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STEAM BUILDERS

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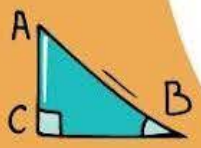

Non-formal Education in STEAMBooklet

5th High School of Agrinio
5ο Γενικό Λύκειο Αγρινίου
CITIZENS IN POWER
FERMAT SCIENCE
Une autre idée des maths
LogoPsyCom
Trànsit Projectes
VEST-HIMMERLANDS MUSEUM

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Chapter 1: Experience is knowledge

1. Introduction to non-formal approach, what is it?

1.1.1. Definition and different types of education

Credits: @timmossholder

How can we distinguish between formal education, informal education, and non-formal education? These fields demonstrate the ways in which education is perceived. Are they complementary, do they have common objectives? Does each mode of education correspond to a moment in life or are we learning throughout life? Let us look at the definitions of these learning methods to understand what distinguishes each of these approaches, bearing in mind that we will come back to these definitions in more detail in Chapter 2 of this booklet.

Formal education: School or university education, provided in educational institutions by permanent teachers, within the framework of study programmes.

Formal education refers to the hierarchically structured education system. Education is chronologically graded, full-time and composed of a variety of technical and vocational training programmes and institutions.

Non-formal education (NFE): Education is organised, for an identified audience with identifiable educational objectives, for a normally voluntary audience. NFE can take place both inside and outside educational institutions and can be aimed

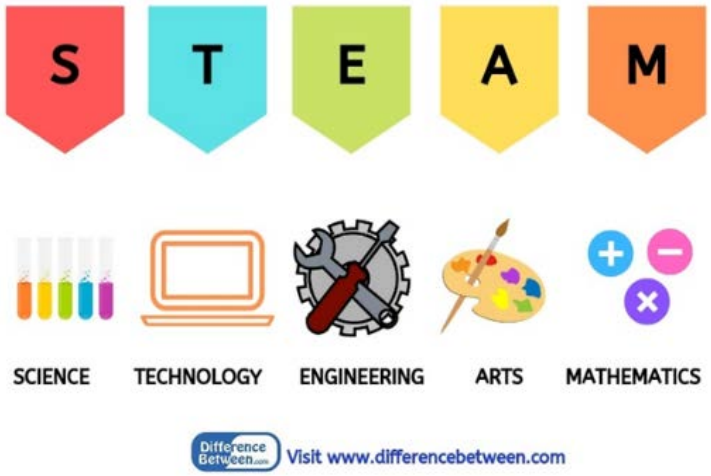
at people of all ages. NFE programmes do not necessarily conform to the school system. They may be of varying lengths and may or may not be sanctioned by a certificate of learning achievement.

Informal education: This is diffuse education in which everyone acquires attitudes, values, skills and knowledge from daily experience and at random from the educational influences and resources of his or her environment. This learning is not subject to strict programming and takes place outside organised institutions and structures. Audiences and knowledge are not established a priori but can be identified most often a posteriori, in particular through the validation of prior learning.

1.1.2. What is a non-formal approach of teaching STEAM?

Let us look at the non-formal approach to STEAM education. What does this mean in practice?

Let us briefly remind you what STEAM is: it is an approach to learning that uses Science, Technology, Engineering, the Arts and Mathematics as access points for guiding student inquiry, dialogue, and critical thinking.



We have also seen in the STEAMBuilders Methodological Guide that one of the main aims of the STEAM method is to create a functional and customisable programme for all types of students, based on natural learning methods. Science

and Technology are interpreted through Engineering and the Arts, all understood with the elements of Mathematics.

It is therefore logical to use NFE in the teaching of this approach. This education, in this context, is based particularly on manipulation, on learning through experimentation. A project based on Robotics is an excellent example: the principle is to work - through robotics - on solving a challenge by jointly addressing technical, scientific, ethical and creative dimensions.

In this way, the student realises that in order to solve a problem, he or she will need, for example, notions of Science, Mathematics, Programming and written and/or artistic expression to report on his or her work. And all this while manipulating!


Source: @robowunderkind

This approach can also be made through visits to unconventional places, for example the Scandinavian concept of **udeskole** (which means "open air school") which has been described in a Norwegian context by Jordet, in a Swedish context by Dahlgren and Szczepanski and in a Danish context by Mygind.

Udeskole is targeted at children aged 7-16 and is characterised by regular obligatory educational activities outside school, e.g. one day a week. Udeskole can take place in natural and cultural settings, i.e. forests, parks, local communities, factories, farms, galleries, theatres, etc.

Credits: Children And Nature

1.1.3. Advantages of introducing a non-formal approach in STEAM didactics

Formal education is a necessary part of learning and helps personal growth, especially in our early school years, but it does not necessarily meet all the objectives in STEAM learning. This is where the non-formal approach reveals its potential, offering learning adapted to individual needs, whatever our age, background, or interests.

Indeed, this approach to education, where the participant takes an active role and is directly involved in the learning process, is not without consequences for the content of what is transmitted. Irrespective of the content of the training itself, the knowledge, and skills it is supposed to provide, the NFE method allows for both autonomy and participation. In this context, mutual aid is essential, as we shall see later. It is based on the child's spontaneous ability to exchange with others, an innate tendency that must be developed for the greater benefit of all.

Credits: Fermat Science

Based on a voluntary approach, this approach to education places learners in a situation of greater self-knowledge, teaches them to analyse themselves, to take stock of their abilities and skills, while at the same time getting them used to taking initiatives within a group and to measuring their impact. It is this participatory approach that makes NFE a great school for citizenship. There are no imposed standards, no obligation to respond within a limited time and no sanctions. The personal evolution of each person is respected. The challenge is not to get a good grade, to please the teacher or parents, but to take pleasure in the discovery and therefore to have the satisfaction of overcoming an obstacle and gaining access to knowledge.

Furthermore, being actively involved in their own education enables learners to be engaged and motivated, which is one of the main drivers for better student outcomes. Indeed, the level of motivation to learn is an important determinant of student achievement.

Indeed, a positive attitude towards science subjects and confidence in learning STEAM go hand in hand with better performance in these subjects. Motivation, in these various aspects, influences decisions about participation in school streams or study programmes in which STEAM is an important subject. These attitudes can shape students' post-secondary education and career choices.

2. Tools for learning in non-formal education

Understanding what the notion of non-formal methods actually entails is not simple. In fact, it would be much easier to try to understand these methods through their characteristics, bearing in mind that they can be concisely classified into four sub-categories: communication methods, based on interaction, dialogue and mediation; activity-oriented methods, based on experience, practice and experimentation; society-oriented methods, based on partnership, teamwork, and networking; and self-directed methods, based on creativity, discovery and responsibility.

Therefore, if the teacher intends to use one or even a combination of non-formal methods based on the above categories in order to facilitate the learning process of a STEAM-related concept, they should firstly design a comprehensive educational tool that will be basically composed of non-formal methods.

Therefore, we consider it important to explain what a learning tool is, how to recognise it and what criteria a tool should meet.

1.2.1 What's a tool for learning

A learning tool is an educational mean, an instrument, used by teachers to enable learning in a particular area of knowledge.

A learning tool makes a training course more effective and promotes exchanges with and between learners. Teaching aids must be adapted and chosen according to the teaching project.

They have different objectives:

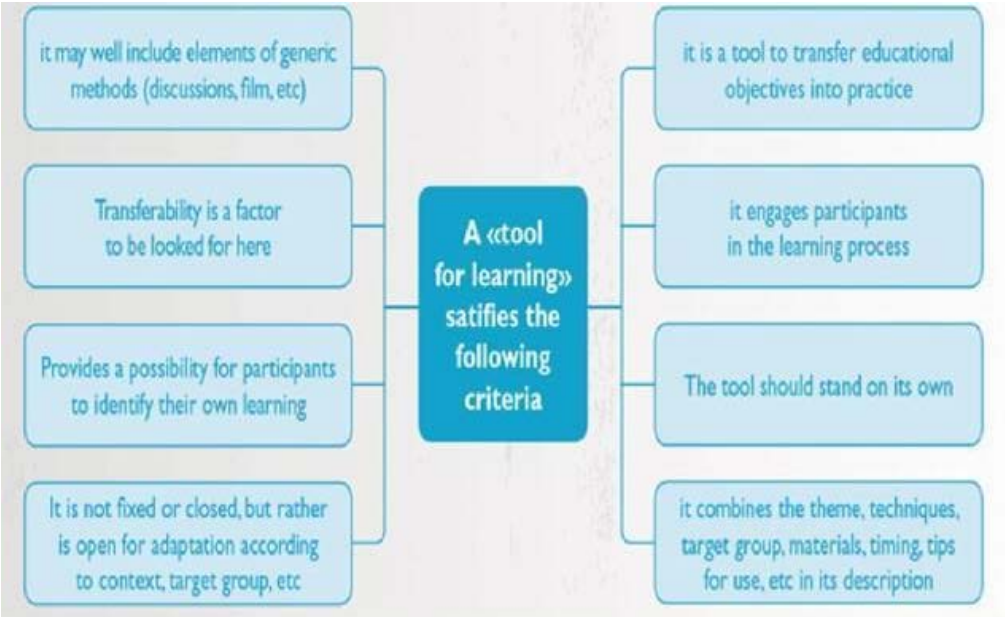
- To inform;
- To acquire skills;
- Transforming representations.

An educational tool must be sufficiently modifiable and open, so that it can be used in different contexts, always giving the possibility to be adapted, combined and developed, according to the real conditions and the environment in which it is applied. This inherent characteristic of a tool - which is at the same time one of its fundamental objectives - is called **transferability**.

Most often, a learning tool is associated with a physical object or material. There are many criteria to consider when choosing a teaching aid.

1.2.2 Criteria for choosing an educational tool

The criteria or principles to which a tool must adhere are presented in the following diagram:



According to the diagram, a good learning tool in NFE should combine all eight criteria at the same time. In addition, some other useful points that need to be considered in the process of constructing an educational tool are summarised below. An educational tool:

- Must make sense;
- Must be written in a precise language and must deliver clear messages;
- Be adapted to the audience concerned: children, teenagers, adults, seniors, people with disabilities (see more in chapter 6);

- Be adapted to the context: place and time of possible preparation and training time;
- Should be an invitation to travel in all possible spaces through the paths of imagination and creativity;
- Should serve the idea of learning by doing.

1.2.3 Importance of assistance / aids / collaboration

A tool should not be used alone. Children like to learn as long as they are accompanied. According to Céline Alvarez: « the child has extremely powerful learning software but needs … the guidance of someone more advanced than him, who can indicate the important elements to observe and take into account in order to evolve ».

Teaching methods determine the nature of the interactions that take place in a classroom or mediation workshop, including those between the adult and a group of children, between the adult and each individual child, or between small groups of children.

The adult must encourage positive exchanges and understanding between children and set the limits of a structuring and reassuring framework so that each child can develop the sense of mutual help that is natural from a very young age.

Credits: Fermat Science

An example of these positive exchanges is **the bâtiTmaths event** in France, proposed by Fermat Science: 16-year-old students from a vocational school are trained to give mathematical workshops related to their professional specialities to 14-year-old students from

general secondary school. The older ones become actors. The feedback is all very positive.

3. Examples of non-formal tools for learning related to STEAM

There are many non-formal learning tools for children related to STEAM that allow better learning.

Whether it is theoretical or playful, each of them allows a better memorization and thus, to be more at ease with learning.

Let us not forget that an educational tool combines non-formal methods which can be communication-based, activity-based, social and/or autonomy-based methods. Thus, a STEAM-related learning tool can be a simulation exercise such as a role-playing game about life in the prehistoric era (How did the Stone Age Man live?), a workshop that fosters creativity and develops imaginary or fictitious characteristics (Painting stained-glass windows as in the Middle Ages), an activity that takes place outdoors or an activity that invokes experiential processes and facts derived from everyday life.

An educational tool can be a game (ancient games such as latronculus or knuckles), an interactive video on the spectacular inventions of Leonardo da Vinci. But it can also be a story, a discussion, a fabrication, a film, a photo or image with text, or even a combination of some (or all) of the above, always given in a logical order and in a way that actually facilitates the learning experience.

Chapter 2: Two Sides of a coin

1. What is the difference between formal and non-formal education?

As seen in Chapter 1, when we think about learning and teaching methods applied to schools, most of us immediately think of formal education. One can characterize it as a disciplined, organised, and structured system that has been used in the teaching process of schools since always (*What Is Formal Education?*, 2019). The first concept of formal education can be seen just after 500 A.D. in Ancient Greece, Ancient Rome, and Ancient Egypt (Broome, 2018). Speech was the major mechanism by which individuals learnt and passed on their knowledge, making accurate memorisation a crucial talent. Ancient Greek education, though, stood out because of its diversity. The Greeks were the first to establish what we now refer to as primary and secondary schools.

Source: https://www.givemehistory.com/education-in-ancient-egypt

Yet, the concept and practice of this worldwide obligatory and public education developed slowly in Europe, starting from the early 16th century into the 19th century (Huston, 2008). Formal learning is considered a more consistent methodology, as all learners receive the same standard of training. It is a classroom-based approach, where learning and teaching come from educational

material such as books (What Is Formal Education?, 2019). It is a highly recognisable educational approach since a great percentage of students around the world spend the developmental years of their lives within a schooling system that uses formal education. The students are obligated to be present in the classroom at a specific time, work through the curriculum, and achieve all goals which the school/institution has set ("What Is Formal Learning?," 2016). Formal education can be further acknowledged as the most important source of students' educational development in most countries (Kurtz-Costes, 2001).

The table below portrays the characteristics of formal compared to NFE:

Formal Education	**Non-Formal Education**
School is engaged	Long process
Structured hierarchically	Learning from experience
Uniform, and full-time	Full-time or Part-time
Subject-oriented and syllabus	Syllabus & timetable is adjustable
Certification/Degree	Certificate not necessary
Planned and deliberate	No-age limit

This chapter will emphasize the significant roles of both sides of the coin, seeking to compensate for the deficiencies of formal education through the use of NFE at schools/institutions (Binazzi, 2016). Within formal education, students "collect" knowledge from qualified educators who offer assessments to ensure their advancement to the next learning stage. While several students benefit from this educational approach, there are a few students who may be bored due to the generally– long delay of the academic session to move to the next level ("Types of Education," 2019). Formal education is often static and is limited to a duration of time – students need to gain knowledge in the specific time provided – from the teaching and learning material. Oppositely, NFE is continued for a lifetime and can be considered a flexible educational method.

The significance of formal and non-formal education through a teacher's experience:

Debono, a sixth-form teacher in Malta, believes that when utilizing NFE, both the educator and the students are on an equal level. It is not about passing on the information but rather about promoting someone's further learning. Additionally, special attention is given to empowering the learners in accomplishing more, and each student transports their individual experiences in the classroom. These elements have to be considered but also valued in the learning process (Spiteri, 2016). Tips for integrating non-formal methods in your everyday teaching:

1. Try to open yours and your students' minds to all non-formal opportunities. These can be found everywhere, not just the traditional learning classroom.
2. Get your students to think about the information they have been given/taught. Information can be found anywhere in the world, but it is not always precise. Thus, encourage students to double-check and challenge the information given, with critical thinking and problem-solving skills.
3. Ask questions and start a discussion. Make learning an engaging, 'two-way' process, rather than just passing your notes to them, moving to a more "dialogue-based teaching".
4. NFE is about offering each student the chance to form their own views and thoughts, and to respect others' opinion, regardless of it being in the boundaries of formal education or not. According to Debono, "If you respect a student's opinion and their right to pass on their knowledge to you as well as vice versa, then you are opening your classroom up to so much more potential for sharing ideas and non-formal learning" (Spiteri, 2016).

2. Why are both “sides of a coin” important?

Source:https://epale.ec.europa.eu/en/blog/bridging-formal-and-non-formal-professionalisation-and-capacity-building-adult-education

The effect and success of NFE can be calculated in terms of its extensive worldwide growth and of the accelerating demand from people all over the world. This success further depicts that formal education satisfies several distinct purposes at once. On the other hand, NFE is usually characterised by everything that formal education is not. Thus, the latter offers a great variety of plans and activities in a range of distinct concepts worldwide, where all have different goals, strategies, methodologies, management, funding resources, etc. (Vicente, 1982).

Formal and NFE are equally important because the theory of knowledge gained from formal learning suggests a perspective as to how individuals understand, connect, and adapt their reality. Education can be regarded as an ongoing development of an individual's understanding, connected to interaction, as well as a reshaping of their self-identity, related to society and environment. Hence, education is present only if an individual is conscious of the process and simultaneously has control over it. Furthermore, individuals who implement both types of education conclude that the fundamental issue with formal education is that students are often asked to achieve things they cannot accomplish, although this does not necessarily indicate that schooling is valueless. However, this understanding does not reflect the broader meaning of

schooling and the impact it has on students, which consequently goes further than the methodology or even the content of the curriculum. Thus, theories of formal and NFE differ not only on their "distinct learning methodologies" but also on the meaning and effectiveness of school (Vicente, 1982). When learning and doing are united, a more suitable and realistic comprehension of the world may take place, and therefore the feedback provided by the teachers may develop students' knowledge even further. Moreover, NFE aspires for a type of learning in a framework of significant action, suggesting motivation and mental gratification. If learning occurs within a typical living environment, according to real needs, capabilities, and motivation, and what is learned is a personally embraced decision, then there is a higher probability of individual growth, which, in turn, is expected to contribute to society as a whole (Vicente, 1982).

3. How to link non-formal approaches to formal approaches in STEAM?

Implementing a pedagogy of using elements of formal education in a non-formal educational environment contradicts some significant principles of an independent learner. Of course, NFE often lacks a structure based on how teaching is directed and how students' learning could take place in an enjoyable environment. Combining both types of education can help students transform information on a broader level and establish strategies for an enduring learning experience through encouraging reflection and asking questions. Moreover, linking NFE to the formal approaches of the school curricula will allow students to manage the objectives gained from their own learning, which consequently offers them an opportunity to formulate their own knowledge (Carlson, 1998). The following 5 steps are significant when connecting NFE to formal learning:

- Experience → by doing the activity
- Share → by communicating and observing the results

- Process → by analysing and reflecting the experience
- Generalize → by comparing the experience to a real-world example
- Apply → by using what was learned in a distinct or similar situation

Source: https://umaine.edu/news/blog/2016/02/29/nsf-teaching-fellowship-program-to-improve-stem-education-in-rural-schools/

Considering that NFE broadly uses mediational tools in activities, it points to a more embodied approach compared to that of formal education and uses cognitive tools which encourage a more active input in the activity by those involved (Bekerman & Silberman-Keller, 2004). As a result, both formal and NFE can be combined to form and deliver the mutual purpose of equipping students with significant skills and concepts. An equilibrium between formal and non-formal pedagogies, cautiously considering their aspirations and applicability compared to the learning context and objectives, could result in a combined, all-inclusive learning experience for the students. Adopting both pedagogies should depend on both the culture and the nature of learning, on students' profiles and logistical limitations, and on how these pedagogies may align with particular purposes and approaches of learning to accomplish the principal goals of education (Ng, 2018).

Here, it is possible to acknowledge that there may be some flexibility in the strictness perceived in the structure of formal education. Therefore, we can distinguish between different degrees of formality in traditional education and to shift gradually from a formal to a non-formal approach, by generating more flexible characteristics or even by replacing or removing others (Dib, 1988).

Chapter 3: Learning by Doing

1. What does “learning by doing” mean?

The premise behind **learning by doing** is that we learn better when we really "do" something. Active participation supports deep learning and welcomes mistakes, as well as how to learn from them. John Dewey, an American philosopher, was the first to popularize learning by doing. This method required a strong focus on student engagement for Dewey. It also defied the conventional wisdom that learning is accomplished through lectures and rote memory. Dewey made a name for himself by saying that we learn best when we are fully immersed in the material. He believed that the best way to accomplish this was to provide a realistic curriculum that was relevant to the lives and experiences of pupils. Dewey's concept, which is almost a century old, is resurfacing as modern scholars objectively demonstrate the significance of learning by doing.

To be effective, you must first lay the groundwork for learning by doing. According to recent research, it works when it occurs at the right point in the learning process. What does this mean exactly? Firstly, it is critical to emphasise the importance of learning as a process. Learning builds on itself, and introducing learning by doing too soon can overwhelm people This makes intuitive sense in real-life situations. It works because the technique requires an individual to actively engage with the material and generate their own knowledge, step by step.

Many teachers are concerned with imparting knowledge to students; they see themselves as “putting information into students' minds.” However, learning scientific concepts demonstrates that students must construct knowledge for themselves, and in many cases, effective learning would be better described as a

process of "pulling information out of students' minds." Next time you read a new text, ask yourself the following questions: What is the topic of this text? What is the author attempting to say? Is there anything here that you find perplexing? These questions direct your attention to the content of the material and guide you through the learning-by-doing process. While some textbooks may include “reading comprehension” questions at the end of each chapter, you will learn a lot more if you ask yourself these types of questions more frequently. The most effective methods of learning are active engagement and techniques that force you to work harder to remember the material.

2. What are the advantages of “learning by doing”?

Learning by doing has been practised for millennia. Aristotle said, "For the things we have to learn before we can do them, we learn by doing them." That way of thinking evolved and changed over time, and it was lost for a time when computers were introduced into schools. This technique has only recently been reintroduced into schools. It's easy to see why teachers are encouraging this because it has five major advantages:

1. It is more interesting and memorable. The first advantage is that it is more interesting and memorable. This is significant because, in the past, students would learn from lectures, books, or articles, and learners could easily read—or not read—the text and walk away with no knowledge at all. When students are forced to do what they need to learn, it is easier to remember what they have learned. Every action provides personalised learning experiences, which is where motivation is developed. This motivation is linked to what is learned and felt. It instils in students the importance of learning that is both relevant and meaningful. Aside from that, this experience allows learners to go through the

learning cycle, which includes extended effort, mistakes, and reflection, followed by strategy refinement.

2. It is more personal. Referring back to the effort, mistakes, reflection, and refinement cycle, this cycle is only possible through personal emotions—the motivation and realization of knowledge of a specific topic that ties into your values and ideals. This connection is strong, and it provides a richer experience than reading from a book or an article like this one. That personal connection is more important because it encourages learners' exploration and curiosity. They could read about it or watch a video. Even if they make mistakes now, they will have a better understanding of what to do the next time they try it.

3. It is community-related. Learning by doing involves students engaging with the world around them rather than studying alone in a classroom or a library. Because the entire city is technically the classroom, students can leverage a wide range of resources. They have the ability to gather local assets and partners, as well as to connect local issues to larger global themes. They thus become part of a community, and this type of learning allows them to interact and connect with it more.

4. It has become more integrated into people's lives. This type of learning is also deeply embedded in our daily lives. Deep learning occurs best when students can apply what they've learned in the classroom to answer questions about their lives that they care about. Students frequently wonder "Why should I learn that?" When it comes to learning, people are more likely to be interested if they believe that what they are learning will be beneficial to their way of life in some way. It's forgettable if they can't connect knowledge to personal aspects of their lives. As a result, learning by doing facilitates the application of knowledge.

5. It helps to develop skills and confidence. The final advantage is that it prepares students for success. Learning by doing encourages students to discover something new, and to try things for the first time. They will obviously make some mistakes, but they will not repeat the errors later. As a result, learning by doing can help them develop their curiosity for new things as well as their perseverance in pursuing growth and development in a field. This could also lead to improved team management and collaboration skills. These are all important aspects of personal development as we move forward.

3. Implementing “Learning by Doing”

Learning by doing involves students being active, hands-on, and engaged. The goal of this teaching method is for students to build mental models that enable "higher order" performance such as applied problem solving and information and skill transfer (Churchill, 2003). Creating lesson plans should essentially focus on "making, producing, practicing, and observing" exercises rather than teacher-directed lecture. Below we provide a list of actions for implementing learning by doing:

Enable collaboration among students: Students can collaborate to investigate important questions or develop meaningful projects as a small group. For example, to develop an artifact. Students can share their experiences in collaborative settings. Students also learn to master group work abilities. The experience improves teamwork, group communication, compromise, and listening.

Promote self-directed exploration: With today's Internet and multimedia capabilities, enormous amounts of information may be found fast. The problem for children is to sort through the deluge of information to determine what is true and what is not. Encourage pupils to develop critical thinking by cross-

checking and confirming information across multiple websites. Self-directed study encourages students to rely on evidence rather than authority (text, instructor, parent) (Haury and Rillero, 1994). Learning to search for information for a group activity improves fact-finding skills and independence. Students learn to answer their own questions using reliable research techniques and to distinguish between fact and fiction.

Share the results and products of the activity-based experience: A key component of a successful "learning by doing" approach is allowing students to share the outcomes of their experiences and self-evaluate their group performance. After allowing students to summarise their experience or share the knowledge they gained from an activity, it is beneficial to ask, "If you could do the activity again, what would you do differently?" or "What improvements would you make?" These types of reflective questions enable students to identify areas for improvement and expand their visionary thinking.

4. STEAM and “Learning by Doing”

When it comes to providing the best STEAM education for tomorrow's innovators, incorporating hands-on lessons and activities is critical. The National Inventors Hall of Fame (NIHF) believes that doing is the most effective way to learn, based on the effectiveness of experiential learning, the process by which students learn from direct experiences outside of traditional academic settings. Below a list of advantages is provided:

Encourages trial and error: Hands-on learning, as opposed to textbook learning, promotes students to learn by doing. They make mistakes and fail as a result of this. Students can try again and learn from their mistakes in a hands-on, stress-free setting. This trial-and-error method of learning allows kids to get a deeper comprehension of the STEAM subjects.

Improved retention: When students are actively involved in the learning process, information is simpler to recall. Students learn topics considerably more quickly with hands-on, practical training than they would if they only read or listened. STEAM students who engaged in hands-on learning improved their exam scores substantially more than students who engaged in the more ordinary listening and reading styles of learning. Students activate multiple parts of the brain by moving objects around and engaging in activities including movement, listening, and talking. The more portions of their brain they use, the better chance they have of remembering things.

Solving problems and using knowledge: Working with real-world challenges improves students' critical thinking and problem-solving skills. Students can acquire teamwork and problem-solving abilities by participating in hands-on activities. Their participation in the learning process, teamwork and creative problem solving are enhanced. These skills are then transferred to other aspects of their lives. Students must be able to use their knowledge in a variety of situations to succeed in life. Hands-on learning helps learners apply knowledge to different problems or issues.

Students that are interested in learning: Some schools' teaching methods emphasise traditional learning approaches rather than creating a social, active learning atmosphere. Students' creativity and perception are enhanced when they are exposed to hands-on, inquiry-based learning methods. When students are working on hands-on projects, they are more focused and engaged.

Mindset of progress: Students learn to adapt and increase their capacities in order to keep up with the changing environment around them through hands-on training. Students who have the ability to develop have an advantage over those who are resistant to change in a rapidly changing world. A practical approach is an excellent method to cultivate a growth mentality.

5. Conclusions

The most effective strategies to learn include active engagement and techniques that challenge students to work harder so as to improve their competences. However, teachers must be cautious about when to use these strategies. If students are involved too soon, or without the appropriate material and instructional approaches, the benefits of learning by doing will be lost.

Chapter 4: All hands - on deck

1. How to implement a "learning by doing" approach / strategies

4.1.1 A theory of education expounded by American philosopher John Dewey

Before Dewey – traditional education

Dewey (1938) described traditional education as education which imposes adult standards, subject matter, and methodologies. He believed that such traditional education was beyond the scope of young learners. Dewey also saw traditional education as hierarchical and undemocratic and argued that to promote the development of a thoughtful and active democratic citizenry, students in schools needed to be able to participate in aspects of the school program democratically. Unfortunately, education today is more likely to be described as a traditional classroom setting, not like a progressive education setting, even though it is known that is not developmentally appropriate for children. Generally, in classrooms children are not personally involved, the centre of the class is the teacher and not the child. Teacher-imposed knowledge, teacher-directed activities, introducing too much academic content, out of context with children's social lives is now very common. This may be boring for student because it does not have any meaning for them, they do not feel any commitment to the teaching material and the learning impact is low. Traditional education also implements standards with passing standardised tests that mainly focus on memorisation and comprehension.

About Dewey - educator, philosopher, and social reformer

John Dewey was a pragmatist, progressivist, educator, philosopher, and social reformer. He was born in 1859 in Burlington, Vermont in the US, in a family that was very active in the democratic vision of the political community and also in social aspects in the community in Vermont. He has known social problems and political aspects in the community and was influenced by it to be a progressive educator and philosopher. Dewey believed all people have a responsibility to make the world a better place to live through education and social reform, which results in social and moral development. Dewey's beliefs about democracy, community, and problem solving played a vital part in the development of his social and educational philosophies. His point of view about education and learning has impacted countless educators over the years and are woven throughout many learning theories, which we will describe later on and are used also nowadays.

Theory explained

Dewey was one of the most influential educational philosophers known to date. He believed the educational experience must encompass the intellectual, social, emotional, physical, and spiritual growth of the whole child.

His theories rely on Kolb's The Experiential Learning Cycle, who believes that "Learning is the process whereby knowledge is created through the transformation of experience".

Also, from Dewey's point of view, the school should be a social institution and represent students' natural social environment. The classroom as a social entity teaches children learning and problem-solving together as a community.

Dewey believes that all students are unique learners and their interests are key points driving teachers' instructions. This is why the focus of the whole educational process should be pupils, and not the class content.

In his theory, education should be a “process of living and not a preparation for future living”. Classroom learning activities should be prepared to represent real-life situations, with students actively involved and participating in activities interchangeably and flexibly in different social settings.

Dewey proposed that experiences are educative if they led to further growth, intellectually and morally; if there was a benefit to the community; and if the experience resulted in affective qualities that led to continued growth, such as curiosity, initiative, and a sense of purpose. If this isn't the case, and the experience stands alone, it has no educational meaning.

Further development and implementation (Responsive Classroom, Montessori Schools, Place-Based Education, and Philosophy for Children (P4C)

Responsive Classroom

Responsive Classroom curriculum is in many ways similar to Dewey's beliefs. This teaching approach is built on the importance of a safe and happy learning community, where there are positive social relationships among students and teachers. It is a research-based teaching approach with defined setting intentions, like creating a warm climate and tone in the classroom in which students feel safe. In the classroom, there are schedules and routines of the school day prepared including students' behaviour expectations, to show them their physical learning space and the materials that they will be using, and teaching them how to care for it. Also learning expectations for the school year are established at the beginning of the year. They use Morning meetings and Closing circles (to start and end the school day with a positive, respectful and trustful learning atmosphere) and Energizers (short 3-minute activities for a mental break, play, physical activity). Also, discipline issues are solved positively, which aims to help children develop self-control and social responsibility.

Students learn best through positive social interactions and building a positive social classroom climate helps increase student achievement.

Montessori schools

The Montessori curriculum is designed through accurate observation of their students and based on students' talents, personal interests, and their physical and social needs and not on the interests of educators, administrators, or politicians. Like Dewey, the first lady of the Montessori school, Maria Montessori, also believed traditional schools were uninspiring, boring and monotonous institutions that stifled student creativity. She observed that teachers get students on-task, and relied heavily on reward and punishment schemes. Montessori school is divided into age ranges, so teachers can stay with the same group of students for a few years at a time, to fully understand their needs, interests, progress, and development. Classrooms offer children an environment that encourages the freedom to choose learning activities and children are expected to use all the materials in the classroom freely, ensuring that they have a choice in their learning tasks. Materials are sequential and designed to be self-correcting, so there is no need for constant adult intervention and students can learn and correct it. Students are working more independently and are building self-confidence with the learning activities most appropriate to their needs. The Montessori teaching approach encourages playful learning because it is engaging and intrinsically motivating also for younger children. Teachers do not use rewards in their classrooms.

Place-Based Education

This education was formed for the purpose of professional development, which would lead to improvement in a school setting. The basis for learning context in this educational approach is the use of the resources, issues, and values of the

local communities. This approach is also called community-based learning, service learning, sustainable education, and project-based learning. It is aimed at multidisciplinary education in nature, with authentic learning activities beyond the school walls and with stress on current environmental issues. In this approach, we can also find components of Dewey's social learning theory. Students build a relationship with each other, their region and their natural communities. Such education connects theoretical learning to real-world experiences and results in constructing meaningful connections among cultural, political, and social issues, creating socially responsible citizens.

Philosophy for Children (P4C)

An innovative teaching method was designed to elevate critical thinking skills and create a community of inquiry among students. Its base is inquiry-based learning, which includes written passages and short stories, designed to introduce students to philosophical issues and cover deeper and sometimes sensitive global issues, such as poverty, war, freedom, and pollution. Students can freely begin the discussions with their background knowledge and sets of beliefs, while teachers are just skilled facilitators among them. Students become engaged and reflective listeners, who respect and challenge the different opinions of their peers as appropriate social behaviour. It fosters mutual cooperation, trust, tolerance, fair-mindedness and a heightened degree of sensitivity to their peers and raises awareness of global and moral issues. This program encourages students to think for themselves and take responsibility for their learning, behaviour, and decision-making.

4.1.2 Implementing learning by doing in the class

Principles of learning by doing

The principle of learning by doing is learning from experiences resulting directly from one's actions and not with learning from watching others perform, reading and listening to their lectures or instructions. The important thing is that the learner actively performs some activity and it is in sensory contact with the results of doing.

The learning-by-doing principle has been advocated widely and in many forms, including learn-by-doing, trial-and-error learning or “proof upon practice”, where practice means a goal-directed behaviour.

Every learning skill is developed—skiing, cooking, writing, critical thinking, or solving mathematical problems—by practice: trying something, seeing how well or poorly it works, reflecting on how to do it differently, then trying it again and seeing if it works better.

Steps of implementation

The main goal with hands-on lessons is to show the students that they are capable of getting knowledge themselves, giving them confidence and power to apply it in another context. Students should learn to do things rather than having them be told about what others have done. They should know that without experience you cannot learn. So, if you want to know something – TRY IT.

First, the educator must identify the student population - what type of learners are in the class, how much experience do they have with the material and tasks? Each lesson has to be tailored to meet the needs of the students.

Then, you can follow a Five-Step Approach to generally guide students’ learning.

1. EXPERIENCE / EXPLORING / DOING

In the first step, students work on the activity and complete it. The most important part of exploring learning is the experience, so students must

complete their assignments with little or no help from the teacher, who is just guiding. The key is what students learn from the experience rather than the quantity or quality of the experience.

2. REFLECTION / SHARING AND REFLECTING "WHAT HAPPENED?"

In the second step, students reflect on what they did, interact and learn from each other and try to see how different approaches affect the process. This step includes sharing the results, discussing feelings about the experience and getting reactions and observations from others.

3. PROCESSING / ANALYSING "WHAT'S IMPORTANT?"

Then it is time for more in-depth thinking about their experiences. Now students need to analyse what happened and think about how the process can be connected with the success of a completed learning activity and to connect it with former and future lessons. Also, the discussion should be made about issues and problems they recognise when completing the activity. Discuss themes and activities which pop up to them when they do the previous steps of the learning activity.

4. GENERALISING "SO WHAT?"

When students reflect on their work and do deep thinking about it, they can assess the importance of obtained knowledge. Students must connect it to real-world examples, where and how they can apply lessons that they have learned.

5. APPLICATION "NOW WHAT?"

Students need to apply the newly obtained knowledge in a different application. They should think about in which way they could use it-in a similar or very different environment, in a similar context or a new one. Students should also think about problems and issues which can occur when performing tasks in new working conditions. Educators should guide in this step, but not with direct instructions-they should just help them with open-minded ideas and approaches.

The aim is to provide enough relevant experience that allows for the acquisition of learned knowledge and for thinking further – about difficulties if there is some exception, if more practice is required. A teacher can suggest new data to consider, a new experience to try, and when asked, can provide answers with facts. But to try, consider and think – this is the student's role.

Examples of implementation in class

1. Laboratory, workshop or studio work

It gives students hands-on experience in choosing and using common scientific, engineering or trades equipment appropriately while giving them a better understanding of the advantages and limitations of laboratory experiments. It enables them to see science, engineering or trade work 'in action', test hypotheses and see how well concepts, theories, and procedures work when tested under laboratory conditions.

2. Exploring different based learning:

- Problem-based learning

Students work in groups, identify what, how and where to access new information that may lead to the resolution of the problem. The role of the instructor (usually called a tutor) is critical in facilitating and guiding the learning process. Usually follows a strongly systematised approach to solving problems. Problem-based learning is better for long-term retention of material and developing 'replicable' skills, as well as for improving students' attitudes towards learning.

- Case-based learning

Students develop skills in analytical thinking and reflective judgment by reading and discussing complex, real-life scenarios. It uses a guided inquiry method but usually requires the students to have prior knowledge that they can actively involve in discussing, analysing and making recommendations regarding the

case. It also creates a collaborative learning environment where all views are respected.

- Project-based learning

It tends to be longer and broader than case-based learning, with more student autonomy and responsibility – students choose sub-topics, organise their work, and choose methods. It is based on real-world problems, which give students a sense of personal engagement and responsibility. It needs careful planning and monitoring by an educator to remain on project focus and to cover essential learning objectives and important content areas.

- Inquiry-based learning

It is similar to project-based learning, but the role of the teacher is less active. The learner explores a theme and chooses a topic for research, develops a plan and comes to conclusions, although an instructor is usually available to provide help and guidance when needed.

3. Experiential learning in online learning environments

There are contexts in which online learning can be used very effectively to support or develop experiential learning, in all its variations: partially or fully online by using online multimedia resources to create reports, presentations, research on the topic and asynchronous tools, e-portfolios and multimedia for reporting.

Advantages and disadvantages of implementation

Advantages

One big advantage of experiential learning is that it is highly engaging for students, who are motivated and feel positive about this type of learning. It encourages their natural ability to learn through exploration.

Experiential learning leads to deeper understanding, to better long-term memory, and develops skills that are crucial for the digital era such as problem

solving, critical thinking, improved communication skills, knowledge management and other social attitudes and behaviours, like social responsibility, tolerance, respectfulness, community service, perseverance, and so on.

Learners are aware that the knowledge can cross subject domains and boundaries and can be managed and applicable in a variety of situations.

With practice, students become handier with the materials and equipment needed, which gives them self-confidence. Students will also possess some freedom in classes, so they will work in a more engaged manner and take risks more freely.

Also new technologies offer a lot of different approaches for experiential learning – use of virtual and augmented reality, 3D printing, use of educational applications on smartphones and tablets and many more. Some of them require special equipment (like 3D printers or virtual reality sets), but some things can also be done with minimum costs – use of tablets or smartphones, which a lot of students already have).

Disadvantages

A lot of people are highly sceptical of the effectiveness of this approach. The educator should know what and how he is supposed to guide students to get the most out of the learning activity-without any guidance and support, the tasks are ineffective. Even though hands-on learning may have multiple benefits on students, there is a problem with assessing learned knowledge. Much of what is learned may not be assessable on standardised tests, which rely on comprehension and memorization of facts. In exams teachers should also include measurements of skills developed with experiential learning.

Experiential learning approaches, if they tend to be performed well, require considerable re-structuring of teaching and a great deal of detailed planning if the curriculum is to be fully covered. It requires time to plan and perform the

activity and also some costs, if some special material, equipment or transport is needed.

On balance, the use of hands-on learning for developing the knowledge and skills needed nowadays is very effective, if it is performed in an appropriate and effective way. The whole culture should rethink the definition of learning and be aware of viewing learning in a more practical way, with the key roles of experience and reflection offered to students.

2. Safety: General Guidelines to implement "learning by doing" safety in class

Safe space in the experiential classroom

Hands-on learning can be much more effective if it is conducted in a "safe" place for children. It is the teacher's role to manage the space, so here are some guidelines on what a safe space might look like:

The space, which consists of appropriate physical aspects, should also include trust, respect, suspension of judgment and censorship, a willingness to share, and high-quality listening that would give children space and the ability to freely share their opinions, ideas and knowledge, between peers and also with teachers. It is proposed that a safe space can be developed and maintained by creating a strong environment early on, establishing ground rules, providing lessons in listening and witnessing, teaching by example, and developing a reflexive attitude. At its best, the experiential classroom is a space that can allow intense situations involving frustration, anger, and conflict, as well as playfulness and allowing discovery to arise but also to be contained. It is a space in which both student and instructor may not feel perfect, but at least "good enough". Creating this safe space—and ensuring that it adapts to the evolving learning situation—is not an end state or a destination, but rather an ongoing process. A

safe space is not always comfortable to be in, although discomfort—even if intense— will be allowed but contained, and no situations are permitted to degenerate to the point where they become destructive.

Guidelines for creating a safe learning environment

A safe environment results in a student's motivation and learning success. The teacher has to create a strong environment at the beginning, through a firm and transparent direction of the classroom process. Ground rules should be established to create a positive atmosphere to encourage class discussion and inclusion and create the conditions that foster a learning alliance.

1. Physical Aspects. The room temperature, the lighting, and the furniture can also contribute to well-being and feeling comfortable in the classroom. Find out which design works better for your classroom.
2. Time and Timing. For a safe and non-judgmental environment, it is important to take the time to digest and to reflect on the class experience. Don't hurry, because reflection should be at least as important as the activity itself. Timing is also crucial in addressing sensitive subjects.
3. Suspension of Judgment, No Censorship. Open minds and the free expression of individual ideas and interpretations are the key concepts of experiential learning. All opinions and judgments are welcome and may be safely expressed, as long as respect for others is maintained.
4. Mutual Trust and Respect. Safe experiential learning requires a high level of trust in the classroom, both between the instructor and the students and among the students themselves.
5. Qualities of Listening. Establishing open communication lines must challenge both the student and the instructor. It should include deep listening and also an intuitive understanding of what is not spoken directly.

6. Reflexivity. Every time the focus should be on students as people, not seeing them as a part of the skill set they should acquire.

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 aid 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, emphasising 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 endeavour. 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: Making History

1. Introduction: Why link STEAM with History?

Cross-curriculum pedagogy is an approach that has been explored more and more in recent history. While its usefulness is not to be proven anymore, the idea to cross STEAM and History specifically is not a widely explored concept as of yet. Indeed, while STEAM is naturally associated with modernity and recent discoveries, history is usually associated with the past, with finished events and with rote memory. The combination of both may seem far-fetched at first glance, but they are actually more relevant than one would think. In this project, we use History to contextualise and anchor STEAM concepts into the concrete reality. While we use science to show that our present is more linked to, and dependent on, history than we think, and that current basic scientific concepts are rooted in history. By using historical techniques and recreating historical manipulations to illustrate and explain present-day STEAM concepts, we contextualise abstract STEAM concepts, make them more concrete and anchor them into real historical events. The historical aspect makes those concepts more solid and relatable while also drawing the past closer to the pupils. The pupils can then relate to it better and feel more linked and involved in history.

From the STEAM curriculum to History, a method.

There are different ways in which STEAM can be linked with History. One of the simplest avenues is to take a present-day STEAM concept, and to go back to its historical roots. Usually, the context in which this concept was discovered or invented can already be used as a history base with which to explain the

concept. Sometimes, one of the later applications of the concept is more relevant to recreate the manipulation.

5.1.1. Science and History

What is history?

Overall, history can be understood in two ways: History as past or lived history, and as conveyed or told history. History – understood as past or lived history – has disappeared. At the same time, the past manifests itself throughout our lives, society and consciousness. Past or lived history has left traces in the form of memorials, buildings, artifacts, infrastructure, images, texts, films, urban spaces, cultural landscapes, etc. The past is in one's own experience and that of others. The past only becomes history when it is reflected and presented as a narrative.

As human beings, ever since we have had language, we have always constructed narratives and notions of past, situations and contexts that have happened. In fact, man is the only species capable of gathering experiences over a long period of time – even generations – and reflecting on and continuing and applying them to the individual, as well as collectively and socially, for example, to the national level.

These historical stories relate to some past – thus connecting past to present. The stories can help form and shape collective memories, create meaning, identity and experience of community feeling and belonging for the individual, like this example:

The community could be a Stone Age settlement, where the tribe spent long winter evenings sitting around the crackling bonfire and told of the recent hunt for an aurochs that not only provided food for the next long time, but also skins and materials to make utensils. The group of hunters who participated in the

hunt eagerly talk about the hunt, while the children listen attentively, for the story is exciting and especially for those who will soon be large enough to participate in the hunt. Perhaps an old hunter interferes with the story and tells about when the settlement starved for a long time before the hunting desire went their way. The history of the old hunter is well known in the settlement, but he is a skilled storyteller and he changes the story a little every time, but it does not matter! History reinforces the sense of community in the settlement.

Told history can have many forms and expressions, from the hunter who tells about the hunt for the aurochs to historians' scientifically based stories about the past. Sometimes you can place learning resources for the school subject and historical feature films. Finally, there is the understanding of research, which decodes and interprets the traces and sources of the past.

History as a subject

The foundations of the profession were laid almost 2,500 years ago in Greece. "Historia" meant something like collecting, examining and processing observations. A "histor" was a person who dealt with it. The Greeks Herodotus (c. 485-425 BC), with works about the Persian Wars, and Thukydid (c. 456-396 BCE) are the fathers of the profession. Both were concerned with a desire to tell the truth and study history from the point of view of the world. Other important authors of history include the Roman philosopher Cicero (106-43 BC) which famous quote: "Historia magistra vitae" (history is the teacher of life) is widely known.

Gajus Julius Caesar's "The Bello Gallico" from 58-51 BC about Gaul, present-day France, the area, its subjugation is a known attempt not only to write history, but was also a PR stunt for Caesar. Publius Cornelius Tacitus's "Germania" from 98 AD is an ethnographic-topographical depiction of northern Europe and the people outside the Roman Empire. It is the only one of its kind from Antiquity that has

since been misunderstood, interpreted and abused, especially in the period 1920-45.

Until the early 19th century, it was widely believed that past/lived history was considered an absolute because of these truth-seeking historians who sought a single truth.

In the 19th century, the natural sciences' methods of gaining knowledge were imitated by the human sciences. In order to legitimise itself as a real science subject, the subject had to have a field of specific scientific methods.

The study of the past was divided between two fields of research: archaeology and history. The archaeologist's field was primarily the time before the emergence of written sources, while the historian dealt primarily with periods when there were written sources. However, the separation does not quite last in our time.

Archaeology's entry into history

The goals and subjects of archaeology and history are identical – they both seek knowledge of the past. Paradoxically, the subjects are absent and alienated from each other. The historical background to the fragmentation of the two subjects can be found in the period c. 1830-1890, when objects were perceived as independent sources. Before that, no one considered the study of antiquities to be fundamentally different from studying antiquities – nor did it have the concept of the enormous time distance that could be between Prehistoric archaeology as a science has evolved with the emergence of archaeological finds and with the ever-growing implementation, which is based on interpretation and age determination of the finds. The Dane C.J. Thomsen is described as the founder of prehistoric archaeology, since in 1836-37 he used the three-period system for dividing prehistory into a stone, bronze and iron age. Not until the mid-19th century were breakthroughs in the natural sciences the basis for an assessment of the length of prehistory and the age of mankind. In 1859, the same year that

Charles Darwin's “Origins of Species” were published, the authenticity of tools found with the remains of now extinct animals was recognised. The first finds of ancient people around the same time paved the way for the exploration of man's earliest history.

Examples of methods used by historians 1/2 page:

Source criticism is a central method used by historians. It's about clarifying what and how we can use a source in our historical study. In order to clarify this, we need to ask some questions about the text in order to arrive at a credible and professionally based presentation of the source. Basically, the historian wants to clarify: what do we know about the past? How do we know? Can we trust the knowledge we have? As help, you can set the standard:

Issue:

1. What do we want to know?
2. In what context do we expect the source(s) to help clarify the issue?

Source analysis:

What kind of source is that (text, image, sound, etc.)?

1. Is the source a document or a report?
2. Is the source real or inauthentic? That is to say, it is the source it presents itself to be.
3. The author: Who produced the source? Why has he produced it (intent, purpose)? What role did the author play in relation to the events he reports on (active participant, impartial)? What expectations does he have and what does he know? Who does he turn to (who is the recipient)?
4. Authorship and situation'
5. Is it a first- or second-hand source?
6. How representative is the source of the area and the historical context?

7. Text determination: How is the source handed over (original or transcript)?
8. Trend: How do the author's attitudes and values show up in the source?

An example from the work of a historian/archivist:

A photo has been submitted to the archivist who wants to know when the picture is from. There's no information in the photo. In addition, you want to know who the picture shows.

U408	Propr. Carl Christensen, Lendrup pr. Løgstør
U409	Fuldm. A. Hansen, Løgstør
U411	Propr. Hans Broll, Dybvadgaard pr. Aars
U412	Bagerm. Bro Jensen, Vindblæs St.
U416	Dyrl. J. A. Larsen, Aars
U417	Fabr. N. Jensen, Aars
U418	Repr. Søren Hansen, Løgstør
U420	Mekan. L. Andersen, Løgstør
U421	Isenkr. C. C. Christensen, Aars
U423	Postkontrahent Henrik Larsen, Løgstør
U425	Propr. T. Haldrup, Haldrupgrd. pr. Løgstør
U426	Byraadssekr. Th. Skipper, Løgstør

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It's a little bit of detective work that's going on. It is the car's license plate that contains the solution and says that it is hardware store owner C.C. Christensen, who is leaning on the car with the family. The year may be harder. The historian will try to find out which car model it is, and when it arrived in the country.

Examples of scientific methods used in archaeology

Archaeology is concerned with interpreting and explaining the existing sources stored as objects in the museums and in producing new sources through collection and excavation, so that the subject is in constant development. It is often difficult for children to understand that our understanding of the past is constantly evolving and that the research results obtained show what we know right now!

Archaeology is often associated with the Stone Age, Ancient Greece, Rome, etc., but there is also industrial archaeology, a branch of recent cultural history that

explores the production facilities of early industrial culture with archaeological methods.

Fundamental to all archaeological work is age determination. Here a distinction is made between absolute and relative dating, which is achieved partly by observing stratigraphy (see the illustration below) during excavation, and partly through the examination of ending finds with several objects, e.g., in graves and depots.

When it comes to age determination, it is important to state that archaeologists use several different methods in dating. Archaeology is based as a subject on methods and results from other sciences — on geological and other scientific regulations and dates. Zoology and botany, through the study of the remains of wild and domesticated animals, as well as of seeds and plants, illuminate man's adaptation to the natural environment.

Stratigraphy showing the location of different layers of culture, e.g., oldest time is deepest and youngest is at the top.

Showing the principle of Stratigraphy: Every period has its "layer" of findings. The oldest part, in this dinosaur, is the deepest.

Source: https://natmus.dk/museer-og-slotte/nationalmuseet/undervisning-paa-nationalmuseet/undervisningsmaterialer/grundskolen/danmarks-oldtid/undervisningsrollespil/vikingetiden/arkaeologi/

Other examples of relative dating methods in typology:

- technological analysis: the disc axe is typical of Ertebølle culture, where thin-nosed, four-sided axe

- wear track analysis: How and what an object has been used for

- raw material analysis

- dissemination analysis

Examples of absolute age determination used by archaeologists:

- Pollen analysis
- Dendrochronology/year rings dating
- Tefrachronology - Ash layer analysis
- Radiocarbon 13 – highlights diets in animals and humans
- Radiocarbon 14 – illuminates the age of the object and has a half-life of 5,730 years
- Phosphate analysis – Shows built-up areas
- DNA analysis: e.g., skin colour, diseases, gender, etc.
- Strontium isotopic analysis: Showing where people reside geographically

5.1.2. Technology and History

Technology runs our lives these days. Smartphones, tablets, and computers – we really can't seem to function without them. In a very short amount of time, technology has exploded and now, many people cannot imagine a life without it.

To understand how we left the dark ages (which really wasn't all that long ago) to where we are today, it is important to understand how technology evolves and why it matters.

All technologies are born of a purpose. For example, the crane was created to lift quantities of "products" to high places or to build in spaces where it was not possible before. With each new update, technology compounds existing technologies to create something better than what was used before.

We are used to relating technology with modern machines. But technology is a wide concept and means much more than machines. As defined in Wikipedia, technology ("science of craft", from Greek τέχνη, *techne*, "art, skill, cunning of hand"; and -λογία, *-logia*) is the sum of many techniques, skills, methods, and processes used in the production of goods or services or in the accomplishment of objectives, such as scientific investigation. Technology can be the knowledge of techniques, processes, and the like, or it can be embedded in machines to allow for operation without detailed knowledge of their workings.

Technology can refer to methods ranging from as apparently simple as stone tools to the complex genetic engineering and information technology that has emerged since the 1980s. When speaking about technology, we consider then those techniques, skills, methods, and processes that can be related to Agriculture, Construction, Communication, Information, Manufacturing, Medical, Power & Energy, Production, and Transportation. And of course, these technologies have

been appearing in different periods of history, evolving from one to another's, or even keeping the same for long periods of time.

We can find examples of the first technologies from the Stone Age, such as the first shaped stones. We also consider wireless communication as technology.

How can we consider such different things as technologies?

Technology is not a neutral word. Different people will give it different meanings depending on their viewpoint and context. Technology concerns itself with understanding how knowledge is creatively applied to organised tasks involving people and machines that meet sustainable goals.

There are three important aspects to this definition:

1. Technology is about taking action to meet a human need rather than merely understanding the workings of the natural world, which is the goal of science.

The invention of the microscope was driven by a need to explore the world of the small. This technological solution to a long-standing problem has, in turn, enabled us to understand more about the workings of the world which in turn has led to the development of more technologies.

2. It uses much more than scientific knowledge and includes values as much as facts, practical craft knowledge as much as theoretical knowledge. The wheel is an example of where the physics of making a simple circle moves the world.

3. It involves organised ways of doing things. It covers the intended and unintended interactions between products (machines, devices, artifacts) and the people and systems who make them, use them, or are affected by them through various processes.

Actual technology is a hands-on sector, where people have to be skilled in many of the following: engineering, communicating, designing, developing, innovating, managing, manufacturing, modelling, and systems thinking. But technology also gives us various products which can be used for good or ill or where the benefits are disputed and similarly the processes involved in producing and using technology means that we should all take an interest in whether it provides us and everyone else with a sustainable future.

When discussing technology and history, it may be necessary to classify technologies into broader areas in order to see them in perspective. This helps us, when we have to teach these technologies to our students, to relate them to the activities to be developed.

Perhaps the concept of technology is not very explicit. When we mention the word technology, we are not only referring to the artifacts created by humans such as a crane or a plow, we are also referring to the creation of writing, paper, and eventually the printing press in a sequential chain that feeds back on itself.

That is why we can speak of "innovations" as technologies. A simple categorization would have this order:

- Innovations that expand the human intellect and its creative, expressive, and even moral possibilities. This group includes the printing press and paper, and now of course the Internet, the personal computer, and the underlying technology for the modern data age, semiconductor electronics, plus photography.
- Innovations that are integral to the physical and operating infrastructure of the modern world. This group includes cement as a crucial early innovation, “at the foundation of civilization as we know it—most of which would collapse without it.” Others, electrical systems, indoor plumbing, and filtration systems to create potable water. Aqueducts, electricity, and sanitation systems.
- Innovations that enabled the Industrial Revolution and its successive waves of expanded material output. These include the steam engine, industrial steelmaking, and the refining and drilling of oil.
- Innovations extending life. This broad group includes the successive agricultural revolutions: nitrogen fixation, notably the Haber-Bosch process, about a century old, which made it modern. Also, the green revolution; the moldboard plow; Archimedes’ screw, which drew water from streams and canals to irrigate fields; and the widespread use of the plough, which is still (with technological improvements) a technology used today. This group also includes the advances in medical knowledge and treatment, as for example, vaccination and optical lenses.
- Innovations that allowed real-time communication beyond the range of a single human voice. The Internet obviously brings new scale and speed to communication, but the real leap beyond previous limitations occurred in

the mid-1800s, with the development of the telegraph, followed by the telephone and then radio and television.

- Innovations in the physical movement of people and goods. Through the past 150 years, the internal combustion engine made possible the social, economic, political, and environmental effects brought on by the age of the automobile. Until the first, tentative balloon flights in the late 1700s, human beings had never viewed the layout of their environment from an elevation higher than that of a treetop or a mountain. In the age of 20th-century powered flight, they could see for themselves the natural contours and man-made features they had approximated on maps. The steam engine enabled the growth of the railroad—which, like the bicycle or the sailboat (with its related technologies as the astrolabe, the quadrant and afterwards the sextant and the compass) are technologies that have revolutionised the way people and goods move around the world.

By studying history, we educate ourselves about past civilizations, leaders, and technology. However, civilizations do not last forever, and leaders are conquered, die, or are murdered. Technology is the only aspect of history that builds and continues to grow. The reason being the relationship between the doers and thinkers of the world. Their interactions result in identifying a problem, communicating a solution to the problem, and creating new technology. And given all that has been explained above, we conclude that Introducing our young people to STEAM is to put them on the runway to better adapt to or create and realise the changes that will come in the future. Certainly, there is an evolution of concepts adapted to modern technology, there are technologies that we have lost and now visualise as innovative, there are others that have remained in time and have improved their structural technology but still do the same job.

We must not forget that technology cannot be separated from culture and therefore the arts and humanities have a direct impact on its creation, ideation, and use. When teaching these technologies in our educational spaces, we will surely not be able to use original elements, but we can generate prototypes with cardboard, 3D printers or other handicraft elements to see how they work.

Today's technology allows us to preserve cultural heritage: digitisation with a scanner, large databases linked to maps or extensive libraries, preserving knowledge of elements on natural or ephemeral supports.

One example of the use of technology to preserve cultural heritage is recovering recordings of old “pianolas” preserved up to now on paper rolls.

A pianola is a musical instrument that incorporates the piano mechanism to which a series of mechanical and pneumatic elements are added that allow the automatic reproduction of perforated music, recorded in a roll of paper (Piano Roll).

The first pianoles were external systems (small closet type) that were placed in front of a commercial piano (Piano player) while the later ones were already incorporated into the resonance box of the piano and the roll at the height of the eyes of the pianist (Player piano).

A pianola, in fact, allows both the manual execution of a pianist (recording of music, roll of perforated paper recorded) and its automatic (semi) execution by music lovers or beginner pianists by rolling paper perforated transcripts that sound metronomically and which include lines drawn on the paper indicating the pianolist (pianola interpreter) the tempo and dynamics of the piece, with two different systems, the so-called themodist and metrostyle, which allowed various interpretations.

Nowadays, technology has allowed us to digitise these rolls. This keeps a digital image containing all the graphical elements of the roll and generating a MIDI file without processing *tempo* and *dynamics* information, in order to preserve the variability of interpretation, which is the main characteristic of the rolls. The resulting file can be edited with different specific programmes, to give the desired performance anytime. This way, the antique rolls can be kept and the heritage can be conserved, without reducing the performance to a particular one.

5.1.3. Engineering and History

We live in an age when it is easy to think that our generation has invented and discovered almost everything, but this is not the reality. Progress cannot be regarded as an unexpected and sudden accumulation of individual brains: such a genius, inventor of everything, has never existed in the history of mankind. What has existed is a continuous and limitless stream of experiments by men and women who were inspired by the rare successes that have led to our comfortable modern reality.

The study of the History of Engineering is valuable for many reasons, not least of which is that it can help us understand the genius of the scientists, engineers, and craftsmen who existed centuries and millennia before us, who solved problems using the devices of their time, making machines and equipment whose conception is so modern that it forces us to rethink our image of the past. Culture, in any field, consists of understanding and not simply know-how. That is why it is essential to learn how a given phenomenon has been understood and how the application of that knowledge has evolved over the centuries. For the same reason, it is important that people of our generation pass on the interest and taste for the achievements of ancient engineers by discovering their

artifacts. Young, meta-engineers must be familiar with the knowledge of the past if they are to understand the present and perceive the future.

Some of the inventions are in the military field since (unfortunately) many inventions and technological innovations were conceived starting from military applications.

Many of the great engineering works of the past are centred on Rome's heyday. First, most of the inventions and technology of the Roman Empire were not invented by Latin inventors; in fact, one of the merits of the Romans was to recognise, appreciate and utilise the intellectual capabilities of other peoples.

However, certainly many inventions which are precursors of the present day were developed in that era.

Most of these inventions are very old, some are forerunners of the knowledge and inventions of our time. Moreover, many of them reveal a surprising modernity in their conception, in their scientific and technical design, and even in their form and function.

The Roman Empire was one of the most widespread powers in human history. On the other hand, most people believe that technology and science were rather primitive during that time, and that their study was largely neglected. The History of Engineering, however, tells us differently, mechanical knowledge was quite advanced, and it has been possible to discover the function and meaning of many archaeological finds and to analyse their ways of working based on simulations and recreations. In particular, the joint efforts of archaeologists and engineers have shown that many devices in common use today were invented and built some 20 centuries or more ago.

As in the previous point where we talked about technology in general, we must compartmentalise the engineering innovations of the past by fields of action.

- Measuring the environment

  The measuring of our environment, the distance (together with the

measuring of mass and force) represent the first step in the development of science and technology.

- Measuring mass

  Ancient balance scales were built in two shapes: one had two arms having equal length, the other had arms of different lengths; the first will be indicated simply as a “balance scale” while the second will be indicated as a “pendulum scale”. This last is also known as a Roman balance because it was invented by the Romans around the 4th century B.C. and was called “statera”.

- Measuring distance

  It would be difficult to determine when the Groma, a land surveyor’s instrument was first invented: it may have originated in Mesopotamia, where it may have been taken from the Greeks around the 4th century B.C., and renamed *gnomona* or little star. The Etruscans then brought it to Rome, calling it cranema or *ferramentum*. It consisted of an iron or bronze cross from whose arms descended four plumb lines. Looking through the opposing pairs, the surveyor could identify two perpendicular directions, which allowed him to subdivide the land into orthogonal alignments. Although this instrument goes back to very ancient times, it was in common use even centuries later. Proof is found in the remains of a groma discovered in Pompeii and its illustration on several funerary steles. As far as we can tell, the approximately 2m long rod supported the cross well above the eye level of the user, who could therefore look freely through the plumb lines. The real limitation of the instrument was revealed when there was even a weak wind, as this caused the lines to oscillate and prevented a

correct line of sight. Or others like, Surveyor Cross, Chorobate, The dioptre by Heron or the naval odometer.

- Measuring time

  The sundial was the first device used to measure (or to visualise) the hours of the day. Water clocks, or clepsydras, were quite common 2,000 years ago but generally they were very simple and not very accurate. During the Middle Ages the art of clock manufacturing was continued by Muslim inventors.

- Ancient computational devices

  What we call today "computing machines" were invented and developed after the 16th century, but older devices are, without any doubt, legitimate precursors in the art of computation.

  The abacus is the oldest computation device and is found in almost any population in every part of the planet. Among others like, The mesolabio of Eratosthenes or The mechanism of Antikythera.

- Using natural energy
  - Wind

    By wind engines we mean all the devices that create energy by using the kinetic energy released by the movement of an aeriform mass.

    The turbine was first defined simply as a paddle wheel or, in respect of its primary use, a mill. Others like wings on the sea: the sails, from the Lateen wings to the Chinese junk.

  - Hydraulic

    The water, requires a moderate energy to be raised, can in turn provide a moderate amount of power when it falls upon a paddle

wheel or when it pulls it. The most famous relics from the past of these systems is unquestionably the wheel of Venafro. The horizontal axis wheel, powered from the top or the bottom, was paradoxically a technological step backward compared with the more archaic oblique paddle wheel. But since it was the only machine of unquestionably simple construction that could provide a significant level of power, it continued to exist, arriving almost unchanged to the present day: one example is the Pelton turbine. The paddle wheel reached its peak in the Middle Ages, when it was used in all production contexts.

- Using Water
    - Water is without doubt the most necessary element for the existence of life; for this reason, devices to raise water from wells were among the first to be conceived. The need to raise water in large quantities from the bottom of a well or from a riverbed, requiring extensive if not continuous time, led to the invention of some simple devices. The Archimedes' screw is the one of the inventions that led to the greatest number of derivations, including the screw for drills, bottle openers, presses, propellers and so on. Norias and pumps are other devices to take in mind in this section. Aqueducts and his derivative plumbing.
- Communication and telecommunication

  Communication started with sounds and evolved as a matter of distance to more visual issues. Acoustic devices to communicate ships, lighthouses, pigeons, and optical (roman rod telegraph or pole telegraph).
- Lift and transports

  The development of a transport system is another important step towards modernity. The concept of transport may mean both vertical and

horizontal movement of things and people. Cranes and tackles, polipastos, pentapastos, gravity driven elevators, the roman four-wheeled cart. Ancient self-propelled vehicles like the Elepoli or early paddle wheel boats. Cable ways and flying machines (from kite's communication in China to japanese giant gliders).

- Engines
  - Motors

    For the Greeks any device that caused another object to move was a motor; this same criterion was used later by the Romans without any alteration. From this to the evolution of our time.
  - Secondary engines

    Most of the ancient secondary motors, before the invention of thermal engines and electric motors, were spring motors since they were based on the principle that mechanical energy could be "stored" by the deformation of a flexible element. Flexion elastic motors (bows, gastraphetes, ballista, catapulta, onager, trebuchet, among others...). Steam engines like Heron's steam turbine, the Architronitro.
  - Spinning and weaving

    Cloth is among the most important and most useful objects of common use by mankind; also, the development of cloth is a milestone in the history of human civilization since it can be considered a first step towards technology. The spindle, the loom, the spinning wheel, have a great evolution up to Samuel Crompton's machine "The Mule".
- Fire

The discovery of fire was obviously man's first conquest, however it occurred; it set the passage of humanity from the simple animal phase to

the intellectual phase; any further development towards civilization starts from the capability of managing it. Apart from the innumerable technical and material consequences, there are others that are even more important but that at first glance escape us completely. Fire shattered darkness and eliminated the cold: with the elimination of darkness, man became master of the other half of the day. Applied for domestic heating, thermal heating, the flamethrower of Boeotia.

- Automatas

  The idea or the desire to build automatic devices is almost as ancient as the early knowledge in the field of mechanics. From the mechanism that opens doors in ancient Greece (built by counterweight system) to the repetitive catapult of the romans, passing for the clocks of the middle age to the automatas of Al-Jazari.

- Building techniques

  Building construction techniques have varied greatly over the centuries and this offers a wide range of styles, techniques, and possibilities. This wide sector includes city walls. Individual strongholds or citadels. Mountain defence barriers. Bases for temples or podiums. Road construction and related works. Paving stones for military roads. Concrete beds for the construction of villas. Sepulchers and cisterns. Isolated towers or “monopyrgi” (isolated towers). Abutments for bridges and, more rarely, the bridges themselves.

STEAM (Science, Technology, Engineering, Arts, Mathematics) education has explored arts integration for more effective STEM learning. However, effective integration is often elusive; the arts are sometimes diluted because of well-intentioned integration within STEM subjects, with STEM learning risking similar superficial treatment within arts curricula.

Students gain observation, visualisation, hands-on creativity skills and self-confidence with arts in the education process. These skills are also based on scientific thinking (Cantrell, 2015). Arts can teach to observe and think deeply about instances, situations and objects. For instance, ancient writers such as Alexander, Heron, Vitruvius, Frontinus and Plinius present information about ancient technology and engineering.

Study the past to understand the present and be able to preserve it with today's tools. To understand the evolutions of engineering contextualised in its time, to be able to take a global vision of what elements have made us the way we are.

5.1.4. Math and History

Mathematics has a history that is nearly as old as humanity. Mathematics has been central to advances in science, engineering, and philosophy since antiquity. It has progressed from simple counting, measurement, and calculation, as well as the systematic study of the shapes and motions of physical objects, to the broad, complex, and often abstract discipline we know today, through the application of abstraction, imagination, and logic.

From early man's notched bones to Mesopotamia and Egypt's settled agriculture and the revolutionary developments of ancient Greece and its Hellenistic empire, mathematics has a long and fascinating history. Before the late Middle Ages and Renaissance, the focus of mathematical innovation shifted back to Europe, particularly China, India, and the Islamic empire. Next came a series of revolutionary advancements in 17th and 18th century Europe, paving the way for the 19th century's rising complexity and abstraction, and finally the 20th century's bold and often disastrous discoveries.

Our prehistoric ancestors would have known the difference between one and two animals. But it took a long time for the abstract concept of “two” to be

represented by a symbol or word. A few isolated hunter-gatherer tribes in Amazonia still only use the words “one”, “two”, and “many”. A formal numbering system is unnecessary without settled agriculture and trade. Early man kept track of regular events like moon phases and seasons. Notched bones from Africa show that numbers were thought of by humans 35,000 to 20,000 years ago. But this is merely counting and tallying, not mathematics. Sumer (modern-day Iraq) was the birthplace of writing, agriculture, the arch, the plow, irrigation, and many other innovations. When Sumerians settled and developed agriculture, they needed mathematics to measure land plots, tax individuals, and so on. The Sumerians and

Babylonians also needed to describe large numbers to chart the night sky and develop their sophisticated lunar calendar. They were probably the first to assign symbols to groups of objects to help describe larger numbers. They went from having separate tokens for sheaves of wheat, jars of oil, etc. to using a symbol for specific numbers of anything. Early Egyptians began recording lunar phases and seasons for agricultural and religious purposes around 6000 BCE. A palm was the width of the hand, and a cubit was the measurement from elbow to fingertips. A decimal numeric system based on our ten fingers was developed later. The Moscow Papyrus, from the Egyptian Middle Kingdom around 2000–1800 BCE, is the oldest mathematical text discovered so far. The Egyptians may have introduced the first fully developed base 10 numeration system as early as 2700 BCE (and probably much early earlier). A stroke represented units, a heel-bone symbol represented tens, a rope coil represented hundreds, and a lotus plant represented thousands. Larger numbers were unwieldy due to the lack of place value (although a million required just one character, a million minus one required fifty-four characters).

Greek mathematics refers to mathematical works and ideas that date from the Archaic to the Hellenistic and Roman periods, with the majority of them existing from the 7th century BC to the 4th century AD along the Eastern Mediterranean coasts. Greek mathematicians lived in towns all over the Eastern Mediterranean, from Italy to North Africa, yet they were bound together by Greek culture and language. The word "mathematics" comes from the Ancient Greek: máthma, which is Romanised as mathema, meaning "matter of instruction" in common Greek. The study of mathematics as an individual subject, as well as the application of broader mathematical ideas and proofs, distinguishes Greek mathematics from that of previous civilizations. Geometry was the foundation of most Greek mathematics. Thales, one of the Seven Sages of Ancient Greece, who lived on the Ionian coast of Asia Minor in the first half of the sixth century BCE, is widely regarded as the first to lay down guidelines for the abstract development of geometry, despite the fact that what we know of his work (such as on similar and right triangles) now appears quite elementary. From the fourth to the twelfth centuries, European knowledge and study of arithmetic, geometry, astronomy, and music were primarily limited to Boethius' translations of works by ancient Greek masters such as Nicomachus and Euclid. The Roman numeral system, although inefficient, as well as an abacus based on Greek and Roman models were used for all trade and calculation. The invention of the printing press in the mid-15th century had a significant impact as well. Numerous arithmetic books were published with the intention of teaching business people computational methods for their commercial needs, and mathematics gradually began to gain a more important position in education.

The Renaissance was a cultural, intellectual, and artistic movement that began in Italy around the 14th century and gradually spread across most of Europe over the next two centuries, resulting in a resurgence of learning based on classical sources. Science and art were still very much interconnected and intermingled at

this time, as evidenced by the work of artist/scientists like Leonardo da Vinci, and it is no surprise that, just as in art, revolutionary work in the fields of philosophy and science was soon taking place.

The work of Newton and Leibniz occupied most of the late 17th and early 18th centuries, as they applied calculus to difficulties in physics, astronomy, and engineering. The Bernoulli family of Basel, Switzerland, has two or three generations of brilliant mathematicians, particularly Jacob and Johann Bernoulli.

They helped develop Leibniz's infinitesimal calculus, Pascal and Fermat's probability and number theory, as well as the "calculus of variations" generalization and extension of calculus.

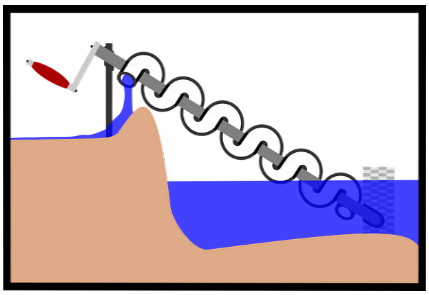
Another significant advance in mathematical analysis was Joseph Fourier's study of infinite sums with terms that are trigonometric functions at the beginning of the nineteenth century. The twentieth century continued the nineteenth century's trend of increasing generalization and abstraction in mathematics, in which the concept of axioms as "self-evident truths" was largely abandoned in favour of an emphasis on logical concepts such as consistency and completeness.

Mathematicians in Ancient Greece

Pythagoras was one of the first Greek mathematicians, immortalised by his famous “Pythagorean Theorem” that still influences geometry. He lived circa 500 BC and was from a Greek colony in modern-day Sicily. But he also studied philosophy and music. He had a group of followers called Pythagoreans with whom he shared his knowledge.

Aristotle is most known for studying at Plato's Academy and then tutoring Alexander the Great at his Macedonian palace. He tutored numerous subjects, including mathematics. His job was to mould Alexander's mind into a leader's mind. His techniques worked because Alexander is immortal. As a physician, Aristotle was mainly interested in science and scientific thought. He addressed his studies methodically. This evolved into “The Scientific Method.” Though not a specialised mathematical discipline, it has had a significant impact on mathematics over time.

Most of **Euclid's** records have been lost, if they ever existed. Historiographers know he may have attended Plato's Academy and worked at Alexandria's library. At heart, Euclid sought knowledge through logic and reason. He devoted his life to it, proving the Pythagorean theorem among other things. He was the father of Geometry and made many other contributions to science.

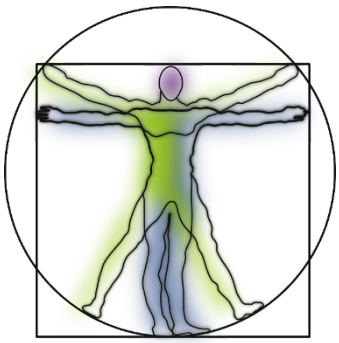


Archimedes grew up with a strong sense of wonder about the world. He was also a physicist, engineer, inventor, and astronomer. He refined “Pi”; an irrational number used in many mathematical calculations. He also invented the Archimedes Screw, which helped lift water from wells.

Famous European mathematicians

Fibonacci, also known as Leonardo Bonacci, Leonardo of Pisa, or Leonardo Bigollo Pisano ('Leonardo the Traveller from Pisa’), was an Italian mathematician from the Republic of Pisa who was regarded as "the most gifted Western mathematician of the Middle Ages. The Fibonacci Sequence is a peculiar series of numbers from classical mathematics that has found applications in advanced mathematics, nature, statistics, computer science, and Agile Development.

Leonardo da Vinci was an Italian polymath of the High Renaissance who was active as a painter, draughtsman, engineer, scientist, theorist, sculptor and architect. He frequently used maths in his works. Two of Leonardo da Vinci's best-known works that employ mathematics are the Last Supper and the Mona Lisa. Each applies mathematical principles of perspective, golden ratio and proportions in its composition. 'Vitruvian Man' is a visual image of the perfect human form through the use of mathematics. To people like Da Vinci, mathematics was a universal constant that allowed proportions to be seen everywhere.



Copernicus was a Polish astronomer and mathematician whose theory that the Earth moved around the Sun profoundly altered later workers' view of the universe, but was rejected by the Catholic church. Copernicus created a new model, where the sun is at the centre, and Earth moves around it in a circle. He also predicted that Earth rotates around its axis once every day.

Leonhard Euler covered almost all aspects of mathematics, from geometry to calculus to trigonometry to algebra to number theory, as well as optics, astronomy, cartography, mechanics, weights and measures and even the theory of music. Euler's important contributions were so numerous that terms like "Euler's formula" or "Euler's theorem" can mean many different things depending on context. Just in mechanics, one has Euler angles (to specify the orientation of a rigid body), Euler's theorem (that every rotation has an axis), Euler's equations for motion of fluids, and the Euler-Lagrange equation (that comes from calculus of variations).

Sir Isaac Newton was an English mathematician, physicist, astronomer, theologian, and author (described in his time as a "natural philosopher") who is widely recognised as one of the greatest mathematicians and most influential

scientists of all time. Newton built the first practical reflecting telescope and developed a sophisticated theory of colour based on the observation that a prism separates white light into the colours of the visible spectrum.

Carl Friedrich Gauss is a great German mathematician of the nineteenth century. His discoveries and writings influenced and left a lasting mark in the areas of number theory, astronomy, geodesy, and physics, particularly the study of electromagnetism.

Pierre de Fermat is a French mathematician widely regarded as the father of modern number theory. Fermat was one of the leading mathematicians of the first half of the 17th century. Fermat discovered the fundamental principle of analytic geometry. His methods for determining tangents to curves and their maximum and minimum points earned him the title of "inventor of differential calculus."

René Descartes was a French philosopher, mathematician, and scientist who invented analytic geometry, which connected the previously distinct fields of geometry and algebra. Descartes is widely regarded as one of the founders of modern philosophy and algebraic geometry, as well as one of the most notable intellectual figures of the Dutch Golden Age as he spent a significant portion of his working life in the Dutch Republic.

Many more great mathematicians influenced the scientific discoveries and facilitated technological progress across historical periods. All the modern products integrate the knowledge and the innovations of these great scientists. Studying their theories separately, by a lecture-based approach, makes it very difficult for many students to see the practical implications. Following a hands-on STEAM methodology is the best tactic, as students will create different artifacts and understand several of the underlying concepts at the same time.

2. Conclusions

As we can see in this chapter so far, STEAM topics are much more connected with history than they seem to be. Almost all recent discoveries, principles, and techniques in STEAM fields are based on ancient discoveries, designed by great people, as described in this chapter. Nowadays, researchers and scientists create new connections, contexts and applications from historical discoveries.
History offers a wide concept of discoveries - what were the needs that led to a discovery, what were the issues when it was »brought to life« and how it was then applied and used can be observed. Lots of fun facts can be found in all these stories, which can give some positive highlights in learning activities. The complete story of an activity can help teachers give a conceptual framework, which leads to a more intensive experience for the pupils when it is connected with the STEAM hands-on learning approach.

The learning process, in which we bind history and STEAM topics, is fun, engaging, educational, and pupils enjoy it. Learning by relying on facts introduced by someone, in complex subjects like maths, technology, engineering and science, is more or less monotonous and non-motivational.
If pupils get to know the historical story, connect it to the historical discoveries and with hands-on experiment try themselves, how it works, we are halfway to successful experiential learning. From here on, teachers should guide the pupils through thinking and debating about what they learn, while helping them apply their knowledge holistically. In such a manner, all the key factors of a successful learning experience will be covered." This learning approach can be widely used in the formal or informal curriculum. Also, the use of new technologies can be incorporated.

Chapter 6: No one is left behind (Inclusion)

As we have seen in the Pedagogical guide, we are endeavouring to create inclusive materials in this project. Inclusion is about making learning and materials flexible, accessible, and understandable to all learners. The idea is to promote STEAM learning through History, and as we have already established, students with SLDs especially are part of the group of students most likely to fall behind in STEAM subjects. The use of manipulations and of contextualising elements is a great help in engaging pupils that face difficulties in STEAM subjects, especially those with an SLD. In order to succeed in our objective, we need to lift up all the pupils, with a special attention given to those who are most susceptible to falling behind. Hence, inclusion is a very important topic to address in this project. As one of the most specific groups in need of special attention, we will concentrate on SLDs in this chapter.

1. Learning Difficulties and How to Help

6.1.1. Small reminder of Learning Difficulties; What are they?

In this project, we will have a special focus on SLDs: Specific Learning Disorders. SLDs are permanent conditions that affect the learning process of someone. The way the brain processes information is affected due to a **neurobiological cause.** This may affect how the brain receives, integrates, retains, and expresses information. Consequently, the **cognitive development of a learning ability** can be disturbed. However, SLDs are in no way stemming from a physical impairment such as a visual or hearing impairment, a motor disability, or intellectual disability. Nor are they due to an emotional disturbance, nor a disadvantage of the economic, environmental, or cultural nature.

We have students with different learning disorders such as: Dyslexia, Dysgraphia, Dyscalculia, Dysphasia and Dyspraxia. Each of these SLDs benefit from an alternative learning style in order to use a different cognitive means of learning than the one with which they have difficulties.

6.1.2 Adaptations in the context of NFE

The adaptations in the context of NFE allow us more liberty in terms of learning styles. The usual adaptations covered in our pedagogical guide can, and should, of course, still be put into practice. Those would be adaptations such as:

- adaptation of the structure of the lesson (clear goal, clear set of guidelines, and subdivision of tasks into small steps, visual elements, etc),
- adaptation of the learning environment (uncluttered, quiet, sufficient multisensory stimulation, no stimuli overload, no long eye-movement, etc),
- adaptation of the tasks (multiple task types, reduced double-tasks modes, good structure and subdivisions, reduced fine-motor-skills-requiring tasks, avoidance of difficult manipulation, etc),
- adaptations of written materials (text aligned on the left, in an adapted font such as Arial, Century Gothic or OpenDys, with a 1.5 spacing, in a font size between 12 and 14. The use of paragraphs, subtitles, colour and bullet points to structure the text, printing on one side, with appropriate contrast)

But also, the added information about SLDs for tolerance goals, the group cohesion and team spirit promotion in the classroom are of importance. However, in the context of NFE, those adaptations are not limited to that. The use of NFE will allow for more flexible teaching materials' types and, as a consequence, will imply different skills requirements.

6.1.3 The importance of information and identification of difficulties

Creating adapted content for the widest array of learning styles possible will help us in creating more inclusive content. However, while this is a vast improvement already, one of the most efficient ways of creating efficient inclusive content is still dependent on knowing your audience's needs and characteristics as thoroughly as possible. In the case of SLDs in particular, one could not underestimate the importance of being aware of the specific special needs of one (or more) particular student(s). Teachers should have a basic understanding of how these learning disorders can influence the learning experience and overall performance of a student. Furthermore, while teachers are not habilitated in giving a scientific diagnostic themselves, they are in the best position to recognise early signs of a potential SLD and to inform the parents of the need to verify it with a professional for a medical diagnosis. If a professional diagnosis has been made, the teacher will be better armed to include the student's needs in their individual lesson planning and in their general method to make sure to cover the student's needs. While proper super-tailored teaching may not be realistically put into place by the teacher for each and every student, being aware of the situation and attempting to include more variety of learning styles in their teaching methods can go a long way in helping students with SLDs in their daily learning journeys. It may also help the students themselves to understand their strengths, weaknesses and potential learning coping mechanisms.

2. Multisensory Learning [visual, auditory, reading / writing, kinaesthetic learners]

6.2.1. What is Multisensory Learning?

There is more than one way of learning and different learning types in students. Some are more visually oriented, some more auditory oriented, but while those are the most used methods in "classic" teaching, some students are oriented

towards different learning styles as well. Multisensory learning is a method that integrates different types of learning elements such as: visual, auditory, tactile (touch) and kinaesthetic (movement) learning elements as the most known ones. But some learning styles are less known, such as: sequential teaching, simultaneous teaching, Reflective/logical teaching, Verbal teaching, Interactive teaching, Direct experience teaching, Indirect experience teaching, and rhythmic/melodic teaching. The idea behind these is to stimulate more senses while learning in order to activate different parts of the brain to reinforce the learning process. The more varied the type of sensory input to reinforce a single concept, the more likely it is to stick in the memory.

6.2.2. The benefits of multisensory education in general

One of the main benefits of this method is that it will be effective for all learners, especially for those with a specific learning disorder such as Dyslexia. This means that a lesson created using Multisensory learning will be beneficial for more learners than a classic one and will be more efficient and flexible in its use, especially for pupils with special needs, without impeding the learning of pupils without special needs. It will also help the learner to find the learning style that is most suited for them, as well as the most effective techniques. This will in turn help them build their personal learning methods and create their own learning process. This method also enables the teacher to customise their teaching methods depending on the pupils present during the lesson. An added benefit is that this method is adaptable to any subject.

6.2.3. The benefits of multisensory education for inclusion

As we discussed above, multisensory learning is especially efficient for pupils with learning disorders. Indeed, by diversifying the types of learning elements, you diversify the means to cognitively assimilate information for the pupils. Students with Specific Learning Disorders have a cognitive issue in terms of

assimilation of information: by diversifying those cognitive processes, you give them more chances to retain information through alternative cognitive routes. This basically levels the field of learning a little bit for learners with a Specific Learning Disorder.

6.2.4. Practical examples of Multisensory education exercises

For example, we could imagine using building blocks to recreate a Medieval arch that would redistribute the Forces into the ground and enable us to build higher, more solid buildings (examples: Roman arches, Gothic arches, etc). This manipulation would give us the auditory aspect by having the teacher explain the activity, the visual aspect by seeing the visual representation in the form of plans but also the visual aspect of the result, the touch aspect by the physical feeling of the weight and texture of the building blocks, the kinaesthetic aspect by the manipulation of actually building the arch and making sure that it doesn't fall down, the interactive aspect by realising the experiment in groups and having to coordinate with other students to make sure the arch doesn't fall down while building, the direct experience aspect by realising a hands-on experiment, etc.

The multiplication of learning elements' types is more efficient in making the information stick in the student's memory.

6.2.5. Applying multisensory Learning in STEAMbuilders

A physical manipulation of a STEAM concept, as we do here in STEAMbuilders and as was taken in the example in the previous point, can be considered as Multisensory education in the sense that we are using History to explain concepts in a concrete way. Pupils are at least able to See, Hear, Touch, and manipulate (Kinesthetic). We could imagine adding other senses into the mix such as associating a smell (the smell of plaster in the previous example? Or, of incense for churches?)

3. The power of Non-Formal Education for an inclusive classroom

6.3.1 How to use NFE for inclusion

The use of NFE for inclusion must be done in the spirit of diversity of learning. The idea of inclusion is to answer the learning needs of all pupils, regardless of any challenges or learning needs they may have. By using NFE, we are opening the door of possibilities in terms of learning styles and elements. NFE is also a wonderful opportunity to raise awareness for tolerance and the valorisation of difference in terms of sets of skills, cognitive types and types of intelligences in a way that is not as possible with traditional learning.

6.3.2 The Benefits of non-formal education for inclusion

The use of NFE allows for a better flexibility of learning and education. As stated previously, pupils with special needs, especially pupils with SLDs, are often ill-equipped to follow a traditional ex-cathedra, text-based teaching style. The added use of NFE will allow educators to multiply both the teaching support's types and the learning elements, while also promoting engagement in all pupils and helping pupils in their life-long learning process.

6.3.3 The benefits of inclusion on Education in a non-formal context

As for the benefits of inclusion in a formal context, first of all, inclusion will allow the whole class to be lifted up in the learning process. By including all pupils in a non-formal context, you provide a wider variety of learning tools and methods to all pupils, helping them in the development of their life-long learning journey and giving them the tools to further their education on their own in the future in a potentially less-inclusive context. Inclusion in a non-formal context also allows pupils to have a better understanding of the variety of learning styles and the

diversity of the neurological pool. This will not only help with learning tolerance towards fellow pupils, but also teach them to recognise and value neurodiversity in the future. This may also help promote better self-image and self-confidence in pupils for whom the traditional system didn't allow for academic success and help them find alternative ways to thrive academically.

While inclusion will benefit the pupils who have special education needs directly, it will also benefit other pupils, as while they do not have a particular need for a different approach, it can only enrich their education and give them more tools to use in their own educational journey. It will in turn promote engagement and motivation with the pupils.

Chapter 7: Existing Practices

1. Existing practices of non-formal / hands-on / experiential education

As we have previously seen in the Pedagogical guide the results of the Pisa study project have concerned the governments through Europe.

Over the years, governments, municipalities, schools and teachers have called for action. Many development projects have been carried out both at national and international levels and it is still as if the students' achieved goals in teaching are not sufficient. Our school system is losing far too many, perhaps because it, with its one-sided focus on knowledge and bookish skills, is not inclusive?

The degree of complexity in the teaching is so high that it calls for human-friendly environments and structures in which teachers must live up to their own intentions and the expectations of the outside world, partly to interact positively with the students and partly to contribute to the students' versatile development. In the school year 2019/2020, the Danish public school, Folkeskolen, had 78.5% of all pupils. The Danish Folkeskole does not offer that framework! PhD, school researcher and school consultant Louise Klinge describes Folkeskolen as follows:

"1 adult for 28 children. In a square room with down to 1.7 square meters per student. Until recently, teachers had to communicate 3,170 common academic goals. At least 122,000 of the students come from families with alcohol abuse, and about every fourth child has been exposed to physical violence in the home. The teacher is confronted with the children's challenges, but as a starting point does not get supervision and the opportunity to turn around major dilemmas and problems with a psychologist.

Many regulations for and in schools have been inherited for generations, and they are often taken for granted. But in the more than 200 years we have had the public school, it has never been proven that it should be best for the child and society:

- to expect children and young people to do the same things at certain times
- to divide reality into subjects
- to consider learning processes as specifically linked to specially designed activities
- to let the children concentrate on many different subjects on the same day, and to let a bell decide when the engagement in a subject should begin and end
- that children and young people can seldom, perhaps never, immerse themselves in what interests them
- to assess children and young people through numbers in relation to whether they can account for the correct understanding of the world that the school has convey
- to weight academic skills higher than the creative and practical
- to divide children by age
- to have one teacher for 28 students
- not to consider children's unequal everyday conditions and serve healthy school meals
- to let almost all teaching take place inside
- to academicise the teaching in such a way that academic meta-terms today must be learned from the youngest students”

Louise Klinge harshly concludes: "We lose a lot of children along the way” and the PISA surveys support her claim.

Her critique of the school system simply shows that if we want to work with the children's benefits of education, then it is a complex issue where there are many challenges to solve. It is probably not solved with a single innovative method. Is the school just a place where the adults have decided what knowledge and what

skills the teaching is organised according to - or do we dare to ask the students what they think?

The following statements are from the Virtual Conference in “Inclusive learning environments: Opportunities for participation for all”, held December 12th, 2020. Louise Klinge presented some children's dreams of school:

Children's dreams about school:

- "A subject where you learn to make your own furniture".
- "Learn about history by building that age”.
- “Week of Stone Age camp on a piece of land away from school ".
- "Contact with children from other countries".
- "Do things by hand instead of looking in a book".
- "Textiles in the class, so you can sew".
- "There can be planks and wood so you can build".
- "In reality every day, have Danish at a publishing house, physics and chemistry in a real laboratory".
- "Sort rubbish".

It is remarkable to see the students' longing for tangible teaching, which must have its origins in the real world, which is not divided into subjects but goes across subjects and may almost certainly have originated in concrete problems.

A sub-area within STEAM teaching is when the teaching is moved out of the class’s normal teaching space e.g., out in nature, in the supermarket, in the cemetery, businesses or museums. This type of teaching is called, in the Nordic countries, "Outdoor school” (In Danish: Udeskole). However, it can be a misleading term, as it is often confused with teaching in nature and nature related subjects. " Outdoor school "is more than that. Therefore, it is the right description: Target-directed teaching outside the classroom”. Moving the teaching out of the classroom offers very special opportunities: teaching in

nature or at cultural institutions in interaction with teaching in the classroom creates special opportunities for students' learning".

A 2014 study published by the American Society for Engineering Education identified several characteristics of quality STEM programs:

- The context is motivating, engaging, and real-world.
- Students integrate and apply meaningful and important mathematics and science content.
- Teaching methods are inquiry-based and student-centered.
- Students engage in solving engineering challenges using an engineering design process.
- Teamwork and communications are a major focus. Throughout the program, students have the freedom to think critically, creatively, and innovatively, as well as opportunities to fail and try again in safe environments.

It is interesting to compare with the experience of the research, which shows the benefits of "moving teaching out of familiar classrooms"

- Physical / health angle: Children who learn in context often move more than children in traditional institutional environments or schools.
- Several meta-studies show a connection between physical activity and learning, and in a statement from the "Consensus Conference on Physical Activity and Learning" held on 25-27 October 2011, researchers from Denmark and Sweden express the following: "On the basis of the presented research results and the discussions at the conference, it could be concluded that there is a documented connection between physical activity and learning regardless of age".
- The social angle: Well-developed teaching and learning activities in the environment support a good social climate in groups, support the ability to concentrate, immerse and lay a good foundation for immersion.

- Learning in context: Learning through the local environment seems meaningful to children, young people, and educators. Teachers report that children enjoy these forms of learning more than traditional classroom teaching.

The versatility argument: Outdoor school can mean more versatile learning. Outdoor schooling can mean more versatile learning compared to:

- catalogue knowledge
- analogue knowledge
- dialogical knowledge
- body-based knowledge

With diverse forms of knowledge, many different parts of the brain are affected, and several complex neural connections are formed (Neuropedagogy):

- Episodic memory - narrative
- Procedural memory - bodily
- Semantic memory - linguistic and factual

The brain research argument: Children contribute more actively to language processes in learning processes in the open air, and the language used in these contexts is more imaginative and exploratory.

2. Existing STEAM education

At a national level in Denmark:

From September 2020, teachers in the science professional group can study a master's in STEM teaching. The idea is part of the national science strategy and takes place through e-learning, practice and guidance at your own school, as well as teaching days at the university.

"The idea is to train future local or municipal resource people within Stem teaching (Science, Technology, Engineering and Mathematics) so that they can help strengthen the person and interdisciplinary teaching within the science range in primary school", says Jan Alexis Nielsen, Head of Studies at the new education and associate professor at the Department of Natural Sciences Didactics, where the new education will be anchored.

The existing teaching takes place primarily in the well-known science subjects, nature and engineering as well as relatively new subjects: "Crafts and Design" in the public Danish primary school "Folkeskolen", which replaces the subjects of Woodwork and Needlework from the school year 2016/17. In the new national Curriculum, it is clarified that the subject must work with innovation and entrepreneurship. Since 2007, in teacher training, Woodwork and Needlework have been replaced by material design.

The purpose of the teaching of Crafts and Design is that the students acquire knowledge and skills through the practical work with different materials - preferably wood, metal and textile. The teaching will contribute to the student's developing knowledge of material culture through craftsmanship and design.

STEM education in private institutions:

There is a lot of interest in offering STEM training and materials – also from private companies such as LEGO, (which is short for Play Well in Danish. LEg GOdt) which are world-known for the toy called the "Lego Brick", which is designed to build models of just about everything from well-known universes such as STAR Wars and Harry Potter, buildings, machines, etc. LEGO is a major provider of educational materials, lessons, software, programming, online portals and support. The teaching is aimed at children of virtually all ages and in many languages. There are even teaching materials for homeschooling. LEGO is a private company that makes a living selling Lego-related products.

STEM education in Europe:

School Education Gateway is an example of Europe's online education portal, where it is possible to find inspiration from Erasmus+ projects based on STEM/STEAM, for example. Innovation starts with STEAM, DLAP, etc.

3. Exploring museums' non-formal techniques - Experimenting with ancient tools and techniques

A different but no less effective "game changer" in STEAM teaching may be found in the museums' school services. The museums are not only an obvious opportunity to see and listen, but also to touch and do.

The Stone Age is an obvious opportunity for the very basic understanding of the emergence, maintenance and materials of life. At the Neanderthal Museum in Germany, students can learn about how to find your way in the dark by making a small oil lamp. Stone Age Center Ertebølle in Denmark offers the opportunity to gain experience with archery, dugout log boat sailing and many small crafts such as the production of Stone Age colours and patterns.

Left: Museum Neanderthal, Germany Right: Stone Age Centre Ertebølle, Denmark.

The Middle Ages also contain tangible historical recognition. The Medieval Center on the island of Lolland is a recreation of a medieval village in the early 1400s in the size of 1:1. Here you will find the city's craftsmen, citizens, and warriors, dressed in authentic suits. In addition, the medieval village, Sundkøbing, also houses a technology park inspired by Medieval/Renaissance inventions, like some of Leonardo da Vinci's inventions which the students can test. In the technology park there is the possibility to book courses.

Guedelon is a living "Reconstructing Saint-Fargeau Castle' in France. It is also a center for heritage skills training. Guedelon also offers courses where, for example, you can follow in the Builder's footsteps and explore crafts, techniques, meet the craftsmen, etc.

Photo: https://www.facebook.com/Guedelon/photos/3761200530627052

Role-playing at the museum

A completely different and highly motivating approach to the dissemination of cultural heritage, techniques, crafts, etc. can be through the so-called role-playing game courses, where students are dressed in costumes, given new names and features in an ancient existence.

Image 1: In The Old Town in Aarhus, Denmark, students can try "One day as children in 1864". Source: www.dengamleby.dk. by permission

Image 2: At Hessel Manor, Denmark, students can try to be employed as a maid or fellow in 1870. They also meet an act with the manor´s strict teacher, Mr. Christoffersen. Source: Vesthimmerlands Museum

Role-playing courses, where students test and learn techniques/crafts, give students an emotional relationship with the past. It is often seen as being very motivating for students to learn through role playing and practical work, where processes and results are followed e.g., cooking, rope slaughter, forging, etc.

Conclusion

The Non–Formal Education in STEAM Booklet is the second written output of STEAMbuilders, an Erasmus+ project – a collaboration between Belgium, Cyprus, Denmark, France, Greece, Slovenia and Spain. The booklet mainly focuses on the tools for learning in a non – formal education, analysing the importance and the difficulties of such an approach.

In the first chapter, an introduction to non–formal approach is discussed. Tools for learning (principles and techniques) and examples of educational experiences are thoroughly examined, always under the scope of incorporating into the official STEAM curricula.

Moving on, the differences between formal and non – formal education are considered, linking the two approaches in a holistic educational experience in STEAM. Additionally, a more hands-on learning environment adapts to the diversities and needs, while educating and involving everyone in the process. Through heritage and history, the booklet presents positive role models that the students can relate to.

If we want to have diversified and educated people, they all need to be involved. STEAM-based teaching -using the correct methods and practices- can be of particular use to students with special learning disabilities. Maybe STEAM teaching can even help to open the eyes for all people, regardless of diagnoses, to meet their personal and educational goals. As we continue to navigate an uncertain future, the existing practices in experiential and STEAM education -as exploring museums or experimenting with ancient tools- call for systematic research to improve and turn into inclusive everyday academic material.

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Chapter 7

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*The definition of “Udeskole” is commonly accepted as an official definition. To Be “An advisor of Udeskole” is a course created by The University of Copenhagen, Denmark.