwin Panofsky and adapted by the art professor Kit Messham-Muir: the three-steps method.

The three-steps method

1. **Look**
   Look at what's there, literally right in front of you. Start with the most basic: what medium or material is it - a photograph, an object, a painting? How does it look? Rough and quick? Slick and neat? Shiny? Dirty? Carefully made? Thrown together?
2. **See**
   What's the difference between looking and seeing in the context of art? Looking is about literally describing what is in front of you, while seeing is about applying meaning to it. When we see we understand what is seen as symbols, and we interpret what's there in front of us.
3. **Think**
   The final step involves thinking about what you've observed, drawing together what you've gleaned from the first two steps and thinking about possible meanings. Importantly, this is a process of interpretation. It's not a science. It's not about finding the "right answers", but about thinking creatively about the most plausible understandings of a work.

Activity 1

The ultimate goal is to reach a **shared meaning**: it can be a meaning per group, if you are divided into heterogeneous groups of scientists / artists, or a collective meaning, if you are collaborating with only one artist in residence. **The important thing is that the artistic and scientific points of view come together in the search for a common meaning**, and that the choice of the meaning of the artwork is democratic, representing the different voices within the group.

A good way to elaborate a meaning that is valid for the whole group is to dedicate a shared reflection to each of the steps: What are we looking at? What do we see? What do we think?

Remember that there is only one rule: **don't stop asking questions**! From "*What does Frida #1 have in her hand?" and "What does Frida #2 have in her hand?" to "What do the scissors represent?" and "What questions did Kahlo ask herself?" etcetera etcetera ...*

TIPS

In order to reach a common meaning:

- Give space and time to all the people who participate
- Listen as much as you speak
- Make an effort to make other people understand your point of view
- Welcome new ideas

Activity 1

2) (Re) creating meaning

Once a common meaning has been established, the next step is to recreate the artwork. Attention! **The goal is not to recreate the same artwork, but an artwork that expresses the same meaning.**

Reflect together on how to use the art field of the artist or artists in your group to express your common meaning. In this phase it is also important to listen to all the voices of the group, that each expresses their own vision on how they would render that meaning through photography, painting, sound or collage.

Once the work has been completed, discuss the process that led you to create it: what surprised you? What troubled you most? How did you solve the problems or the bottlenecks? If you have practiced the activity divided into groups, share the comparison with others, starting with the interpretation that each group gives to the artworks of the others.

TIPS

- Don’t wait until you have defined the artwork in all its details before starting to create it: get your hands on it as soon as possible!
- After each attempt, take a moment to discuss what convinces you and what could be improved or done differently

Activity 2

STEAM: PROCESS > USELESS MACHINES: WHY?

Useless machine, 1956 by Bruno Munari

"A useless machine that does not represent anything is the perfect device by means of which we can easily revive our imagination, daily afflicted by useful machines." (*Bruno Munari, artist and designer*)

To give value to a process it is necessary to reverse the paradigm according to which the process must necessarily be oriented towards an objectively useful result. It is this reversal that allows us to stay in the process, not to be discouraged by failures, to interpret obstacles as an opportunity for discovery.

This activity aspires to stimulate attention to the process as a free space for experimentation, errors and discoveries.

Activity 2

STEAM: PROCESS > USELESS MACHINES: HOW?

What are the characteristics of a useless machine and how is it built?
Bruno Munari explains it to us

>

What Useless Machines Are and Why
Let us first establish the function of the useless machines: that they are machines is not in doubt, given that the lever is a machine, commonly referred to as ‘that piece of iron over there’. However, it is necessary to clarify the word ‘useless’: they are useless because they do not make anything, they do not eliminate labour, they do not save time and money, and they do not produce any commodities. They are nothing but colourful, mobile objects, specially designed to create a specific variety of combinations, movements, shapes and colours. Objects to look at in the way one looks at a drifting group of clouds after spending seven hours inside a factory full of useful machines. There may be very slow or very fast machines, with an infinite variety of movements, machines for the garden, for the home, to be hung from the ceiling, to float on a pond, to stand on a tabletop or a terrace, and perhaps even to carry around in one’s pocket.

In the useless machines each piece must have its logical function both in relation to the motion and the artistic sense of proportion, colour and form; and the whole assembly must represent the harmonious fusion of sculpture, painting and motion. Sculpture is here to be understood as geometric form: an exact balance of shapes, spaces and volumes; light and dark. Painting is to be understood as colour: exact balance of colours, (a curved colour has a different value from a flat colour). Motion in

Activity 2

its pure state: rhythm, sense of movement; (that is: one person walking and another dancing; useful movement and useless movement) the motion of a useless machine must be the heart of the construction, the vital point. The important thing is that they are absolutely useless.
(Bruno Munari, *La lettura*, July 1937)

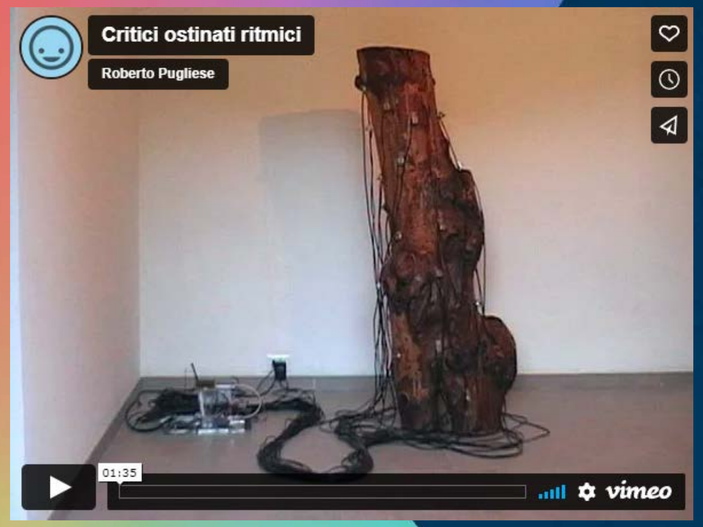
BE INSPIRED: take a look at some of Bruno Munari's useless machines.

TIPS

- Do not pause for too long to think before starting to build the machine, otherwise you will inevitably end up assigning it a function
- Make sure you have a certain amount of heterogeneous materials, which guarantee both the construction of a mechanism and the aesthetic quality of the output
- Take some retrospective moments to discuss what you are doing and to make sure everyone is happy with the direction the process is taking
- Don't just focus on what you already know: let yourself be influenced by the functioning of a mechanism, if you are an artist, or by the harmony generated by an aesthetic intervention, if you are a scientist, and find out where that suggestion takes you
- Remember that even new technologies can be a machine to play with: in the age of AI, a useless machine can be, for example, an Artificial Intelligence that differs from all the others for only one aspect: what it does is useless!

Activity 3

STEAM: OUTPUT > ARTSCIENCE PROJECT: WHY?



Look at the video. Each “click” you’ll hear represents the falling of a tree.

Critici ostinati ritmici, 2010 by Roberto Pugliese

“The installation is made on the trunk of a hollow tree on which were set solenoids which, energised by an electric current, produce a loud “click”. The software that manages the playback of the pulses is connected to a website from which, real time, statistics are downloaded on the state of global deforestation. The downloaded data is then translated into pulses to be distributed in time to the various solenoids.”
(*Roberto Pugliese, artist*)

This installation, created by the artist in collaboration with an electromagnet production and assembly company (Elettromagneti s.r.l.), is an excellent example of what art can do for science - and vice versa.

Thanks to the multidisciplinary approach, **artists can express their voices on issues of global concern** - such as climate change. Not only that: artists can express their voices on scientific research itself, giving their contribution on issues such as the ethical development of AI or eugenics.

Thanks to the multidisciplinary approach, **scientists can find new interpretations and new applications for their research**. Not only that: **scientists can find a creative and empathic voice** to bring subjects and results of their research to those who often struggle to understand it: the public.

Activity 3

STEAM: OUTPUT > ARTSCIENCE PROJECT: HOW?

The purpose of this activity is the creation of an artwork that represents a scientific phenomenon. It may be a phenomenon on which you want to raise public awareness, such as deforestation in the installation by Roberto Pugliese, or a complex phenomenon that you want to make more accessible, as in **this video** which represents the theory of implicit order by Bohm in just a minute. Or again, it may be a phenomenon that artists and scientists are investigating together, as you will see in several examples among those that we will propose shortly.

TIPS

- The phenomenon that you choose to investigate has to be significant both for scientists and for artists
- Remember the principle of holism: collaboration must be based on mutual respect and the awareness that there is always something to learn: make sure that everyone has the opportunity to express their voice in the conception of the artwork
- Give time and space to the process: discuss at each step what convinces you and what could be improved
- Do not rush to finalize the artwork

BE INSPIRED

Here you can find some Artscience projects and artworks: take a look at them before starting your activity to explore the infinite possibilities of the encounter between art and science!

REFERENCES

Networks that promote and support the STEAM approach:
New European Bauhaus: https://europa.eu/new-european-bauhaus/index_en
S+T+ARTS: https://starts.eu/
Universities and research centers:
Bellarmine University: https://www.bellarmine.edu/
University of the Arts London: https://www.arts.ac.uk/
Artsformation: https://artsformation.eu/
CERN: https://arts.cern/
Web magazines:
Nature: https://www.nature.com/
The conversation: https://theconversation.com/global
Artists:
Bruno Munari: https://www.munart.org/
Roberto Pugliese: http://www.robertopugliese.com/
Research materials and inspirations:
World Economic Forum - The Future of Jobs Report: https://www.weforum.org/reports/the-future-of-jobs-report-2020
Lego Foundation: https://learningthroughplay.com/explore-the-research
The Impact of Science Capital on Self-Concept in Science - A Study of University Students in New Zealand: https://www.frontiersin.org/articles/10.3389/feduc.2020.00027/full
Exploratorium San Francisco: https://www.exploratorium.edu/

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