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STEAM BUILDERS

Pedagogical guide

5th High School Agrinio-Greece · Citizens in Power · Fermat Science – Une autre idée des maths · LogoPsyCom · Trànsit Projectes · Vesthimmerlands Museum · GoINNO

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Introduction

Welcome to the first tool of the STEAMbuilders project, the Pedagogical Guide on how to use Historical heritage in order to explain and contextualise Mathematics and Science concepts.

The world is evolving fast thanks to an ever-developing technology. However, most countries are experiencing a growing shortage of qualified professional workers in critical fields such as Science, Technology, Engineering and Mathematics. The root cause of this shortage may find an explanation in our education system.

Indeed, despite attempts at boosting STEM education, recent PISA studies (2018) have shown that our education system is still insufficient in the STEM field. In mathematics, 22.4% of European students are low achievers in maths and 21.6% in science. This means that more than one out of five youngsters in Europe is not equipped with the basic skills necessary for numerous valuable jobs in our current economy.

These results are a clear incentive to find alternative solutions and support systems to improve STEM education. It is very important to engage students more in these topics as they are critically important.

However, to create relevant support systems or pedagogical tools, we need to find out where these underachievement levels originate from. Our research in the literature has come up with an element of answer. According to Pr Kouider Ben-Naoum's interview, underachievement in Mathematics only really spike in secondary school, when we go from contextualised mathematics to abstract mathematics. The students are unable to link what they try to learn in class with a concrete life situation. While the classical abstract theory-based approach has had its results, it is no longer adapted to our now much more pro-active based society. This is confirmed by Martin Andler, from the Department and Laboratory of Mathematics of the University of Versailles, attached to the CNRS, who summarizes the problem:

"But where mathematicians make a mistake is in assuming that learning mathematics is a prerequisite, before showing what concrete problems they can solve. We end up with students who no longer understand why they learn maths".

As those professionals in the field of mathematics, we are convinced that a more hands-on approach to STE(A)M may be able to engage students more and interest them in pursuing STEM careers in the future. Once we show them how Mathematics and Science are present in every aspect of life, and has been since the dawn of civilisation, and if we use cross-curriculum teaching methods, we will be able to interest the students in the mechanics of the world, and ultimately, in STEM. These are the reasons why we think the STEAMbuilders project is a good opportunity to improve STEAM education.

Not only will we explain how STEAM theory can be applied in heritage techniques, but we will also talk about the way these theories were first thought of, the context of their discovery and the consequences they had on our society's evolution. This will give meaning to the importance of learning STEAM subjects and ground the abstract theories into concrete, existing historical examples.

This guide is the first pedagogical tool that we are creating for the project, and the basis on which we will articulate all the next ones. It will be designed to help teachers adopt a cross-curricular approach and link the STEAM curriculum with heritage applications and principles in History. It is meant to be practical and user friendly, with clear structure and concrete in-situation explanations to facilitate daily use by the target groups.

Special attention will be given to make this guide and all the other materials provided inclusive and user-friendly for students with Specific Learning Disorders (SLD) but also for any student that is part of the groups most likely to fall behind in STEAM subjects; young girls, students with fewer opportunities, etc.

To achieve the objectives of this first guide, we will structure it around the following chapters:

First of all, "Part 1: STE(A)M: The integration of the Arts and Humanities in STEM", in which we will define the terms STEM & STE(A)M, where these concepts come from, as well as their differences and objectives. We will explore the importance of this method, the different benefits of this approach and we will draw the outline of STEAM education.

The second part of the guide will be about: "How to approach the European heritage by adopting a STEAM method?" In which we will explore the links between the STEAM curriculum and heritage (from prehistory to the industrial revolution). We will give some examples of activities for schools that explain the name of the project STEAMbuilders; the rebuild STEAM concepts through Heritage techniques and History. Those examples will focus on: Techniques and the Stone Age, Mathematics and Ancient Greece, Technical inventions and the Roman Empire, Construction and measure and the Age of Cathedrals, Art, science, technique and Renaissance, and finally, Scientific discoveries and the Age of Enlightenment.

In the third part of the guide, we will explore the role of digital in this project and education in general. This part will include examples of STEAM or Heritage techniques made with digital, among other things.

The fourth part will be about being an actor of STEAM education, who, how, when and where to use the STEAM approach to education.

The fifth and final part will deal with the aspect of inclusion in our project and education in general.

Now, let us begin with STE(A)M: The integration of the Arts and Humanities in STEM.

Part 1: STE(A)M: The integration of the Arts and

Humanities in STEM

1. STEM VS STE(A)M Definition and objectives

The scientific administration of the US National Science Foundation (NSF) officially introduced the abbreviation STEM in 2001. Nonetheless, emphasis on the subjects of science and technology in education was extended way back, during the early days of the "Space Race" between the Soviet Union and the US, when Sputnik – the first satellite to orbit the Earth – was launched by the Soviets, in 1957 (Lathan, 2015).

The term STEM stands for Science, Technology, Engineering, and Mathematics. STEM education is a multidisciplinary[1] method to learning where demanding academic notions are joined with real-world lessons as students make use of science, technology, engineering, and mathematics. The subjects are used in a framework that associate between school, work, community and global enterprise allowing the development of STEM learning (*Defining STEM in Education – Science, Technology, Engineering and Mathematics*, n.d.). In other words, it is the learning of STEM subjects by the use of a unified method; a method that offers practical and at the same time significant learning experiences. There needs to be more STEM education integrated into everyday schooling, into the traditional learning system, by starting students at a young age (*What Does STEM Stand For?*, 2015).

Objectives include learning subjects such as science, technology, engineering, and math as one (in a combined way), as well as acquire skills of explanatory learning, problem-solving, and critical thinking that can be incorporated with the subjects that make STEM education beneficial (*What Does STEM Stand For?*, 2015).

An engineering and technology teacher, Georgette Yakman, is the key innovator who updated STEM to STEAM by adding the A of arts stands for "Arts and Humanities".

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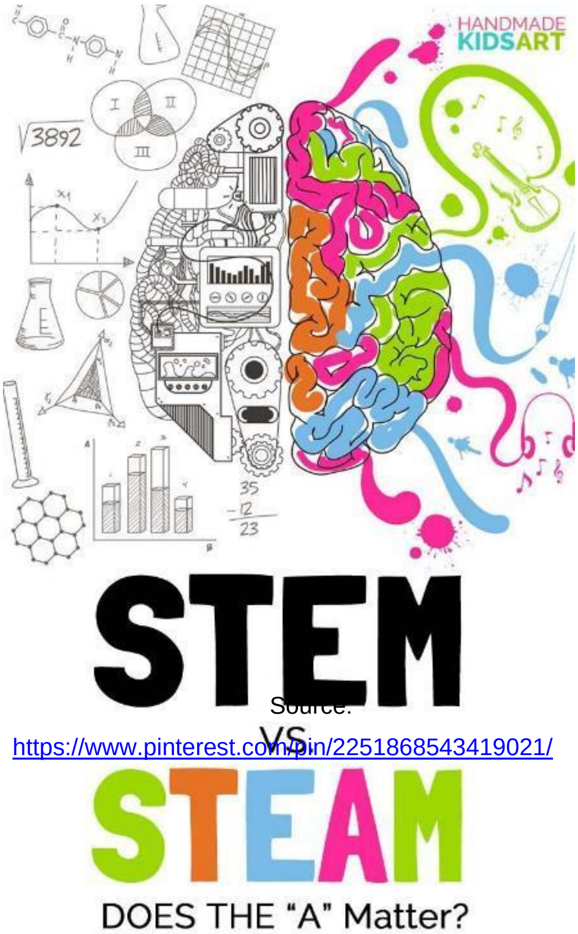
[1] combining two or more academic fields (*Definition of Multidisciplinary | Dictionary.Com*, n.d.)

Georgette was the founding researcher of the educational context of STEAM in 2006. This update was not only about adding a field to STEM or converging design thinking and fine arts into the context of STEM but rather the arts, the who and why, to reform to the what and how of STEM subjects (Lathan, 2015).



Source: https://www.pinterest.com/pin/2251868543419021/

STEAM represents Science, Technology, Engineering, Art, and Mathematics. Therefore, STEAM expresses STEM with the addition of Arts – i.e., language arts, visual arts, humanities, dance, music, drama, design, and new media. While STEM focuses on scientific subjects, STEAM examines the same subjects but rather through analysis and problem-based learning approaches used in a creative procedure. That is, different learners working together to generate a visually interesting product based on the key understanding of the concept of STEM. For instance, the mathematics of the parabola used in the creation of fine art imagery, depicting that STEAM is not a new concept and that artists such as Leonardo Da Vinci have portrayed the significance of combing science and art to make important discoveries (Wade-Leeuwen et al., 2018).

When the arts become a part of STEM, the concept of STEM regenerates and kindles connections for many more students and helps them engage confidently, creatively, and critically in their learning. According to Forbes, today's world needs all students to be involved and have STEM-based problem-solving skills in order to solve the challenges of our society. The role of educators is to open new doors and create an excitement for learning, especially in STEM, and therefore, STEM combined with arts education opens numerous possible doors (Milgrom-Elcott, n.d.)Moreover, one may consider that STEAM takes STEM a step further, by giving emphasis to the arts, encouraging the field, and applying its notions in multi-disciplinary learning supporting creativity in subjects such as science, mathematics, engineering, and technology. STEAM emphasizes on educating students to form a connection between several subjects for them to get the most out of learning about whichever subject; from coding and robotics to music and reading. Further, we can conclude that there is less testing, but more problem-solving, analysis and instructions using STEAM concepts. Although both STEM and STEAM deal with scientific and mathematical subjects, they differ in their approach of classroom teaching and learning (Vaden, 2020). For instance, STEAM aims to stimulate and form an interest and permanent love of the arts and sciences in children starting from a young age (Lathan, 2015).

2. Why this method is important

In our current world, preparing students for future accomplishments means revealing them, these disciplines comprehensibly to develop their critical thinking skills. This method is important because education is under pressure to react to a changing world. The earlier the students are laid open to STEAM concepts, the better.

A study made by Microsoft depicts that 4 out of 5 STEM college students (78%) decided to study STEM in high school or before, one out of 5 college students (21%) decided in middle school or before. Still, only 1 out of 5 STEM college students have a feeling that the secondary education equipped them well with knowledge used in their college courses in STEM. Furthermore, the study depicts an inequality in the female to the male ratio when it comes to employability in the fields of STEM. Therefore, it is also important to aim in getting more girls interested in STEAM concepts (Lathan, 2015).

Apart from the fact that STEAM context help students adopt problem-solving skills, think critically, and use their creativity, it also prepares them for jobs in fields that are positively growing. According to a report from the US Bureau of Labor Statistics, growth in both STEM and STEAM-related professions between 2019 and 2029 is estimated to cover 8%, compared to 3.4% for jobs not related to STEM. Even if students decide not to follow one of the STEM/STEAM-related careers, all skills students acquire from the education of STEAM can be interpreted and used in several different careers (*Employment in STEM Occupations*, n.d.). According to Stephen F. DeAngelis – technology innovator and President of Enterra Solutions – "Educating students in STEM subjects (if taught correctly) prepares students for life, regardless of the profession they choose to follow". Finally, one of the most significant parts of this educational method is that students taught under the context of STEAM, not only learn about the subject but are further taught how to learn in general, how to experiment, how to ask questions, and how to create (Lathan, 2015). This STEAM context of learning leads students in the direction of implementing skills of the 21st century, such as connection, community, and culture (Wade-Leeuwen et al., 2018).

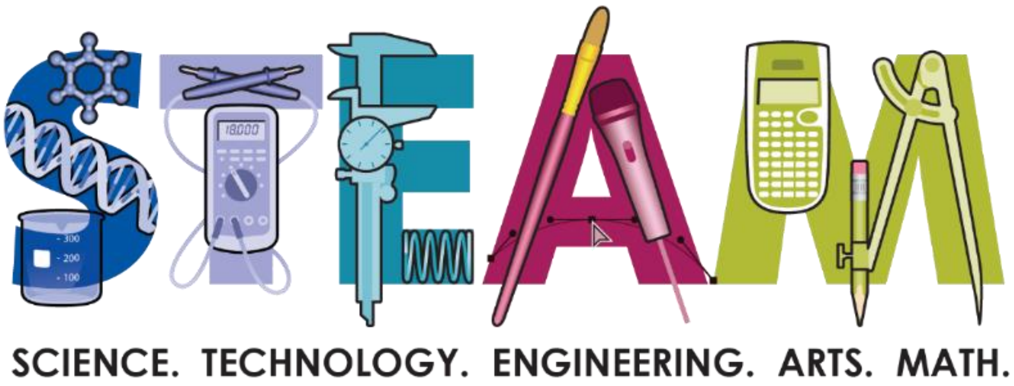
The education in the context of STEAM supports the following:

- **The learning using hands-on activities**
- **The development of a growing mindset**
- **Increasing the engagement in classrooms**
- **Connecting the real world with the learning in the classroom**

Source:
https://acerforeducation.acer.com/education-trends/5-

The above aspects are significant, considering that education should no longer be about teaching particular skills, but about preparing students to be ready for the future. Although several traditional school regions emphasize the standardized test scores as well as memorization for the provision of a well-balanced education, there is a powerful case for including interest and creativity into any syllabus. In a rapidly changing world, the jobs of the future will necessarily require all young people to be skillful in STEAM. Undoubtedly this is not just to prepare students for jobs but also, what these experiences provide to students; to help them grow up to be independent, capable, and intellectually curious. Even though today's world is becoming more and more focused on STEM, in reality, students tend to have a diversified interest. Students are not only interested in math, but also in the essential aspects of developing across several academic areas which prepare them in succeeding in any curriculum they select. The learning tools in STEAM, used in creating experiences that approach subjects from several angles in order to make the learning accessible and exciting, go further than the basics of coding. A well-rounded lesson, or even education, means educators need to provide students with as many subjects and contexts as possible, starting from a young age, to help them recognize what are their main strengths and interests (Vaden, 2020).

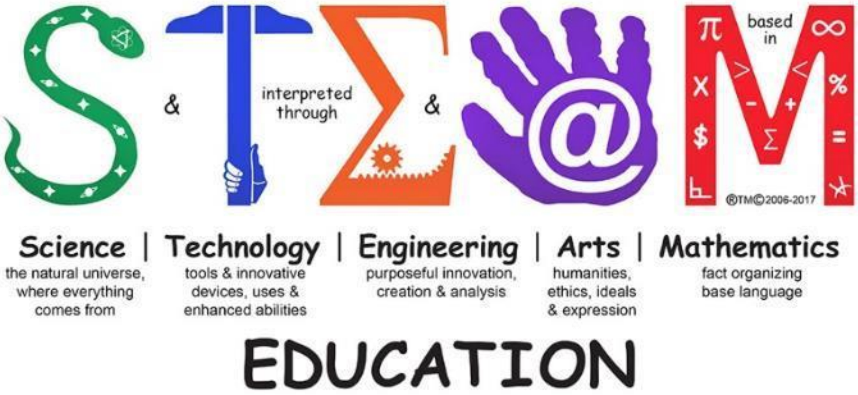
Finally, while the economy and the job market continue to evolve rapidly over the years, the education system has not evolved and educators continue to teach students the same subject content in the same classroom setting.



Source: https://scholarlyoa.com/the-change-of-education-trends-to-

STEAM-based learning has an aim to help the student develop skills needed in being successful – both professionally and personally - in the future. Irrespective of the industry and position, students going off to college or enter the workforce need to be provided with a set of fully developed skills that give them permission to adapt to a fast-paced and evolving environment. By bringing together five significant disciplines, STEAM creates an inclusive learning environment that inspires students to collaborate, participate, and solve problems. This comprehensive method helps students use both the left and right side of their brains concurrently, and inspires them to exercise both sides, as they are supposed to do in a working environment of the 21st century (Thomas, 2020).

3. Outline of the STEAM method



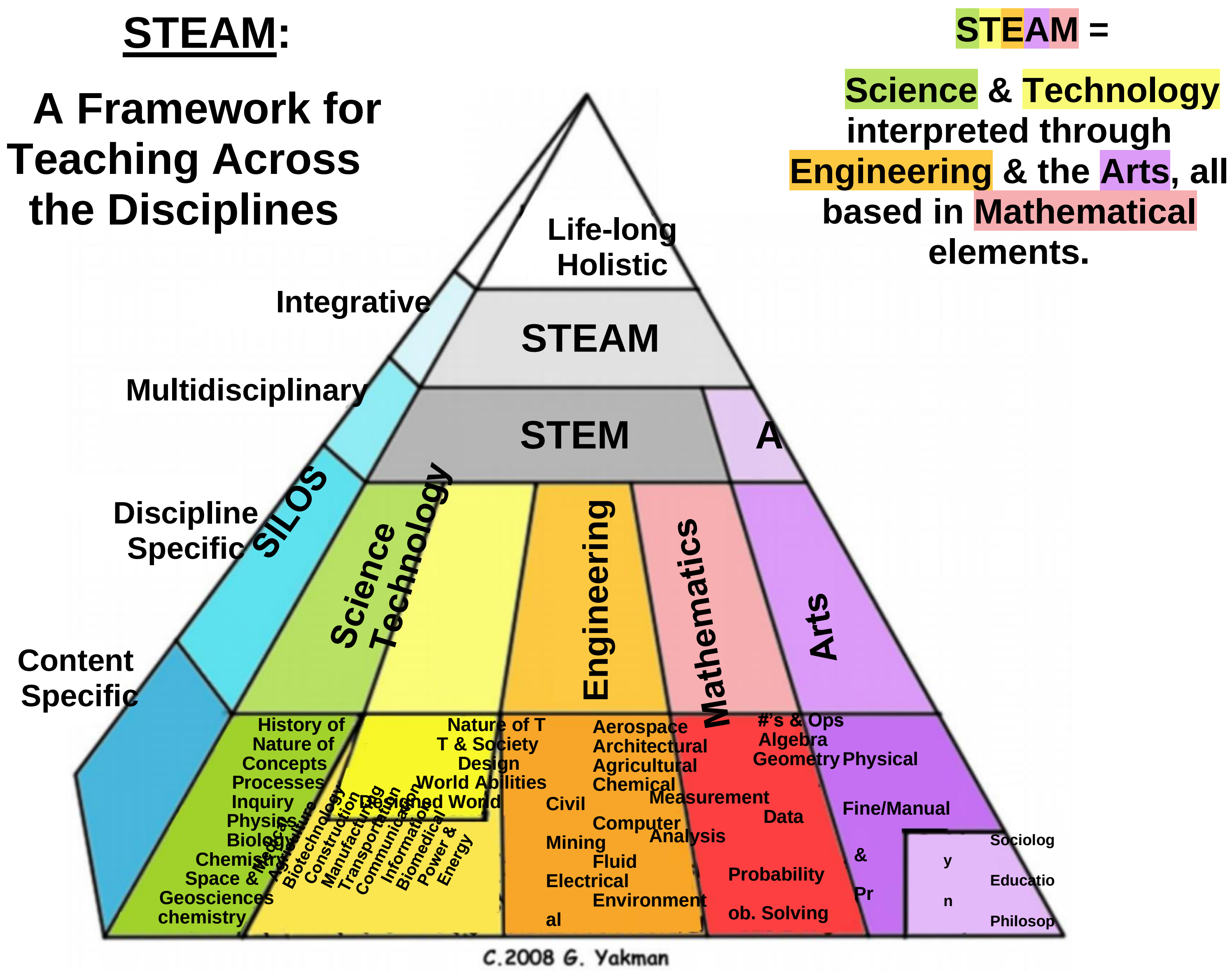
Source: https://steamedu.com/developing-steam-education-to-improve-students-innovative-ability/

One of the main objectives of the STEAM framework is to create a functional and customizable program for all types of students, based on the natural ways of learning. Science and Technology are interpreted through Engineering and the Arts, all comprehended with the elements of Mathematics. Educational examples often leave behind the explanation of where these fields connect as well as what and where this STEAM framework can be used to help students outside the depths and fields of their specialty (Yakman et al., 2019).

This notion started with the development of an educational framework that officially connected the study of sciences to the divisions of the arts. Further, this examination leads to a vast extent of each of the main subject areas which are expected to provide higher educational divisions that could additionally be classified as having influence and value within each of the other “silo approaches” together with all the areas of physical, social and fine arts. A general outline of a STEAM-based learning approach:

- **Science**: consists of everything that exists naturally and how this is affected. It includes the following subjects: Biology, Biochemistry, Chemistry, Physics and Space, Geosciences, Inquiry as well as Biotechnology and Biomedicine.
- **Technology**: refers to everything human-made. It can be defined as the innovation, modification or change of the natural environment to content the perceived human wants and needs. It includes subjects such as Agriculture, Construction, Communication, Information, Manufacturing, Medicine, Power and Energy, production and Transportation.
- **Engineering**: the design and invention, research and development or “Design under constraint”. This includes subjects such as Aerospace, Architectural, Chemical, Civil, Computer, Electrical, Environmental, Fluid, Industrial and Systems, Materials, Mechanical, Naval and Ocean.
- **Mathematics**: can be defined as the study of symbolic relationships, numbers, patterns and shapes, uncertainty, and reasoning. Mathematics consists of the following subjects: Algebra, Calculus, Data Analysis, and Probability, Geometry, Numbers and Operations, Problem Solving, Reason and Proof, Theory and Trigonometry.
- **Arts**: includes fine art, language and liberal arts, motor and physical arts.
  - Language Arts: the way in which all different types of communication are used and interpreted. This includes: written, signed, spoken, sung, or even shown with one’s body, etc.
  - Physical: ‘manual’ and athletics arts including ergonomic movements.
  - Liberal and Social: this includes Education, Philosophy, History, Psychology, Politics, Sociology, Science Technology Society (STS), Theology, etc.
  - Fine arts: can be defined as the aesthetics together with the oldest sustainable cultural pieces and where do they come from teaching the earliest records of civilization.

Disengaging the field of the social, manual, fine, physical, and liberal arts leads to the comprehension of how these fields expand to influence as well as be encouraged by the practices and studies of STEM fields. The above examination leads to the development of a framework based on STEAM that helps educators teach these subjects in a way that links one another in reality. The following diagram establishes a framework based on the structure and analysis of the interactive nature of both the study and practice of the formal areas of Science, Technology, Engineering, Arts, and Mathematics (Yakman et al., 2019).



STEAM-based education can be delivered in a pleasant and meaningful way to engage and deeply embed more students within an already well-established field and education (Yakman et al., 2019).

Part 2: How to approach the European heritage by adopting a STEAM method?

Introduction

Science progresses at an amazing pace with the aid of technology and more specifically with the evolution of computerized machines. Modern equipment and services support the collaboration of scientists and allows the testing of new theories and the design and implementation of new experiments at an unprecedented rate. However, the ground rules for sciences have been established early in the history of humankind. Brilliant minds like Aristotle, Pythagoras, Galileo, Newton, Boyle, Democritus, Pasteur, Descartes, Euclid, Fibonacci, Hypatia, Gilbert, Kepler, and many more, laid the foundations for science and philosophy throughout the centuries. By using improvised tools, they studied various phenomena, from a scientific perspective, and proved their views empirically or theoretically.

But what are some of the discoveries of these great scientists? What are some of the procedures used in ancient Greece or in medieval times or various civilizations in Europe? How can we learn history and art from a scientific point of view? These are some of the issues which are covered in the following sections. Each section contains some historical notes and step-by-step experiments and activities. These activities relate to different historical periods. Teachers can replicate some of the activities in their class or use the proposals to develop a new activity. Students can develop their scientific skills and learn more about our culture and history. These STEAM activities improve student engagement and foster their understanding in an interdisciplinary approach.

We present activities that relate to Ancient Greece, the Roman Empire, the Age of Cathedrals, the Renaissance, and the Age of Enlightenment. That way, students will get acquittanced with various historical periods, the scientists, and the culture of each period. Through hands-on activities will gain a better understanding of the physical world and the natural sciences.

Example 1: Techniques and the Stone Age

From a historical / European perspective, the Stone Age is important, as all nations have had a Stone Age. It is an age all countries have been through but at different times. The period length is very different from every European country to another, as the Scandinavian countries were covered by ice until 13 000 BC. The Stone age is a period with different Stone Age cultures, but often divided in two: The Mesolithic/ the hunter gathers and the Neolithic / peasant stone age. Although the period is long and distant, it is our view that through the right approach can be very present for both children and adult. As we do not have written sources from the Stone Age, it is through the results of archeology and the science of the finds that we get answers to the questions we may have. It gives not only an interest in the Stone Age, but also a view of the methods and the science that is being used. The Stone Age is the foundation on which our civilization rests, and as the age is so distant, it is obvious to take as a starting point the basic living conditions of man how they lived, food, clothing, conflicts, climate change, and life in interaction with nature.

An example of a specific Stone Age culture

The Ertebølle Kitchen midden is considered one of Europe´s most significant monuments. Situated next to the coastline of the time, it was formed over 1.500 years by groups of Stone Age hunter-gatherers. Originally the midden was 140m long, 20m wide and up to 2m thick, and it contained oyster shells, food remains, discarded tools and a few human skeletons. The shell heap is an archaeological gold mine, and it is well protected beneath the turf by the Stone Age coastline approximately 500m from the village called Ertebølle

Not only did the small village of Ertebølle give its name to the Ertebølle Culture (5400-3900 BC), the discovery of the site also made it possible to divide the Stone Age into Mesolithic and Neolithic periods – the Stone Age of the hunters-gatherers and that of the first farmers.

A small part of the original Kitchen Midden with example of the size of Stone Age man and woman.

Photo: Kim Callesen, Vesthimmerlands Museum, Denmark

Techniques from the Ertebølle Culture

The Ertebølle Culture is known for special ceramics such as pointed-bottomed vessels and cod-liver oil lamps. High specialized fishing gear: small fishing hooks made of bones from red deer, fishing nets, and fishing rods. They used 10 m long dug-out boats made from linden logs. They produced Core axes and Flake axes from the local flint as well as using flint stains for the transverse bodkins.

From left : Flint stains, flint block, core axe, Flake axe, drill, transverse bodkins, string with heart clam, pointed-bottomed vessels, model of dug out log boat.

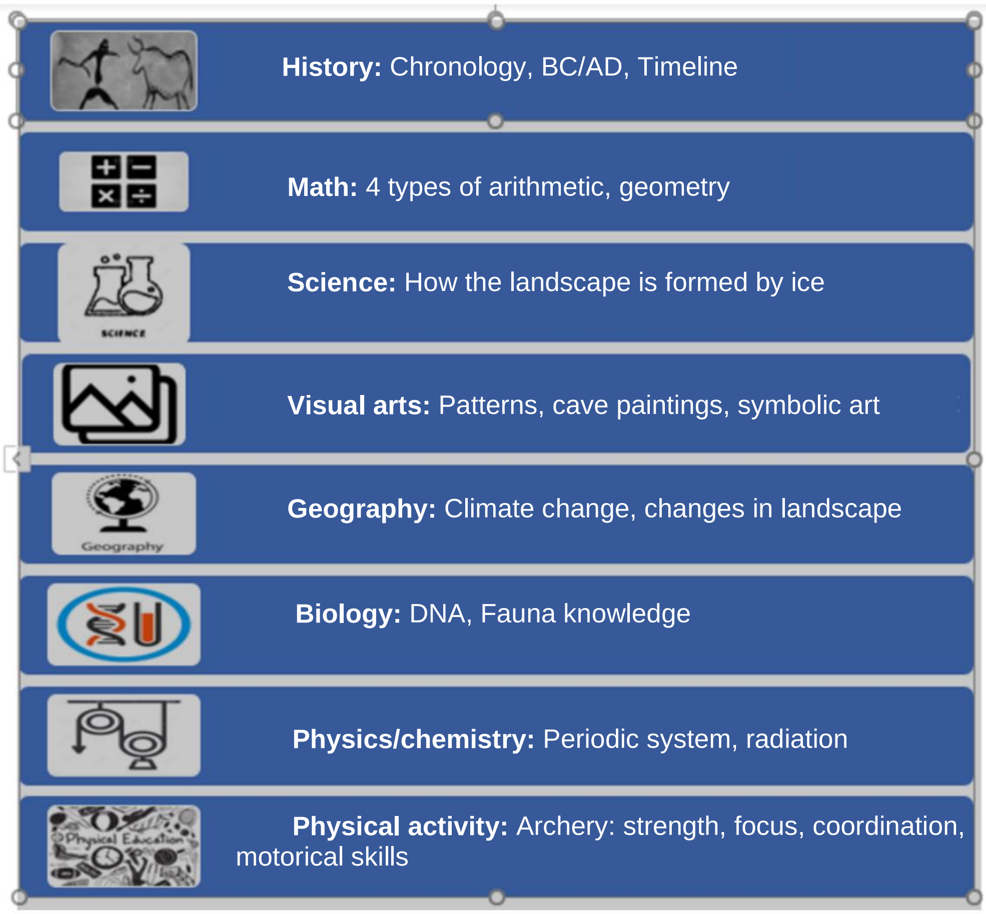
Flint knapping tools: antlers and stone.

Behind: Eel-trap made of willow and string from Linden bast.

Photo: Kim Callesen, Vesthimmerlands Museum, Denmark

The Stone Age is included in the Danish curriculum either as periods to be taught, part of the chronology or cultures to be presented e.g. The Stone Age covers quite a long time, where knowledge about the period is based on archeology. This offers some very special possibilities viewed in the STEAM context.

It is of course obvious that the Stone Age is placed in the subject history, but the period contains so many possibilities seen in an interdisciplinary context, which is illustrated in the model below:



The model shows only a very few ways to accommodate the various subject areas when the starting point is the Stone Age. There are certainly many more, but the period shows its relevance precisely in that the professional areas extend over each other, and the art must be to be able to perspective to the present, for example. Climate change is very topical and an area that students often encounter.

How to get close to the Stone Age?

The key word here is motivation through identification, hands-on activities and use of approach of STEAM. The Stone Age techniques are often very little known among the students as well as most of the teachers! It is important- if possible- to have some artefacts/copies the students can see, touch, smell or try. But most of all it is important that they can identify themselves with the subject – they can relate to the theme. It can be beneficial to start with what they know best: themselves and compare with the Stone Age man.

There can be many ways, to begin with, teaching about the Stone Age, but it can be beneficial to start with what they know best: themselves and compare with the Stone Age man. Here we need to back ourselves up from research.

Activity 1: The Stone Age Man – a narrative introduction

Main subject area: History, Science, Biology

Other possible areas: Physics, visual arts, writing based on archaeological facts

Age of students: From 10 to 17 years

Skills asked: Chronology, knowledge of the Mesolithic, knowledge through the scientific method. They see how scientific method is used at a museum, like DNA[2], dating methods, radiocarbon[3] dating, and other scientific techniques

Development of the activity:

The teaching course is a narrative course where the children learn what a skeleton of the Mesolithic can tell, which methods are used to find out when a person has lived, etc. and what the children's skeleton can tell.

The skull shown in the picture below is called The Hedegaard man. The skull has several signs that the man has received several blows with a blunt object. Although he must have been badly injured, it must be noted that wounds and skull injuries have healed. He has survived! The skull is also quite thick compared to today's "modern" skulls. Robust bones belonged to that time.

Teachers or educators can talk with the students about some facts of the Ertebølle people that

[2] DNA-analysis are opening for new knowledge about the ancient population and rewriting our history. DNA is often extracted from the teeth or bones if possible

[3] Technique based on Carbon-14 decay to determine the age of organic materials. Glosbe.com

may interest them:

- The average height of the Stone Age was 153-155 cm for women and 166- 168 cm for men. Try to compare with the height of the students
- The brain of the Stone Age people was bigger than modern people's brain – why?
- How or why did The Hedegaard Man[4] got his wounds?
- The Ertebølle people might have been lactose intolerant – how did we become lactose tolerant?
- They might have darker skin and blue eyes – how did our skin become lighter?

Many small holes must be drilled in a skull to get a little over half a gram of bone. The result showed through Carbon14- dating, that the man lived almost 10 000 years ago, and the main part of his food was from terrestrial animals.

Photos: Kim Callesen/ Bjarne H. Nielsen Vesthimmerlands Museum, Denmark

The skeleton is an archive of information about a person, these are some of the methods used by archaeologists:

- The Radiocarbon dating/ Carbon 14- analysis shows information about when you lived
- Visual observations can indicate if the skeleton was a man or woman
- If a skeleton is complete it´s possible to measure how tall the person was
- If you had any injuries such as a broken arm
- If any DNA is left, it may show skin color, sex, eye color and certain diseases
- Radiocarbon dating/Carbon13 – analysis show what you ate: How much marine-, plant- or food from terrestrial animals
- The wrist shows if you got enough to eat or starved for some periods

[4] The Hedegaard Man is displayed at Vesthimmerlands Museum, Denmark

- Through Strontium-isotopic analysis[5] of the teeth show where the person was when it was born, as a teenager and become old – if it did
- If any hair was left a Strontium-isotopic analysis can show where the person has been. Hair grows about 1 cm every month. If the hair is 30 cm long, it shows the 30-month period of where the person has been.

A simple introduction is to ask the students: Which story does your skeleton tell? Draw or write it. The teacher can put the stories on the wall and ask the students, if any of them wants to tell a bit of their story.

Activity 2: To make a string and a piece of jewelry

Main subject area: History, Technology, Science

Other possible areas: Math, biology, visual arts, cooperation, hands- on history.

Age of students: From 6 to 17

Skills asked: Using the history, twisting, problem-solving, cooperation

Children with special needs: Yes, the teaching course can be very suitable

Development of the activity:

The students learn how to make a piece of string out of plant fiber and a pearl of cherry stones or cockle, which they can use for a necklace or a bracelet.

This activity is brilliant as it is the first intro with Stone Age techniques. It has been tested on different ages and kind of students. It´s been tested with children with special needs and works fine because it is a very specific task, it isn´t too complicated to learn and you´ll quickly get a quite beautiful result.

What did children do in the Stone Age? In fact, we don´t know! But if we study native people, children often take part in daily life and learn the craft.

Maybe they produced a string in the evening when sitting around the campfire. The string

[5] Strontium Isotopic analysis: Strontium isotopic ratios are widely used as tracers in geological processes and as indicators of provenance in an archaeological context. ... Archeologists use the isotope ratios of strontium to determine residential origins and migration patterns of ancestral humans. The human body incorporates Sr by way of diet. www.cals.uga.edu

could be used as a fishing line, or if you needed to tie something, or simply use it as a kind of bracelet or necklace.

A string can be made of animal tendons, skin, or different plant fibers. In this activity, we use plant fibers.

Plant fibers from: Nettles, blackberry, different type of grass, bark from willow or linden wood or simply palm bast which is cheap, easy to find in supermarkets, plant centers. When you´re a trained string maker. It is fun to produce your own material, but it demands knowledge about the different plants, when to harvest, how to dry them and how to produce the string.

Once the students have made a piece of string with two cords, it is obvious to make a piece of jewelry in the form of a bracelet or a necklace. They can make a pearl of a mussel by grinding it against a stone. It is also possible to make a pearl from a cherry stone. It is quite simple: you just have to wet the cherry stone and grind it on two sides until the core appears as a circle, which you can stick out with a piece of flint or a small stick.

It is an interesting experience to see how students' perceptions of a cherry stone change. Nowadays, the cherry stone is a piece of rubbish we throw away. By making beautiful pearls, what used to be waste suddenly becomes a valuable resource!

Making a piece of string is maybe seen as a simple activity, but it requires knowledge, technical ingenuity, creativity, and logical thinking in order to succeed. It is important to succeed the first time, which the simple workflow ensures.

Bracelets with pearls of cherry stones and Heart Clam shell. Strings are made of Linden tree bast.

Behind: The raw material, separated from bark from Linden tree by a kind of fermentation through 7 months.

Photo: Kim Callesen, Vesthimmerlands Museum, Denmark

Closeup of pearls made of cherry stones.

Photo: Kim Callesen, Vesthimmerlands

In addition, it is a social activity where students are equal, as it is a new craft for them all, where they benefit from being able to help each other naturally. The students experience knowing something special that they master a small craft that strengthens their self-confidence.

It is noteworthy that students' views of the plants often change through the activity. At first, stining nettle is often perceived as an unpleasant plant, a weed to get rid of. But when you realise it's uses, it turns into a plant you value and take care of, because it suddenly becomes a significant resource. The realization becomes greater as the students themselves find them.

Activity 3: The Stone Age patterns

Main subject area: History, Visual Arts, Math, Science

Other possible areas: Technology, biology

Age of students: From 9 to 17

Skills asked: Chronology, ancient art, pigments and how to make color, symbols, geometry

Development of the activity:

Students will learn about the first graphic expressions of our culture, which have often been geometric patterns, animals, or Symbolic expressions. Students must try to produce color pigment, mix the color and give their artistic stone age- expression.

At the same time, there are different kinds of patterns in the form of lines or geometric shapes: Diamonds, circles, or trapezoidal patterns are known.

Showing experiments with color made of different types of sand mixed with vegetable oil or egg.

Photo: Kim Callesen, Vesthimmerlands Museum, Denmark

Showing advanced pattern made of tar on a copy of a paddle oar from the Ertebølle Culture. Experiments show that the pattern was not painted on, but printed from the veins of the wood in a complicated process which almost is magic)

Photo: Kim Callesen, Vesthimmerlands Museum,

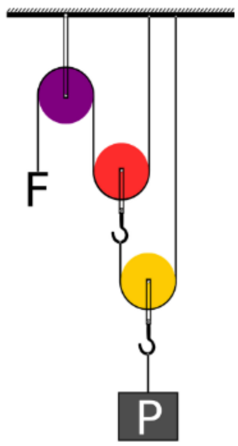
Charcoal, ocher, dried clay, chalk, or burnt soil types are crushed using stones and mixed with water, vegetable oil, or eggs. The paint can be applied with the fingers, feathers, wood splinters, flower stalks, or tubular bones.

Example 2: Mathematics and Ancient Greece

For many ancient civilizations, the unknown, i.e. earthquakes, volcanic eruptions, or other natural hazards, was explained solely by religion. The Greeks were one of the first civilizations to use logic, reason, and science to try to understand why certain events around them were happening. Ancient Greek scientists have many inventions and discoveries attributed to them, especially in the areas of astronomy, geography, and mathematics.

The Greeks developed philosophy as a way of understanding the world around them, without resorting to religion, myth, or magic. Early Greek philosophers, some of whom have been influenced by Babylonians and Egyptians, were also scientists who observed and studied the known world—the Earth, seas, and mountains, as well as the solar system, planetary motions, and astral phenomena.

Astronomy, which began with the organization of the stars into constellations, was used for practical purposes to fix the calendar. The Greeks:



- Estimated the size of the Earth
- Figured out how a pulley and levers work
- Studied refracted and reflected light, as well as sound

In medicine, they:

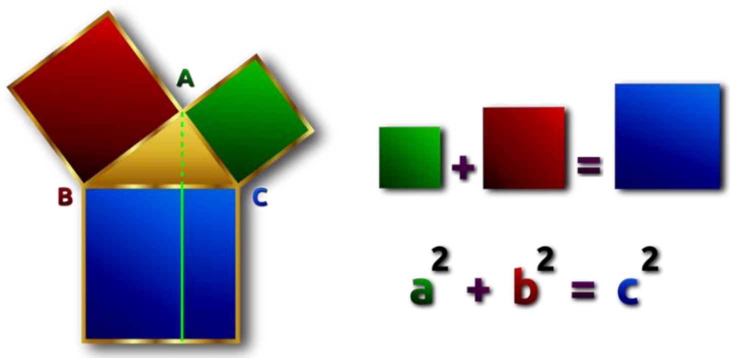
- Looked at how the organs work
- Studied how a disease progresses
- Learned to make inferences from observations

Their contributions in the field of mathematics went beyond the practical purposes. Many of the ancient Greeks' discoveries and inventions are still used today, although some of their ideas have been overturned.

Well known Ancient Greek Scientists

- **Pythagoras of Samos (Sixth Century BCE)**

Pythagoras realized that the land and sea are not static. Where now there's land, there once was sea and vice versa. In music, he stretched the string to produce specific notes in octaves. In the field of astronomy, Pythagoras may have thought of the universe as rotating daily around an axis corresponding to the axis of the Earth. He is most known for his Pythagorean theorem.



Pythagorean theorem

- **Hippocrates of Cos (c. 460-377 BCE)**

Hippocrates studied the human body and discovered there are scientific reasons for ailments.

- **Aristotle (of Stagira) (384–322 BCE)**

Aristotle concluded the Earth must be a globe. The concept of a sphere for the Earth appears in Plato's Phaedo, but Aristotle elaborates and estimates the size.

- **Thales of Miletus (c. 620 - c. 546 BCE)**

Thales was a geometer, military engineer, astronomer, and logician. He invented abstract geometry, including the notion that a circle is bisected by its diameter and that the base angles of isosceles triangles are equal.

- **Archimedes of Syracuse (c. 287-c. 212 BCE)**

Archimedes discovered the usefulness of the fulcrum and lever. He began the measurement of the specific gravity of objects. He is credited with having invented what is called the screw of Archimedes for pumping up water, as well as an engine to throw heavy stones at the enemy.

- **Euclid of Alexandria (c. 325-265 BCE)**

Euclid thought that light travels in straight lines or rays. He wrote a textbook on algebra, number theory, and geometry that is still relevant.

- **Eratosthenes of Cyrene (c. 276-194 BCE)**

Eratosthenes made a map of the world, described countries of Europe, Asia, and Libya, created the first parallel of latitude, and measured the circumference of the earth.

Activities on the Archimedes solution

Archimedes was asked by King Hiero of Syracuse to find out if the gold wreath made by Hiero's goldsmith was truly pure gold and not mixed with some other alloy. The king suspected his goldsmith was embezzling some of the gold. If the wreath was pure gold, it would have a certain density. If it was made of a mixture, the density would be different. However, in order to find the density of the wreath, its volume must be determined. This was the problem Archimedes faced.

The story goes that Archimedes decided to take a hot bath to help his mind relax and find a solution to this problem. When he noticed the water rise as he got into the tub, Archimedes suddenly realized the solution. Archimedes was so excited that he jumped out of the tub and ran down the street, shouting, **"Eureka! Eureka!"** which means "I have found it!" Unfortunately, he was so excited that he forgot to put on his clothes and ran through the streets naked! ☺

The solution to the problem was that he placed the wreath in a container of water and measured its displacement. That could be done by filling the container to the rim, placing the wreath in the water, and then measuring the overflow.

By measuring the volume of the water and the mass of the wreath, Archimedes was able to determine its density. Unfortunately for the goldsmith, the density of the wreath showed that it was not pure gold. He was robbing the king and he was most likely punished.

Activity 1: Measuring the volume of a solid object

Main subject area: Physics
Other possible areas: Mathematics, history, heritage
Age of students: From 10 to 17
Skills asked: To make calculations, to use measures, to use natural sciences' tools

Development of the activity:

The purpose of the activity is for the students to understand how to measure the volume of an uneven object. Teachers provide a solid object and a volumetric cylinder with liquid. Note the level of the liquid (i.e. the volume). Then add in the solid object and note the level again. The volume of the body will be equal to the difference of the final minus the initial level. Students have to repeat the procedure five times and find the average volume. In our example the volume increased from 400 ml to 420 ml. Thus, the volume of the solid is 420ml-400ml = 20 ml or 0.02 lt (1lt=1000ml).

(a) Volumetric tube with some liquid

(b) Volumetric tube with some liquid and the solid object

Activity 2: Measuring the purity of an object

Main subject area: Physics

Other possible areas: Mathematics, history, heritage

Age of students: From 10 to 17

Skills asked: To make calculations, to use formulas, to use measures, to use natural sciences' tools

Development of the activity:

In this activity students will repeat the Archimedes experiment. Students will measure the purity of solid objects and the density of solid objects for which we know the density. Density is commonly expressed in units of grams per cubic centimeter. For example, the density of water is 1 gram (1gr/ml). Density of ice is approximately 0.92gr/ml.

So why ice floats in water? A substance floats if it is less dense, or has less mass per unit volume, than other components in a mixture. So that is why ice floats in water. It is about 9% less dense than liquid water. In other words, ice takes up about 9% more space than water, so a liter of ice weighs less than a liter water.

Having a scale, we can measure the mass (weight) (*m* in grams) of an object. Then by repeating the previous example we can measure the volume (*V* in ml) of the solid object.

(a) Digital scale

(b) Volumetric tube with some liquid

The result of the experiment is the calculation of the purity of an object.

Activities based on Xenagoras & Thales

The measurement of the height of structures, even mountain peaks, in antiquity was based on Thales' theorems in similar triangles. Two triangles are similar when all their respective angles are equal. According to Thales's theorem, similar triangles will have corresponding sides.

The first scientific study of Xenagoras (2nd century BC) was based on the theorems of Thales. He calculated the height of the peak of western Olympus Mountain, named Flambouros. Xenagoras used a kind of "diopter" to measure the altitude differences between this peak and the point of the ancient temple of Pythian Apollo where he was located. There, in the ancient temple at the foot of Olympus, he calculated the height of the peak to be 2479m. The exact height is 2473m as measured with modern tools. So the deviation was only 6m. This experiment is saved through the texts of Plutarch.

Activity 3: Measuring the height of a building

Main subject area: Mathematics, Geometry

Other possible areas: History, heritage

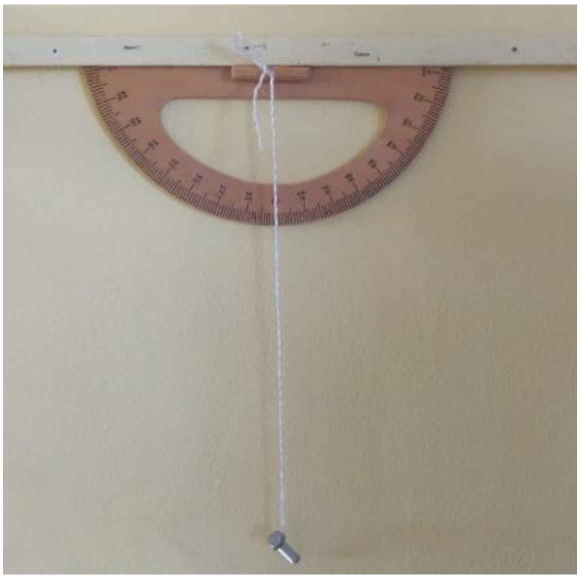
Age of students: From 10 to 17

Skills asked: To make calculations, to use measures, to use natural sciences' tools

Development of the activity:

But how could we use these facts to measure the height of a school building, for instance, without climbing to its highest point.? By using an improvised sextant.. It is essentially a goniometer used in ancient times to calculate the angle under which a point is viewed from an observer.

For creating the sextant, we need a straight stick, a regular goniometer, a string and an object to be tied up at the end of the string, as shown in the image.



Using this improvised object, an observer Π will aim at the top K of the building and with this construction we will find the angle φ under which we see the top of the building.

Students should aim at point K from a point Π and the angle θ (formed by the fishing line and the wood) is, for example, 60º then the angle φ will be 30º, since the angle formed by the fishing line and the horizon will be right angle i.e. 90º.

Example 3: Technical inventions and the Roman Empire

Roman civilization has emerged around 700 years BC. when inhabitants of small farming towns and villages around Tibera river started to connect. This was a meeting point of different ethnical groups, influenced by Etruscans, Phoenicians and Greeks. The civilization that emerged there, later ruled over the entire Mediterranean, Britain, big part of Europe and Middle East. Civilization was until 6th century BC. organized as monarchy, followed by republic turning in to an empire in year 27 BC.

The empire has been in 4th century AD. divided into western and eastern half. Western part has collapsed in year 476 with the rule of Odoacer. Eastern empire on the other hand lasted for almost another 1000 years, when in 1453 fell apart after Ottomans conquered Constantinople. Nowadays in Europe, more than 600 bigger sites can be found, where remains of roman civilization (such as remaining of cities, roads, border posts, etc.) can be seen.

In Slovenian educational system students learn about the Roman civilization in 7th grade (age 12). It is presented as an independent topic and as a part of the antique era. Students learn about history of the civilization, life in that period, the advancements of the era, the influence that the romans had in Slovenian territory and the influence of the Roman civilization in later periods. In the curriculum of British education system students learn about the roman civilization between year 7 and 11. Most of the topics are connected with the influence the civilization had on British ground.

Romans managed to create inventions still used today. Fundamental innovations, such as development of roman numerals, enabled easier calculations, whereas Julian calendar allowed higher levels of organization. Furthermore, invention of newspaper, postal service and bound book increased the flow of information. The best known technical advancements of the Roman period are invention of the arch, allowing the construction of complex buildings (such as aqueducts, colosseums, etc.), invention of plumbing, construction of roads, usage of concrete and many more. From military perspective two main advancements were the usage of **corvus** (boarding device for naval warfare) and **testudo** (the tortoise approach that allowed higher protection of battle group against projectiles).

In school classes today, students learn about the Roman advancements mostly in history classes. The only other encounter with Roman advancements in STEAM subjects is when learning roman numerals as part of the mathematical curriculum.

As Romans have many inventions that can be used and presented in classrooms couple of examples of STEAM activities have been prepared which can be done at school or a museum.

Activity 1: Introduction to Roman numerals

Main subject area: Arithmetic, Algebra

Other possible areas: History

Age of students: From 6 to 10

Skills asked: To know basic numerals and some historic dates

Development of the activity:

Students should first get introduced to the concept of Roman numerals. They should try to think of some important dates in history and try to write them in Roman numerals. Later, each student should get secretly assigned a single historical date. They should write it on the whiteboard with roman numerals. Other students should try to figure out which event this date represents.

To make the whole process a bit more engaging and active, students can instead of whiteboard use sticks, toothpicks or pens, with which they can construct the desired number on a flat surface.

Roman numerals made of popsicle sticks

Activity 2: Construction of Roman road

Main subject area: Mechanics

Other possible areas: History

Age of students: From 7 to 11

Skills asked: Understand the importance of infrastructural networks (roads) and simple statics principles.

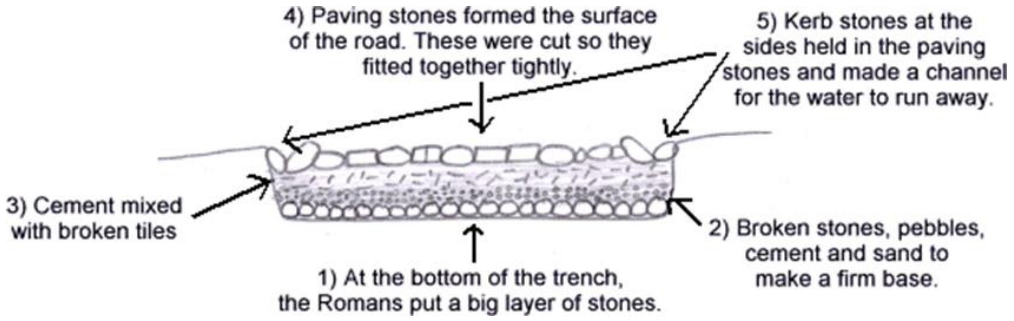
Development of the activity:

Students should first be introduced to the history, the role, and importance of roads in the

Roman Empire. Later, they should be introduced to the simple blueprints of Roman roads. Later, they can, with the following materials construct a smaller model of Roman road.

- Shoe box
- Multipurpose glue
- Sand,
- Flat pebbles, smaller approx. 2 x 2 cm and larger approx. 6 x 2cm
- Plaster

They firstly add the glue on the bottom of the shoe box, cover it with sand and shake off the excess. This layer presents ground. Afterward, student place another layer of glue and pave the sand layer with small pebbles and cover it with another layer of sand and fine pebbles. They mix plaster, create a thick layer of plaster on top of which they place bigger flatter pebbles, as close together as possible, trying to match them in a way living minimum gaps in between.



Profile of Roman road (Warner, n.d.)

Model of Roman road, build with glue, plaster, sand, and pebbles

Photo: Weird, unfocalized homeschoolers,

Activity 3: Making your own Roman oil lamp

Main subject area: Chemistry

Other possible areas: House economics

Age of students: From 7 to 8

Skills asked: Understanding the importance of roman innovation and its effect on our everyday lives

Development of the activity:

Students can use clay, a piece of cloth or some other material for a wick and kitchen oil or other types of liquid fat as fuel for an oil lamp. First, they create a small pot. They stretch and punch one of the sides so that just a tiny bit of oil can fill the little ledge on the outside of the pot and the wick can reach the inside of the pot. The pot can be decorated and left to dry (or bake it if the type of clay requires it). The pot is filled with fuel, a wick is inserted into the slot and the end is lit. The process can be optimized with a thicker wick, different designs of the pot, various types of fuel.

Usage of the lamp has to be supervised by an adult.

Example of a Roman oil lamp

Photo: Albi, 2019

Activity 4: Making your own aqueduct

Main subject area: Physics

Other possible areas: History and mechanics

Age of students: From 7 to 8

Skills asked: A basic understanding of the importance of water supply, public infrastructure and water for our organism and our everyday lives

Development of the activity:

Students should be introduced to the concept of aqueduct. They should discuss its function, construction and difficulties that first engineers faced when they were building them (debate about fluid dynamics). Students should be supplied with the following material:

Students use plastic sheeting to cover the cardboard, which is later used to create the channel for water. Students are given full freedom to design the structure of the aqueduct and encourage to use arches and complex structures and later discuss the importance of water supply for our society.

Example of assembled aqueduc

Photo: The Kid Should See This, n.d.

Example 4: Construction and measure in the Age of Cathedrals

The Middle Ages or Medieval Period is a period of history that extends approximately from 500 to 1500 AD, between Antiquity and Modern Times. Indeed, for the majority of the

countries of Europe, the Middle Ages began after the fall of the Roman Empire and ended after the discovery of the new world. Each country of Europe was affected at different times throughout this period.
Between the 5th and 15th centuries, medieval architecture was characterised by the construction of major military and civil works.

During this period, societies were built and organized around different religions, mainly Christian (Protestant, Orthodox, Catholic, Jewish ...) but also around the Muslim religion - especially Spain.
In Western Europe, the society was principally Christian and was organised by the Catholic Church, while in Eastern Europe, after the schism of 1054 AD, it was the Orthodox churches that guided the population. After the Carolingian art, Romanesque and then Gothic art developed, covering Europe with monuments testifying to the faith of the population. Many cathedrals were built, such as the Cathedral of Notre Dame in Paris.

Credits: Wikipedia Common

It is from the meeting of new requirements and a new methodology that was born the flowering of new cities in the late Middle Ages. Indeed, several requirements appeared:

- demographic: increase of the population
- economic and commercial: increase of commercial exchanges
- internal politics: to set up the royal power and to allow the organization of the society, but also to ensure a security of the population

The medieval sciences, based on teaching and writing, extended the ancient sciences. This continuity can be seen in the techniques based on practice and manual work. This period saw important technological advances, including the use of gunpowder and the astrolabe, the invention of telescopes, the significant improvement of water mills, construction techniques, agriculture, clocks and boats...

Credits: Wikipedia Common

In STEAM - mathematics, age of students 12/15: Space and geometry

In history class, French students study this historical period around the age of 12-13. It is included in the theme: Society, Church and political power in the feudal West (11th-15th centuries)

In the STEAM disciplines, we can link it with the teaching of mathematics (space and geometry) for 12–15-year-old students.

Activity 1: Line workshop

Main subject area: Geometry, architecture

Other possible areas: History, heritage

Age of students: From 10 to 15

Skills asked: To use tools of mathematics measures / knowledge of basics geometric shapes

Development of the activity:

Guédelon, in the centre of France, is a scientific, historical, educational, tourist and human site. The aim is to recreate in situ the construction processes and organisation of a site in the first third of the 13th century.

From season to season, the Guédelon workers take up this extraordinary challenge. From the fortified enclosure to the dwelling and its frameworks, not forgetting all the rooms of the castle, everything was built, using the techniques, materials and tools available at the time the castle is trying to reproduce in front of the eyes of thousands of visitors who came to visit this unique site in the worl.

Source: Guédelon Castle (Treigny, France) on 19 August 2019 by Benoit Prieur

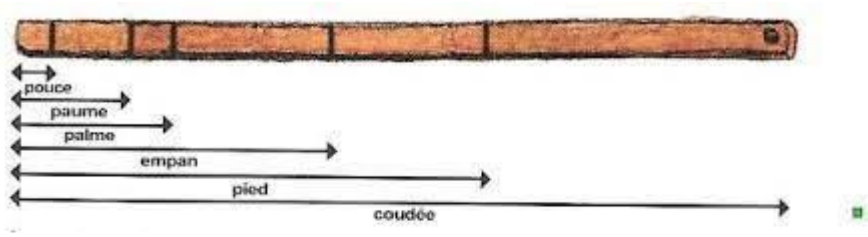
A booklet on units of measurement in the Middle Ages is offered as a workshop for children. They offer a simple and playful approach to geometry to raise awareness of the pragmatic aspects of drawing and figuring, while advocating active participation by the children.

Fermat Science also proposes a workshop of this type, proposing to design a paper “pige” with its own dimensions, and a 13-knot string.

The Fermat Science workshop is called Medieval Measurement workshop.

After a short introduction, the first part of the workshop deals with medieval measurement.

The students, considering their own dimensions, have to design a paper "pige".



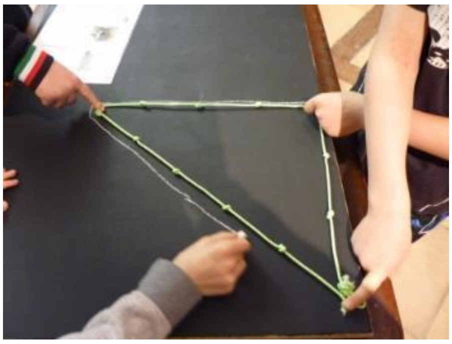
Afterwards, the students discuss the different "piges" designed: are they identical?

In fact, no, because as the values varied from one student to another, the measurements changed. As in the Middle Ages, the values varied from one master builder to another, from one region to another, from one period to another, each worker transferred the measurements of the master builder on his own "pige".

The students can now design a common cardboard "pige" where each one transfers the same measurements (that of the teacher for example).

The second part deals with measurements with a 13-knot rope.

The teacher demonstrates the use of a large 13-knot rope.



Presentation of the 13-knot rope

Photo: Fermat Science

The teacher then gives the students in groups of 3 or 4 a prepared rope. Students test and research to construct geometric shapes with the rope.

On a large sheet of paper unrolled on the floor or on a blackboard on the floor, the students construct geometrical figures with the designed tools.

Activity 2: Cathedral's builders

Main subject area: History, architecture, heritage

Other possible areas: Mathematics

Age of students: From 10 to 15

Skills asked: To use tools of mathematics measures / knowledge of basics geometric shapes

Development of the activity:

This activity is based on Pierre Bellenguez's work on traced cathedrals.

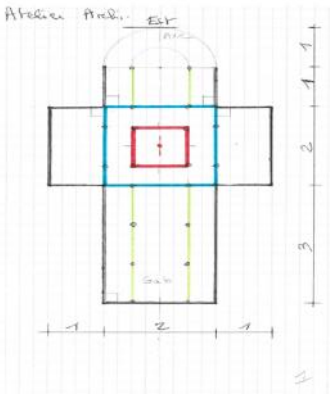
Passionate about medieval architecture, Pierre Bellenguez lives in France where he runs a computer development agency. As an independent researcher, he has been taking a fresh look at the secret architecture of cathedrals and gothic geometry for several years. This work, which crowns several years of research and two tours of France, has just been recorded in the book *Les cathédrales retracées*.

The aim of this activity is to draw a plan of a cathedral with medieval tools.

First, the students handle and discover a rope with 13 knots: how many intervals for 13 knots?

The teacher then asks them to make a square, a rectangle, an isosceles triangle...

Then they have to draw the cathedral: mark the axis of the cathedral, draw the plan...



Finally, the final step, the construction: on the basis of the plan drawn in the second step, the students have to build a "cathedral" in a free way out of KAPLA® -type wooden boards. The first objective is to achieve a coherent elevation in terms of construction and solidity (search for an efficient constructive system with the KLAPA®), the second is to achieve a harmonious and original whole on the aesthetic level.

Activity 3: Stained-glass windows and rosettes

Co-funded by the Erasmus+ Programme of the European Union

Main subject area: History, geometry

Other possible areas: Mathematics

Age of students: From 7 to 18

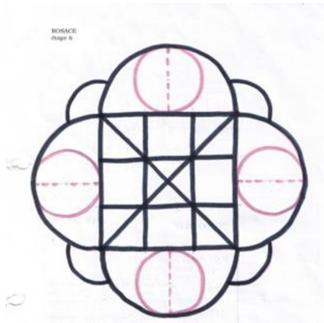
Skills asked: Knowledge and representing geometrical shapes / Applying instructions

Development of the activity:

A stained-glass window is a panel made of pieces of glass, usually coloured, assembled and set to form a decoration. They are usually found in churches, cathedrals, cemeteries, etc. They can use tools seen in the other activities to draw some of the patterns: a 13-knot rope and a "pige".

Fermat Science propose this activity. The students must choose a figure and make it according to a construction diagram.

Then they have to put your drawing sheet under a plastic sheet and use a silver marker to iron all the lines. Finally, they colour in each part of the drawing on the plastic sheet with the coloured markers.



Example 5: Art, science, technique and Renaissance

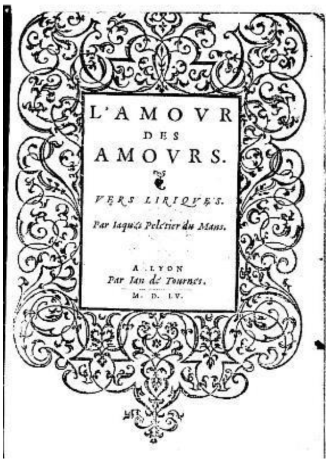
The Renaissance is a period in the West at the end of the Middle Ages and the beginning of modern times, associated with the rediscovery of literature, philosophy and the sciences of Antiquity.

The artistic Renaissance began in Italy in the 14th century and then spread to the rest of Europe, particularly in the regions concerned by trade and thanks to patrons who financed artists such as Leonardo da Vinci.

The styles and techniques differed greatly from country to country, but there were some common features: a search for realism, the use of perspective, the use of light and new techniques. Science and mathematics in particular have their place in this artistic evolution.

Co-funded by the Erasmus+ Programme of the European Union

The mixtures that the artists have made between art and science to capture reality and to imitate nature allows innovative approaches and advances. Painters and architects invented methods of representation in perspective. Leonardo da Vinci's paintings are instructed by dissection practices and anatomical knowledge. Johannes Kepler establishes a link between consonances and constructible polygons with a ruler and a compass. The mathematician Jacques Peletier du Mans, invents "scientific poetry" ...


L'AMOVR DES AMOVRS.

VERS LIRIQVES.

Par Iaques Peletier du Mans.

A LYON
Par Ian de Tournes.
M. D. LV.

L'amour des Amours, book which inaugurates in France the genre of the "scientific poetry"

Renaissance sciences and techniques are also discoveries of considerable magnitude in the history of social, cultural, and technical development in medieval Europe. Indeed, this period allowed Europe to embark on world-class maritime expeditions, known as the Great Discoveries.

Astronomy was directly made possible by the mathematics of the 15th century, and it became independent of astrology. Solving third degree equations enabled Johannes Kepler to calculate the rising of the earth on the moon. The astronomical discoveries of Nicolaus Copernicus, Tycho Brahe and, above all, Galileo, who invented the telescope at the end of the 16th century and drew up the first maps of the stars in the solar system, had the greatest impact on modern science.

Science as a discipline of knowledge thus acquired its autonomy and its first great theoretical systems. This period is rich in descriptions, inventions, applications and representations of the world.

In history class, French students study this historical period around the age of 12-13. It is included in the theme: Transformations of Europe and opening to the world in the 16th and

17th centuries.
In the STEAM disciplines, we can link it with the teaching of mathematics for 12–15-year-old students.

Activity 1: Renaissance Art and Geometry

Main subject area: Art, Mathematic
Other possible areas: Geometry, history
Age of students: From 13 to 15
Skills asked: Space

Development of the activity:

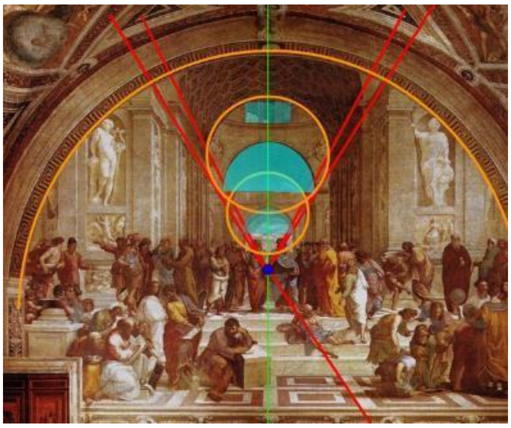
Mathematics and art seem to belong to two very different ways of thinking, respectively logic and creativity. As art is supposed to express emotions and mathematics is used to express facts and thoughts, one might think that they are completely unrelated. However, many artists have decided to study mathematics in their work. The improvement that geometric knowledge could bring to artistic creations made it an invaluable theoretical tool in the visual arts. Many Renaissance artists studied perspective, polyhedra and other mathematical concepts to achieve a more realistic representation of the world.
In this exercise, Renaissance art, its influences, and the applicability of mathematics in artistic and architectural works are highlighted. Works of some famous artists and architects who changed their perspective and dimensions during the Renaissance will be discussed. The primary objective is to discover the mathematical concepts hidden in Renaissance art, using perspective techniques and the Golden Ratio. The students will explore both areas, drawing the art or watching proposed paintings, books, or videos. They will learn the basics of the math concepts mentioned.

Works studied:

- Painting The School of Athens.

This monumental fresco was painted by Raphael for the Pope's palace in the Vatican in the early 16th century. It represents the thinkers and scholars of Greek and Roman

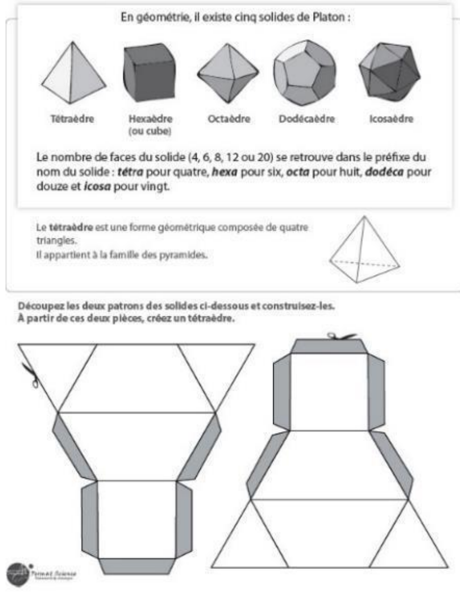
antiquity, whose writings were revived during the Renaissance.
A geometric reading of the organization of the painting is proposed using circles of different diameters. The students reproduce the geometric tracings.



The *lignes de fuite*, i.e. the straight lines that are in the direction of the painter's gaze, are extended until they meet at the *point de fuite* of the painting, following the rules of central perspective. The *point de fuite* is between the two philosophers Plato and Aristotle, leading one to look at these two characters.

- Book De divina proportione by Luca Pacioli, monk and mathematician

The first part dealing with the golden ratio is illustrated by the perspective representations made by Leonardo da Vinci. 60 polyhedra are visible!
After having seen the principle of the golden ratio, the students can discover polyhedra and learn their characteristics. A game of head box can also be proposed on the Platonic solids.



At the end of this tool, the student will be able to:

- Understand the logical process behind the artists' use of linear and aerial perspective;
- Understand how the Golden Ratio is used in Renaissance Art;
- To recognize a platonic solid and know what constitutes a polyhedron.

An ERASMUS+ project proposing tools on this topic is available here : https://artofmaths.eu/

Another pedagogical tool on this theme is the exhibition **La perspective à la Renaissance** (Perspective in the Renaissance) proposed online by the Institut de recherche sur l'enseignement des mathématiques de Limoges (France).
Three panels (downloadable as A4 images) are associated with the theme perspective in the Renaissance:

- History of perspective;
- Central perspective;
- Some of the Renaissance works reproduced by Reg ALCORN.

Exhibits can be downloaded here: http://www.irem.unilim.fr/les-maths-vues-par-un-artiste/convergences/renaissance/

Activity 2: Leonardo da Vinci

Main subject area: History, Architecture, Heritage

Other possible areas: Mathematics, physics

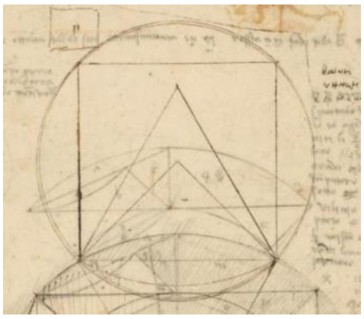
Age of students: From 10 to 15

Skills asked: To use tools of mathematics measures / knowledge of basics geometric shapes

A. Workshop A: Geometry in the notebooks of Leonardo da Vinci

The group from the IREM of Limoges was interested in "the geometry of Leonardo da Vinci's notebooks" to set up teaching sessions for students aged 10 and over around the construction of figures and the writing of construction programs.

Students discover, with great curiosity, the notes left by Leonardo da Vinci on the famous codex **atlanticus** to discover the secret of his constructions.



The aim is to work on the circle and the square by isolating elementary figures from the reasoned observation of complex figures drawn during the Renaissance.

Credits Wikimedia Common

Development of the activity:

The aim is to work on the circle and the square by isolating elementary figures from the reasoned observation of complex figures drawn during the Renaissance.

Students first study the geometric shapes that are present in the document. Then, taking the dimensions, they have to reproduce them by trial and error.

When they have succeeded, the teacher asks them to write a construction text.

Then, to go further, the students can reproduce the figure on computer software (such as Geogebra).

B. Workshop: Parachute of Leonard da Vinci: discovery and design

The Parachute of Leonardo da Vinci activity designed by Fermat Science intends to build a successful parachute through the observation of the fall of different parachutes. Students can study the properties of air in STEAM.

Development of the activity:

The teacher must first build several models of parachutes: with or without chimneys, with round or rectangular canopies, following the model of Leonardo Da Vinci...

He/she tests them in front of the students who note their observations in a table. What are the advantages and disadvantages of each one?

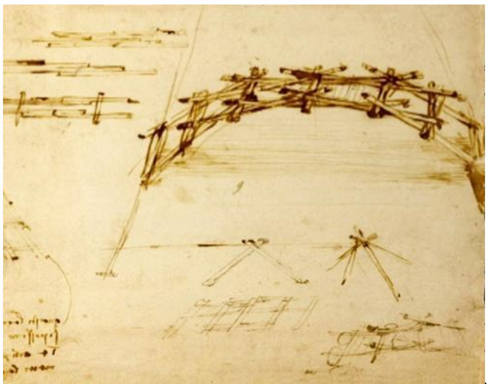
Next, they will focus on the parachute designed by Leonardo Da Vinci... They observe it, test it.

After this observation period, the students, with the help of their teachers, have to build this parachute by following a construction instruction.

Another workshop on this theme can be found at the **Manoir du Clos-Lucé**, Leonardo da Vinci's home in France.

C. Workshop: Play with a machine of Leonard de Vinci

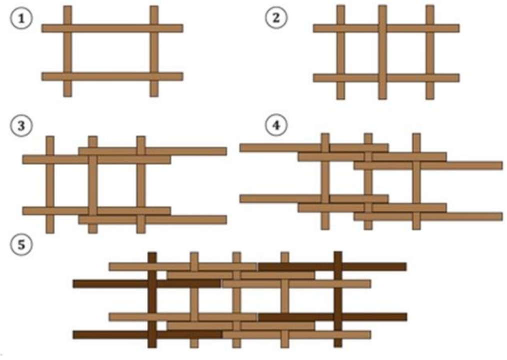
The Leonardo bridge consists of interconnected pieces of wood: the number and dimensions of the bridge elements are variable but determine the length and height of the bridge.



The Leonardo bridge consists of interconnected pieces of wood: the number and dimensions of the bridge elements are variable, but determine the length and height of the bridge. **Credits Wikimedia Common**

The purpose of the workshop is to get the students to build a bridge between two tables two meters apart. Several different materials can be provided. Work on forces in STEAM can be done. The objective is to build Leonardo da Vinci's bridge. For miniature bridges, small pieces of wood, e.g. popsicle sticks, can be used. Miniature bridges are easy to build alone or in pairs.

In the following diagram, we illustrate the construction of a bridge of at least 9 elements (6 in length and 3 in width).



Credits science.lu

Leonardo's bridge owes its stability solely to the friction between the individual embedded construction elements.

Example 6: Scientific discoveries and the Age of Enlightenment

Term Enlightenment presents the period of the 17th and 18th century which germinated on the foundations of Renaissance humanism, Reformation and Scientific revolution that was in peak at the start of the Enlightenment period. The period was defined by ideas cantered on the sovereignty of reason and evidence as primary sources of knowledge and advanced ideals such as liberty, progress, tolerance fraternity, constitutional government and separation of church and state. People became sceptic about the power and influence of the church and monarchy. The church started to lose power with the Peace of Westphalia (1648). The reduction of its influence continued with the American declaration of independence and culminated with the French revolution. The last two events also reduced the power of monarchy.

Enlightenment was a period of great opposites. While on one side there was growing support for individual liberties and freedoms, it was at the same time also a period of flourishing slavery that presented one of the most profitable economic activities of the period[14].

In the Slovenian educational system students learn about the period of Enlightenment in

8th grade (13 year old). Students learn about the general idea of the period, its representatives, its effects on Slovenian territory and its role in the history of the USA. In Britain, students learn about this period in key stage 3 (age between 11 and 14) and discuss similar topics as included in Slovenian curriculum[3,15].

The scientific revolution started more than a hundred years before the period of Enlightenment, which was a response or consequence following the Scientific revolution. This was the period when science started to take up the form that we know today. Basing on advancements of the Renaissance period, scientists started to abandon the deductive approach (explanation of set assumption) and took up the inductive one, combined with systematic experimentation. This way the period produced many new, important scientific discoveries causing the shift in the way people thought or perceived the world around them. Many authors consider the year 1543 as the beginning of the period. That was the year when Nicolas Copernicus published **De revolutionibus orbium coelestium** (On the Revolutions of the Heavenly Spheres). Copernicus, Kepler and Galileo were the main protagonists in the promotion of heliocentric theory. Breaking down and reshaping the fundamental understanding of the position of our planet in space they opened the niche for further research of general principles and phenomena. This niche was exploited by the likes of Descartes and Newton, who managed to provide a theoretical background to the heliocentric theory, explain basic principles in physics, define the concept of gravity and even determine the shape of Earth (geoid).
The period also brought advancements in other fields of science. Medicine improved a great deal with the popularization of anatomical view that was, with the more common use of dissection method broadening the knowledge about the human body. Robert Boyle laid the foundation for chemistry becoming independent from alchemy.

Other breakthroughs were happening also in the field of optics (first telescope by Galileo), electricity (research by Robert Boyle, Benjamin Franklin, etc.), mechanics (first steam machine), etc.

Students start to learn about advancements of Enlightenment in subjects such as Physics, Chemistry that are a part of the British curriculum in key stage 3. They get introduced to the scientific method already in year 3. In the Slovenian system students learn about Physics and Chemistry in 8th and 9th grade (age 12 - 14).

Activity 1: Chain reaction

Main subject area: Physics
Other possible areas: Mechanics
Age of students: From 9
Skills asked: A basic understanding of simple mechanics.

Development of the activity

Students should try to build long and complex chain reactions that would serve as an example for learning about forces, energy transfer, etc. They can use any kind of material available. They can help themselves with Lego® toys to engineer more complex links between the steps in the chain. The teacher should supervise the process and ensure that students apply different types of energy (potential, kinetic, elastic, chemical). The building process should be followed by testing, optimization and discussion.

Example of chain reaction
Photo: Primary Science Teaching Trust, n.d.

Activity 2: Falling objects

Main subject area: Physics
Other possible areas: /
Age of students: From 6 to 10
Skills asked: Basic skill of investigation and design

Development of the activity:

Students should find an elevated position and observe the difference in falling of different objects. They should attach a simple parachute to an object, drop it from the same spot and observe the difference in fall. Activity should be guided by a teacher who provides safety (appropriate spot and objects used) and theoretical background, discussed at the end of the experiment.

Activity 3: Static electricity and electric charge

Main subject area: Physics, electricity

Other possible areas: History

Age of students: From 10 to 14

Skills asked: Basic skills of observation and deductive thinking

Development of the activity:

- **Experiment 1: Static charge**

Students rub a plastic stick, hair comb, balloon, etc. against woolen cloth to produce static charge. They approach the stream of water coming out from the faucet (slow, steady flow) and observe what happens. They can experiment with a bigger or smaller object, multiple objects, stronger or weaker water flow, etc. The experiment is followed by a discussion and explanation of the phenomena.

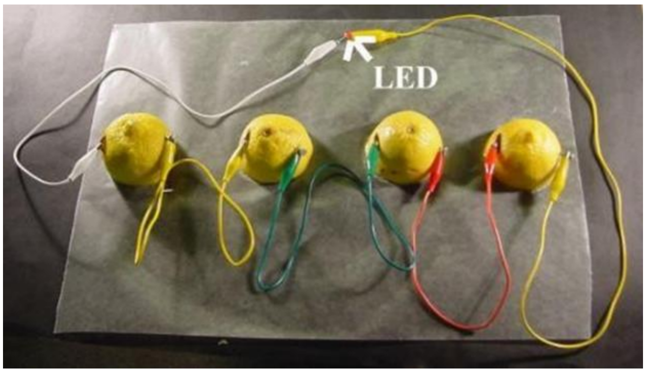
Charged balloon bending flow of water

Photo: The Daily Observer, 2014

- **Experiment 2: Lemon lamp**

Students stick a single copper and zinc nail on each side of 4 le lemons in the way that a copper nail of one lemon is connected with a zinc nail of the other and so on. When all 4 lemons are connected in line, we connect free zinc nail from one side and free copper nail from the other side of the string on a LED diode. It should start to shine.

Students should try to optimize the experiment with the use of different types of fruit or vegetables, number of links, etc. After the experiment students and teacher should discuss why light is shining, what is the purpose of each link, etc.



Example of lemon battery (Photo: Hila – Projects, n.d.)

Conclusion

In the previous sections, we presented a series of project-based activities. Each section includes some historical information to immerse the reader in the specific historical period. Then, specific step-by-step activities are described in order to help students collaboratively develop their skills and to understand the foundations of technology and the respective scientific and cultural principles.

The first part presented activities that relate to the Stone Age. The Stone Age differed among countries. However, people in different areas around the world developed various activities and cultural items using primitive techniques. The learning activities include, among others, the creation of jewelry and the understanding of the patterns in artefacts.

The next section presented some experiments which originally performed by famous Greek scientists. The section first introduces some of the most important historical figures of the respective time period. Through the experiments of Archimedes, the principles of Thales, and the measurements of Xenagoras, students can use principles of mathematics, physics and chemistry to calculate the density of objects and the height of buildings with handmade tools.

The Roman civilization is discussed next. Innovations like the roman numerals, the Julian calendar, and the invention of postal services are some of the accomplishments made during this historical period. Students are introduced to the Roman numerals, the construction of a road part and a lamp. All these activities are based on techniques developed by Romans.

Section 5 focuses on the Middle Ages or Medieval Period. Since the Middle Ages was also a period of religious devotion, the projects focus on cathedrals and their parts and the study of their architectural patterns.

The next section discusses the art and science techniques of the Renaissance. The use of Raphael's works on symmetry and the works of Leonard da Vinci are discussed. Students are guided on how to construct specific objects and through the activities they study the works of these artists.

Finally, the Age of Enlightenment is explored. Although the Age of Enlightenment was an intellectual and philosophical movement, important scientific discoveries have been made. Electricity and the laws of mechanics are some of the activities in which the students are involved in this section.

The key component of STEAM education is integration. Rather than teaching each subject independently, it is better to focus on comprehensive, project-based and inquiry-based courses, with an emphasis on interdisciplinary learning. This is consistent with the way we solve problems in the real world. That is the main focus of the activities presented in this chapter.

Part 3: And what about digital?

1. Digital in formal and non-formal Education

Today's formal educational environment is undergoing a series of transformations. On the one hand, the implementation of digital technologies increases the interaction dimensions of students. On the other hand, a change in methodological strategies encourage more participatory learning processes. The growing interest in crossing disciplines from art, science, technology, engineering, and mathematics fits together to increase learning possibilities (STEAM).
The Horizon report "NMC Horizon project"[6] (Educause, 2018), identifies and describes the higher education trends, challenges, and developments in educational technology likely to have an impact on learning, teaching, and creative inquiry.

Beyond the initial hopes placed in digital media, their use in schools places new demands on the students' brains. Tablets and computers overload the attention span of students, who find it difficult to distinguish between relevant and supplementary information.

Students will have to become more independent and competent in order to make use of the benefits offered by the new technologies. This will require more active and participatory teaching.

Digital devices in the school environment often become an unwieldy burden for teachers, as the curriculum has to be adapted and educational activities have to be prepared differently. The use of misused digital devices can lead to frustration that can end with true scientific and technological vocations, especially in young girls.

While formal education follows a specific curriculum, informal and non-formal education techniques don't. It is necessary to have a study plan and curriculum but in the case of the first it is more rigid, little changes are to be made to it since school administration and teachers resist in doing so. In the case of the second technique, there is a standard flexibility, which makes it more adaptable to student needs and interests. The focus is on giving students the ability to self-educate, to be curious, and follow their passion and interests.

[6] https://library.educause.edu/resources/2018/8/2018-nmc-horizon-report

In recent years we have witnessed the unstoppable awakening of what we call "maker culture" or more specifically of digital fabrication spaces and all the activities related to this concept. We can see that the common axis around which they revolve is the promotion, sharing and dissemination of projects dedicated to allowing children to "make" their developments related to technology or not, with an emphasis on design and creativity. Makerspaces are just spaces with some stuff where people can make stuff. They can look very different, like a traditional shop class, tech education class, more crafty, or fiber arts, or computer design focused, high tech, low tech- etcetera-. The purpose of the space is for people to have tools available to integrate hands-on learning.

In non-formal education, as it is developed by organizations that usually do not have rigid frameworks as in formal education, the use of digital devices appears as a natural part of the activities to be developed. Many of these activities are based on the use of other tools that require the use of computers or digital devices to be able to create or manage them.

The experience of Trànsit Projectes leads us to think of pedagogical activities as processes where technology is used as just another tool, and we emphasize the methodology of learning to learn.
Informal education programmes offer incredible opportunities for young people, allowing them to broaden their learning, immerse themselves in new and exciting environments and focus on their interests.

It seems that these environments are also ideal for the development of activities linked to the school curriculum or challenging work, as young people can spend a lot of time working on a single project or honing a set of skills. A general look at spaces that develop informal education activities, it is evident that, regardless of the educational setting, youth-oriented makerspaces and maker programmes are working through similar challenges.

While project-based work is a compelling means of assessing learning and skills, centres are still figuring out what facilitation methods are most effective, what tools to use and how best to capture the work, the work in progress, and the process of creation. These informal programmes bring groups of passionate trainers and peers together, determined to pave the way for young people to learn and grow.

Non-formal education allows for hands-on, kinesthetic, active learning. In their article, “Learning through making: Emerging and expanding designs for college classes” (Trust, Maloy & Edwards, 2017), Trust, Maloy and Edwards explain, “makerspaces can shift how learning happens (...) settings by allowing students to become active producers of knowledge rather than passive recipients of information. By encouraging creative thinking, design, and expression of ideas, making activities can increase student engagement, encourage problem solving and collaboration, and foster creativity”.

The process of learning by doing through hands-on activities, or kinesthetic learning, is often connected to “increased learning outcomes for all students”. Non formal educational spaces allow for this type of learning by harnessing the “intellectual playground concept to inspire deeper learning through deep questioning”. This provides a great opportunity for “just in time” learning, or learning tied to a concept.

This learning approach also works well with the “frustration aspect” and learning new ways of thinking and learning “frustration combined with motivation may act as a powerful agent for learning”. Just in time- not too early so the teacher doesn’t end up solving the problem, but not too late so frustration turns into disinterest.

2. Examples of STEAM / HERITAGE activities made with digital

Heritage and digital may sound like quite opposites, but there are interesting examples that show how digital tools can explain or reinterpret heritage, making it more alive than what we may read in books.

Hereunder you will find two examples that use digital technology -3D printing in both cases-. The first one reinterprets ancient traditional basketery techniques and the second one explains how specific things were made in the Roman era.

Example 1: Re:Making Africa - African handmade basketry combined with digital 3D printing[7]

This activity is a combination of workshop and dialogue in the framework of the activities around the exhibition Making Africa at the CCCB[8] in Barcelona. It was done in collaboration between Maker Convent, the CCCB in Barcelona, and the architect Amir Gazit[9].

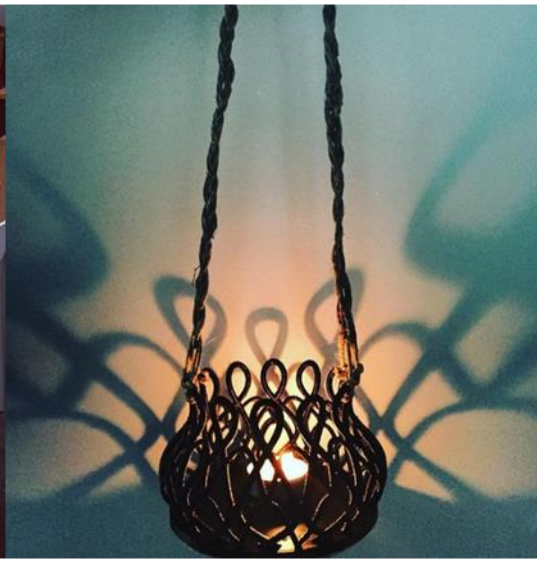
In Africa there is an emerging maker creation that uses new rapid prototyping tools to solve local problems from a creative perspective. One of the most characteristic features of the African continent is the use and the natural combination that its inhabitants make of the most ancient traditions with the most current technologies.

The workshop is conceived as an experiment in which we will combine traditional African basketry techniques with current methods of digital fabrication. The idea was to design, model, and 3D print, and then weave a basket, combining different geometries, materials, textures, patterns and colours.

7 https://conventagusti.com/maker/remaking-africa-artesania-digital/

8 http://www.cccb.org/ca/exposicions/fitxa/making-africa/213052

9 https://www.amirgazit.net/

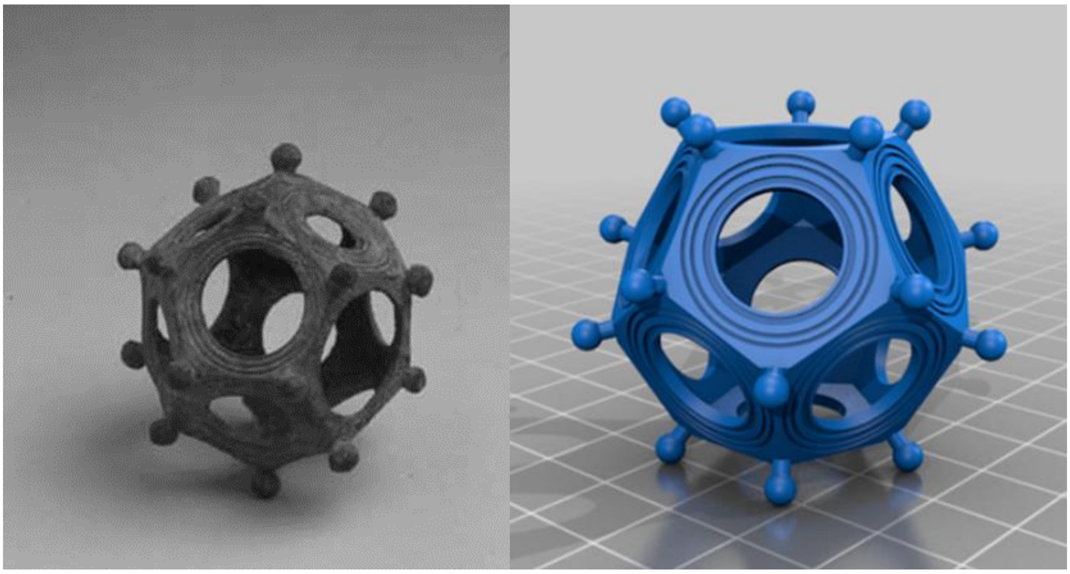


Example 2: Embroidery in Roman Empire - How we make gloves with roman technology

The Roman dodecahedron is an object that has the most diverse (and even fanciful) interpretations of its use (Guillier et al., 2008, p. 269-289). Some of the hypotheses are: surveying instruments, aspersors, lamps, jewellers' jigs, measures, linings for goupillons, gauges for monetary blanks, toys or bilboquets, sceptre pommels, game dice, candlesticks with multiple gauges, masterpieces of mastery or even elements illustrating Pythagorean theories.

This object is 59 mm high (laid down) but only 48 to 52 mm from front to back; its maximum diameter is 74 mm and it weighs 81 gr. It has twelve pentagonal faces with 21 mm edges, ten of which have a circular opening, highlighted by concentric circles engraved in the metal. These openings vary in diameter from 10.5 to 22 mm. The other two faces, without concentric circles, have oval openings (21x26 mm), they are placed in opposition on the object, possibly materializing a "top" and a "bottom". Each vertex, at the junction of three faces, is decorated with a small ball of about 5 to 6 mm in diameter, welded to the body of the dodecahedron.

This object from the history of the Roman Empire has been reproduced in 3D printing[10], and the activity explores one of the possible uses of this incredible object: knitting. This video shows how: https://www.youtube.com/watch?v=76AvV601yJ0.



10 https://www.thingiverse.com/thing:4323797

Part 4: Being an actor of STEAM

1. Who can teach STEAM?

"The role of the teacher is to create the conditions for invention rather than provide ready-made knowledge". Seymour Papert

According to trend analysts, more than 65% of today's students will grow up with careers that do not yet exist. Today, more than ever, it is crucial to prepare our young people to be ready for the future and to have the confidence to invent the world they want to live in. To this end, many schools are changing their curricula and are increasingly looking to teach key 21st-century skills, such as science, technology, engineering, art and mathematics (STEAM), in a cross-curricular way to their students.

Over the past six years, STEAM and coding have been popping up in both formal and non-formal educational settings, where they have found a ground to develop multiple educational activities. With STEAM content we can help educators find the best strategies to scale their programs to make them closer to the students' reality.

While we continue to navigate an uncertain future, one thing we can count on is that the work of tomorrow will be tied intrinsically to proficiency in STEAM fields. Just look at how quickly STEAM is taking hold.

Why is it important that all of our students have the opportunity to participate in STEAM education?

An important point to make here is that the goal of STEAM education is not to turn every student into a programmer or an engineer. The world needs diversity, the interests of the students are diverse after all. Instead, the goal is to give every student an opportunity to learn about the technologies they use, adopt a series of new skills and competences, and more importantly, to help them identify themselves as innovators and changemakers with critical thinking that can take active roles in inventing solutions for problems they care about.

Today’s world is highly interactive; technology is integrated with all aspects of our lives, from our social interactions to the most private aspects of our life. To make sense of this new world, our students need to be comfortable with technology, have a good understanding of how they work, and have ideas of how to innovate in a tech field.

By adding art into STEM education (STEM + A = STEAM), not only are we making the program relatable to more students, both girls and boys, but we are also giving them the opportunity to engage in creativity and to express themselves through their projects while tinkering, making, sharing, and playing.

One of the major differences between formal and non-formal education is the proximity between the educational environment and the content of the activity. One of the educational methodologies that are being used the most, especially in spaces where technology and education intersect, such as makerspaces, is Vygotsky scaffolding.

It may sound like a construction term, but Vygotsky scaffolding and the related concept of the zone of proximal development are teaching methods that can help students learn much more information much more quickly than they would with traditional teaching.

The theory behind pedagogical scaffolding is that, compared to traditional learning, students learn more when, in an environment, they collaborate with other students and other types of content, and who have a wider range of skills and knowledge than the student does at the time. These become the "scaffolding" that helps the learner to expand their learning boundaries and learn more than they would be able to on their own. Thus increasing their autonomy.

Vygotsky's scaffolding is part of the educational concept "zone of proximal development" or ZPD. The ZPD is the set of skills or knowledge that a learner cannot perform on his or her own, but can with the help or guidance of others. It is the skill level that is just above where the learner is at the moment.

As we move into STEAM education, collaborative work is one aspect to take into account. STEAM educators or facilitators should co-operate with their students by removing the standard, traditional role as the central figure in the education process (with all the answers) and replacing it with a model of education where the students take the central role as “educators” or searchers of knowledge, while at the same time deepening their knowledge about different subjects.

So, who can teach STEAM?

There is no need for very specific or expert profiles to teach STEAM. Neither very technical nor pedagogical. Hybrid profiles sensitive to technology and pedagogy is needed.

As said before, we must take care of the scaffolding of learning, we must take care of the space where activities will take place, we have to be clear about the results regarding the learning process that we are expecting, and we have to be respectful of differences and deviations that might appear during the activity, not trying to teach something in a top-down logic, but accompanying learners in their learning processes.

The person teaching STEAM must work to facilitate the results to be produced, combining the different elements needed in the design of the activity.

2. How to teach it? When and where can the STEAM method be implemented?

Education is an ecosystem that is designed taking into account an environment, learners, resources, teachers or facilitators, tools..., and when we talk about STEAM activities, we have to think about including; open-source resources, affordable electronics and technologies, crowdsourcing, and participatory culture, a focus on STEAM education, access to information and DiWO methodologies for inclusion.

The environment where the activity takes place can become an aid to the process and motivate expression, creation and communication. A friendly space allows people to explore. Here, we will give some advice on how to create such a space.

An educational-making activity or a STEAM activity is one that brings together creative and innovative processes with an educational perspective, emphasizing practical learning during the process, and includes technology in all or some part of the process. It has long been argued that children and youth can learn by playing and building with interesting tools and materials (Montessori, 1912).

These are activities that work under a framework of cooperation, respect for one another, teamwork, inclusion, promotion of creativity, learning by doing and innovation.

Doing and creativity are not new concepts, but focusing on learning by doing has introduced a new type of practical pedagogy. A pedagogy that fosters communication, community, and collaboration (a DiT mentality "Do it Together"), distributed learning, crossing boundaries, and receptive and flexible teaching practices.

Physical creations can also enable social engagement through a shared endeavor. This can bring more- and less-experienced participants together around a common task—a configuration that often proves fruitful for learning (Lave & Wenger, 1991; Vygotsky, 1978).

When designing a STEAM activity, special care must be taken in certain areas:

- **Facilitation:** Every activity with learners must have facilitators that encourage the activity to run and achieve its pre-defined goals. The role of the facilitator is as important as any other tool. He or she is a guide, knows where the activity starts and where it is intended to go but does not know what happens during the process, offering that margin of freedom.
- **Environment:** Activities are carried out in spaces, but sometimes these spaces are not well-equipped to receive them. Space is important because it helps the activity to develop. We have to design the space with the activity. We have to mark out different spaces for working together, or working with the computer or

tools, spaces where to get dirty... and also identify and locate the materials well, those that are fungible and those that are not fungible.

- **Materials | Resources:** Choosing the materials to develop the activity is key. Working with recycled, reused materials and doing so in a sustainable way with the environment adds value. Aesthetics are relative when it comes to creativity and hands-on learning.
    - Expendable material: Recycled materials help expand creativity, respect the environment and improve experimentation skills.
    - Non-expendable material: The non-expendable materials are the ones suitable for activity and that fit the fungible materials that will be used.
- **Participants:** we must take into account who our participants are. Activities for all diversity of children or young people are not the same as for adults or the elderly. In any case, people are the key element of every workshop.
- **Contents:** the workshop activity step by step. Pedagogical program with clear aims and detailed development.
- **Communication:** communication plan, prior, during and after the activity. Broadcast material, pictures, videos. Have signed authorisation for the use of the images by the participants.
- **Documentation:** who will take the record of the activity, videos, text, and photos, and in what formats.

For more detailed information, please check the Methodology for Educational Making Activities here (http://m4inclusion.com/IO-1MethodologyForEducationalMakingActivities.pdf), an outcome of the European Project Makers for Inclusion, co-financed by the Erasmus+ Programme.

Part 5: A beneficial approach for all: inclusion

One of the main concepts to consider in order to achieve the objective of the STEAMbuilders project is to include all types of learners through innovative and engaging materials. The inclusion of all learners is essential for this innovative way of promoting STEAM education to work efficiently. In this part of the guide, we will have an overview of the students to pay special attention to, different types of Specific Learning Disorders, the challenges they may encounter and potential ways to adapt materials to make them inclusive.

1. Objective of the project in terms of inclusion

One of the main aims of this project is to make sure no one is left behind and that all students feel engaged and motivated to get involved in STEAM subjects. Students who are most at risk of dropping off the STEAM subject, are girls, students with SLDs and students with a migrant background.

2. What is Inclusion?

Definition of inclusion:

Inclusion is about making learning and materials flexible, accessible, and understandable to all learners. It is about constantly rethinking the teaching process so that all students feel included in the process. The idea behind “inclusion design” is to go back to the original design of the process and to build it in the most inclusive and efficient way for all.

Categories of students susceptible to falling behind or dropping out of STEAM subjects:

- Girls and students from difficult backgrounds

Girls and students from difficult backgrounds are at higher risk of dropping out of a STEAM subject. In this project, we will use heritage and history to promote STEAM education, through which we can present positive role models to which those categories of students can relate to. This can be a powerful motivator, confidence booster, and an inspiration that it is possible for them to succeed as well.

- Students with Specific Learning Disorders

Specific Learning Disorders are permanent conditions that affect the learning process of someone. They have a **neurobiological cause** that affects the way the brain processes information: how it receives, integrates, retains, and expresses information. It can thus disturb the **cognitive development of a learning ability** but is in no way stemming from a physical impairment such as a visual or hearing impairment, a motor disability, or intellectual disability. It is also not due to an emotional disturbance, nor a disadvantage of the economic, environmental, or cultural nature.

Presentation of the Different Specific Learning Disorders.

Each SLD generates their own set of challenges that impact students school life:

- **Dyslexia** causes difficulties in reading and language-based processing skills. This is the most common disorder and it is not rare to have it overlap with another one (phenomenon of co-occurrence). It can affect reading fluency, decoding, reading comprehension, recall, writing, spelling, and sometimes speech.
- **Dysgraphia** affects a person's handwriting ability and fine motor skills. It will often show as illegible handwriting. It can also lead to difficulties with: remembering specific orthographic combinations, spelling, spatial planning on paper, sequencing sentences into words, composing writing, or thinking and writing at the same time.
- **Dyscalculia** generally translates in difficulties with understanding math symbols, counting, memorizing, and organizing numbers, thus hindering them in calculus or abstract mathematical operations.
- **Dysphasia** typically manifests into difficulties speaking and understanding spoken words. This leads to challenges with oral exercises and presentations. It can translate into difficulty to "sequence sentences into words" when heard.
- **Dyspraxia** will cause issues with coordination, movement, language, and speech. It typically affects fine motor skills and muscle control (including eye control), which leads to problems with movement and coordination, especially hand-eye movements, language, and speech.

3. Why is the inclusive approach beneficial?

Diversity is a source of enrichment. Students that are not adapted to classical teaching methods are not any less intelligent than those who “fit the mold”. Nurturing their complementing qualities and allowing them to access education is beneficial for the whole classroom.

- ☐ Benefits for the students that need to be included

Being included allows them to develop skills that they will need to thrive in their future professional and personal life. They will be better equipped to face the challenges of a society that is not adapted to their needs and they will be able to navigate through life more comfortably.

- ☐ Benefits for the other students

The inclusion of different profiles will broaden their horizon and will help them learn tolerance. This will also allow them to realize that one person doesn’t need to succeed at everything to be successful and that teamwork is one of the best tools you can have to achieve any given goal.

- ☐ Benefits for teachers

Inclusion of all profiles will lower the number of underachieving students and allow for a smoother and more efficient teaching process. By helping all students to follow, the rhythm of the class will be steadier, and the students will be less likely to fall behind.

- ☐ Benefits for society in general

People with SLDs might not display the usual “professional strengths” sought-after by recruiters, but they also have the potential to develop complimentary competences that are just as useful and essential. For example, they tend to be hardworking, to visualise things in 3D, to see links between concepts, and they are big picture oriented. Including everyone results in a more diversified pool of neurodiversity with a wider set of skills and competences and will give us a broader array of potential solutions to the problems of tomorrow.

4. Inclusion in STEAM education

Some basic tips and adaptations can be made and will go a long way into making any kind of class work more inclusive.

Structure: starting the lesson with an explicit explanation of the activity, a clear set of guidelines, and subdividing the tasks into small steps if necessary is advised. The use of visual elements to illustrate the concepts and bullet points to clearly structure processes is advised. Make sure to give enough time for each task and that all students understand the task beforehand.

Environment: should be quiet, but with enough multisensory stimuli to allow for in-depth learning. Space should be uncluttered and not overcrowded, to help with the students' spatial orientation and with their focus. It is also advised to avoid the necessity of long eye movement and to give special support to learners with tasks involving space management.

Tasks: multiple types of short exercises will help train the students to process different types of situations, by having them focus on one task at a time. It is better to focus on logic-based exercises rather than memory-based ones.

To reduce the instances of double-task mode, try to reduce the number of tasks requiring the use of fine-motor-skills, such as writing tasks, and to avoid difficult manipulations. This way, students will concentrate on the content of the lessons rather than on executing a supporting task.

Written materials: The formatting of written materials can be a source of challenge, and as such the text should be aligned on the left, in an adapted font for written guidelines such as Arial, Century Gothic or OpenDys with a spacing of **1,5 in between the lines**, in a font size that ranges between **12 and 14**. The use of paragraphs to break down the text into more manageable units with short, clear sentences is also recommended. The use of subtitles, colour (but be consistent with your colour codes) and bullet points can help with that.

The written materials should be **printed on one side** of the paper only, with a paper that is of an off-white pastel background to avoid having a stark contrast with the ink.

One crucial point in dealing with a classroom that has students with SLD is to raise the **awareness** of what is happening, why, and how. This can go a long way in avoiding discrimination and stereotypes in the classroom. Transparent communication and an open attitude are key to achieve inclusive education.

History may be a great tool to show **role models**, famous STEAM professionals who would have been part of the groups that are falling behind in STEM today and are the definite proof that it is possible for them to succeed in the STEAM field as well. Seeing someone they can relate to being represented as successful can have a real impact on the psyche of the student. But History should always be presented in context as well, so this must be addressed with care and objectively as well.

5. Conclusion

As we saw, including all students is a beneficial approach for all students, but also for the teacher and society in general, as it will elevate the whole group. In this part, we focused mostly on practical adaptations in the classroom in order to include all students, but one should not forget the adaptations that are more subtle and that we need to pay attention to as well. As we saw through time, education is key to the elevation of society. If we want to have diversified and educated people, then all of them need to be included in the process. In the long run, it will provide more complementary skills' sets to meet the future challenges lying ahead and fewer societal problems as tolerance will be a social staple of our mindset.

Conclusion

The pedagogical guide is the first written output of STEAMBuilders, an Erasmus+ project – a collaboration between Belgium, Cyprus, Denmark, France, Greece, Slovenia and Spain. STEAMBuilders is a project created based on Pisa studies from 2018, which showed that primary school students underperformed in mathematics and science. Compared with trend analysis studies showing that more than 65% of today's students grow up with a career that does not yet exist. Today, more than ever, it is essential to prepare our young people for the future and have the confidence to invent the world in which they want to live. The STEM area has its roots back in the era of the space race between the United States and the Soviet Union in the 1950s. The term STEM stands for Science, Technology, Engineering and Mathematics. Stem teaching involves interdisciplinary teaching between 2 of the professional areas associated with real-world issues. In other words, it is the learning of STEM topics using a unified method; a method that provides practical and at the same time significant learning experiences.

By adding art into STEM education (STEM + A =STEAM), not only are we making the program relatable to more students, both girls and boys, but we are also giving them the opportunity to engage in creativity and to express themselves through their projects while tinkering, making, sharing, and playing.

While STEM focuses on scientific topics, STEAM examines the same topics, but rather through analysis and problem-based learning methods used in a creative procedure. That is, different students work together to generate a visually interesting product based on the central understanding of the concept of STEM.

An educational activity or a STEAM activity is an activity that brings together creative and innovative processes with an educational perspective that emphasizes hands-on learning during the process and includes technology throughout or part of the process. It has long been argued that children and adolescents can learn by playing and building with interesting tools and materials (Montessori, 1912). This method is important because education is under pressure to respond to a changing world. The earlier the students are open to STEAM concepts, the better.

In a rapidly changing world, workplaces in the future will necessarily want all young people regardless of gender to be proficient in STEAM. This is not only to prepare students for jobs, but also what these experiences give students; helping them grow up to be independent, skilled and intellectually curious and STEAM-based learning aims to help the student develop the skills needed. Thus, education is no longer only about teaching specific skills; it is also about preparing students for the future. Students need to be more independent and competent in order to take advantage of the benefits of the new technologies. This will require more active and participatory education.

Today's formal educational environment is undergoing several changes. On the one hand, the implementation of digital technologies increase students' interaction dimensions. On the other hand, a change in methodological strategies encourages more participatory learning processes.

Today's world is very interactive; technology is integrated with every aspect of our lives, from our social interactions to the most private aspects of our lives. To make sense of this new world, our students need to be comfortable with technology, have a good understanding of how they work, and have ideas on how to innovate in a tech field.

While formal education follows a specific curriculum, informal and non-formal training techniques do not. The focus is on giving students the opportunity to self-educate, to be curious and to follow their passion and interests. Non-formal training allows for practical, kinesthetic, active learning.

Our experience leads us to point to pedagogical activities as processes where technology is used as just another tool and we emphasize the learning method to learn.

The learning process of performing practical activities or kinetic learning is often associated with "increased learning outcomes for all students". Non-formal training spaces allow for this type of learning by leveraging the concept of "intellectual playground with the aim of inspiring deeper learning through deep interrogation". This provides a great opportunity for "just in time" learning, or learning tied to a concept.

This guide had presented 19 activities that relate to the Stone Age, Ancient Greece, Roman Empire, the Age of Cathedrals, Renaissance, and the Age of Enlightenment. That way, students will get acquittanced with various historical periods, the science and scientists, the culture of each period and through hands-on activities will gain a better understanding of the physical world and the natural sciences.

As we move into STEAM education, collaborative work is one aspect to consider. STEAM educators or facilitators should co-operate with their students by removing the standard, traditional role as central figure in the education process (with all the answers) and replacing it with a model of education where students take the central role as "educators" or searchers of knowledge, while at the same time deepening their knowledge about different subjects.

One of the most important concepts to consider in order to achieve the objective of the STEAM Builders project is to involve all types of students through innovative and engaging materials.

It is about constantly rethinking the teaching process so that all students feel involved in the process.

In this project, we will use heritage and history to promote STEAM education through which we can present positive role models that these categories of students can relate to. Diversity is a source of enrichment. Students who are not adapted to classical teaching methods are no less intelligent than those who "fit the mold". STEAM-based teaching using the right methods can be of particular use to students with special learning disabilities, for example. Dyslexia, Dyspraxia, Dyslexia and Dysgraphia. Maybe STEAM teaching can even help to open the eyes for all people, regardless of diagnoses, to meet as the person they are!

If we want to have diversified and educated people, they all need to be involved in the process. In the long run, it will provide more complementary skills to meet the future challenges ahead and fewer societal problems, as tolerance will be a social integral part of our thinking. As we continue to navigate an uncertain future, one thing we can count on is that tomorrow's work itself will, for sure, be tied to a skill in STEAM areas.

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