

E-Book pedagogical for STEM-Xhibitions

Table of content

Introduction to exhibitions in education and exhibitions in STEM	2
Chapter I: Benefits of Exhibitions as a learning and pedagogical tool (inclusiveness of Dys students)	6
Chapter II: Types of learning (experiential learning; PBL)	15
Chapter III: Co-creation in STEM	27
The chapter IV: Explore Digital, Physical, Phygital and tech and software for digital creation of art	36
Chapter V : Best Practices from Similar EU Settings	50
Conclusions:	59
References of Chapters	60

Table of Figures

Figure 1: Cartoon image of students sourced from Freepik (freepik.com).....	3
Figure 2: Canva sourced picture for STEM education	5
Figure 3: Exhibition in a Greek school (High school of Proastio Karditsa)	7
Figure 4: Dyslexia-children-Stem. (From https://www.sdsquared.org/)	8
Figure 5: Jobs of the left and right hemispheres of the brain. (https://www.stepbystepdyslexiasolutions.com/)	9
Figure 6: This diagram highlights the connection between the identification of dyslexia and Curriculum for Excellence (from https://www.open.edu/openlearncreate)	9
Figure 7: Pythagorean liquid disk, Pythagorean balance and Pythagorean decomposition puzzles at [Meet Math Museum] (https://www.mathcom.wiki/)	10
Figure 8: The display board of a science fair project.....	11
Figure 9. Exhibition in a Greek school (High school of Proastio Karditsa)	11
Figure 10: Exhibition in a Greek school (High school of Proastio Karditsa)	11
Figure 11: Math's in the stage (https://leverageedu.com/blog/mathematics-movies/).....	12
Figure 12: group of students participate in a theatrical role «Waiting for a job interview»	12
Figure 13: Nadja Vohradsky – Sliceforms (https://www.maths.ox.ac.uk/about-us/art-and-oxford-mathematics/oxford-mathematics-online-exhibition-2020)	13
Figure 14: National Museum of Mathematics (https://momath.org/).....	15
Figure 15: Six prominent learning style models (Hawk, Shah, 2007).....	16
Figure 16: VARK learning styles.....	17
Figure 17: Kolb's model of experiential learning.....	21
Figure 18: Kolb's learning styles	22

Figure 19: Essential Elements of Project Based Learning.....	26
Figure 20: Picture Art modern (Image credit: Getty Images / lithiumcloud)	39
Figure 21: Physical and digital combination of art exhibition (source www.behance.net)	40
Figure 22: Picture digital Art creation (source: https://www.lifewire.com/best-digital-art-software-4705458)	42
Figure 23: Steps diagram for a successful implementation	43
Figure 24: Types pf physical activities (souce: https://newsinhealth.nih.gov/2020/07/personalized-exercise).....	47
Figure 25: PERFORM project logo taken from the project website (http://www.perform-research.eu/)	51
Figure 26: I-STEM project logo taken from the project website (https://istem-project.eu/)	52
Figure 27: STE(A)M IT Project logo taken from the project website (https://steamit.eun.org/)	52
Figure 28: STEAMBUILDERS logo taken from the project website (https://steambuilders.eu/)	53
Figure 29: VXDesigners platform link taken from the project website (https://vxdesigners.eu/)	55
Figure 30: DLaB project logo, taken from https://dlaberasmus.com/	55
Figure 31: STEAMonEdu project logo taken from https://steamonedu.eu/	57
Figure 32: Choice project, source https://www.euchoice.eu/	58

Introduction to exhibitions in education and exhibitions in STEM

In a world where most of our everyday activities are increasingly becoming reliant on STEM subjects and STEM-oriented jobs, there has been a significant upsurge in the need to improve education on these subjects. Andrews (2015) speculates that the rhetoric around STEM jobs translates to ‘jobs for the future’, and the World Economic Forum (2016) determines that STEM literacy is a measure of the future readiness of countries (Sheffield, Koul, Blackley, Fitriani, Rahmawati & Resek 2018, p 67). Hence, it is vital to attract more students to STEM-oriented career paths.

What is STEM education?

STEM education at its heart, means educating students in the four disciplines that make up its name (Science, Technology, Education and Mathematics). Instead of training students in each discipline separately, STEM combines all four in an interdisciplinary approach (Myhill, 2020). However, STEM education has been going through great reform in the modern day, with the integration of art subjects and art-styled teaching, creating the **STEAM** (A, now standing for Arts) educational approach.

How does STEAM benefit STEM and non-STEM subjects?

The integration of Art subjects and subsequently, Art-style methods of teaching, has greatly benefitted both STEM and Non-STEM education. In order to understand the benefits that come with STEAM education we need to understand the concept of hard and soft skills and the role they play in education.

Hard skills are skills that have been acquired and enhanced through education and experience (Connett, 2023). They are specific abilities, capabilities, and skill sets that an individual learns and performs job-specific tasks (Gillis, 2023). **Soft skills**, on the other hand, are more behavioural skills than technical.

They are interpersonal skills that allow people to communicate with others, and personal attributes that help team members interact with each other and succeed in their tasks (Kenton, 2023). STEM subjects are therefore limited by hard skills, making students think more mechanically, work on their subject goal and not promote collaborative work and discussion. Through the incorporation of Art soft skills, STEM students are able to learn new ways of working around a target subject and innovate their work. The same can be said for non-STEM students who, up until now, have been more soft-skill-oriented. Thus, they can also benefit from learning hard skills and getting educated in a different interdisciplinary way. Through this new way of teaching STEAM subjects, exhibitions have also started being implemented as a way of non-formal education.

Exhibitions are used as a common educational practice to improve the audience's critical thinking, problem-solving and reflection skills (VXDesigners, 2020). Furthermore, they give a platform to students allowing them to present their ideas and hone their skills by linking their learning and practical knowledge. Using exhibitions, students can focus on addressing areas of study through model-making and model presentation (Experifun Educational Solutions Pvt. Ltd., 2018). Museums and exhibitions are vital for informal learning. They offer untapped potential for communicating social, cultural, and scientific information, correcting misconceptions, and improving attitudes and cognitive skills (SchoolEducationGateway, 2021), allowing for a more hands-on experience that improves the audience's understanding of the concepts presented.

Connecting STEM (Science, Technology, Engineering, Mathematics) subjects with methods derived from Art subjects, such as exhibitions, is a great way to incorporate non-STEM audiences attracting a greater pool of people while also educating them. Non-STEM audiences can significantly benefit from exhibitions on STEM subjects simply because they can be a reliable source of information for them. Because of the ease of access that the internet has provided in the modern digital age, there has been a remarkable rise in misinformation and malinformation, especially in the STEM sector. Hence, STEM exhibitions have the ability to provide accurate information to their audience, helping to stop the spread of this false information. Depending on the type of STEM exhibition, different education opportunities can be presented to the audience. For example, science museums can cover many different STEM subjects as they typically hold exhibitions for all sciences involved. Another example would be exhibitions for technology and/or engineering which can both provide their audience with new information on Research and Innovation in each respective sector.



Figure 1: Cartoon image of students sourced from Freepik (freepik.com)

Exhibitions and students:

Using exhibitions in STEM has also proven to be more effective in increasing student interest and motivation in following STEM fields as career paths (ARTeria Foundation, 2020). Exhibitions provide a great variety of opportunities for shedding light on scientific topics. They can attract students from all educational disciplines due to the flexibility they can provide when created. Exhibitions in STEM education have also been shown to be effective in promoting student interest and motivation in STEM fields (Wahono, Lin & Chang, 2020). Having student-curated exhibitions (SCE), the students can gain insights into the topics they are investigating (Kampschulte & Parchmann, 2015, p 462). They can help develop the skills known as the '4Cs': critical thinking, communication, collaboration, and creativity (Kampschulte & Parchmann, 2015, p 479).

Exhibitions can provide an interactive and engaging way for students to learn about a particular subject or topic. Developing an exhibition can offer students a multi-layered environment for learning. This way, students can be pushed in developing skills, such as project management and critical thinking, supporting them in their private and working lives and enabling them to be a part of a global society, skills that usually are not addressed at school (Kampschulte & Parchmann, 2015, p 462).

Exhibitions and teachers:

Schools have a critical impact on developing knowledge and social interactions. It is an arena for shaping identities, characteristics, and personalities, and this process plays a vital role in shaping society. However, formal educational paths can be limiting and not fulfilling the expectations and interests of students, making the teachers' job of keeping the students motivated and interested in their topics a lot harder. This is why non-formal educational paths, such as exhibitions, can help both students and teachers (ARTeria Foundation, 2020).

With the integration of Art and STEM subjects, teachers can employ different approaches when developing exhibitions, making these topics more engaging towards their audience. This, in turn, is vital in restoring interest in STEM subjects from students, allowing teachers to impart knowledge to them more efficiently.



Figure 2: Canva sourced picture for STEM education

Exhibitions in STEM:

Developing an SCE on a STEM subject specifically, provides many opportunities for training various skills. It has been argued that there is a connection between art and STEM subjects. Using exhibitions allows this relationship to be expressed diversely allowing a bigger audience to consume knowledge (Karch, 2021). Research has proven (Cesar, 2008) that exhibitions allow students of varying levels of competence to progress better down their academic paths (Karch, 2021). The skills that inquiry-based learning, used in exhibitions, focuses on are the core skills required when designing said exhibitions. Students have to manage their own research, “formulate questions, plan their activity and draw and justify conclusions about what they have learned” (Kuhn, Black, Keselmann & Kaplan, 2000, p.497) (Kampschulte & Parchmann, 2015, p. 464-465). Lai (2018) concluded in their study that STEM academic performances had considerably risen because of inquiry-based learning and recommended that this teaching method should be further promoted (Lai, 2018, p 115).

SCEs offer opportunities to learn how to find reliable sources, gather different opinions on the topic and reflect on their findings during the preparation of the students’ exhibitions. Furthermore, SCEs promote cooperation and collaboration skills as they cannot be easily prepared single-handedly, and students are required to form teams and delegate tasks among themselves. In summary, SCEs are considered the perfect environment to train and reflect students’ skills due to the diversity and quantity of the tasks that are involved in their development. (Kampschulte & Parchmann, 2015, p. 466).

There are many exhibitions in STEM fields. These exhibitions can be used to showcase and educate on the latest advances and innovations in science and technology while allowing their audience to have a more hands-on experience and learn about complex scientific concepts.

Regarding STEM subjects such as mathematics, educators have been increasingly interested in teaching in informal settings. Using cross-disciplinary methods, such as exhibitions, allows them to utilise out-

of-learning environments that promote skills to pupils who have difficulties in learning in the more traditional class-system type of learning (Vainikainen, 2015, p. 15).

The dilemma educators face is whether exhibitions can promote learning for the subjects that educators are tasked with teaching. This is also one of the biggest challenges for open learning environments, such as science centres (Salmi 1993, 2003; Salmi, Sotiriou and Bogner 2009). However, it has been proven that exhibitions help keep the students' motivation and interest peaked, allowing teachers to have a greater pull over their students and impart knowledge to them. (Braund & Reiss, 2004; Csikszentmihalyi & Hermanson, 1995; Frantz-Pittner, Grabner, & Bachmann, 2011; Salmi 2003; Thuneberg, Salmi, & Vainikainen, 2014) (Vainikainen, 2015, p. 16). Utilising exhibitions for curricular learning allow teachers to guide students to specific educational goals determined by the teachers (Huan & Kolsto, 2014, p. 99), allowing, in turn, students to remain focused.

Learning outcomes:

The importance of exhibitions in education and STEM education has been introduced. The following sections of the guide will explore the following topics:

- **Benefits of exhibitions as a pedagogical tool (inclusiveness of Dys students)**
- **Types of learning (experiential learning; PBL)**
- **Co-creation in STEM**
- **Explore Digital, Physical, Phygital – tech. software for digital creation of art**
- **Best Practices from Similar EU settings**

Chapter I: Benefits of Exhibitions as a learning and pedagogical tool (inclusiveness of Dys students)

Introduction

Exhibitions are a popular tool in education because they can provide a highly engaging and interactive learning experience. Rather than simply reading about a topic in a textbook, students can see and experience the information firsthand through exhibits, displays, and demonstrations.

Benefits of exhibitions in the learning process

One of the key benefits of exhibitions is that they can be designed to cater to a variety of learning styles. For example, some students may be visual learners who benefit from seeing images, graphics, and videos. Others may be kinesthetic learners who prefer to learn through hands-on activities and

exploration. By incorporating a variety of different types of exhibits, exhibitions can help to engage students who might otherwise struggle to learn through traditional teaching methods.



Figure 3: Exhibition in a Greek school (High school of Proastio Karditsa)

Exhibitions can also be highly effective in promoting critical thinking and problem-solving skills. Rather than simply being told information, students can interact with exhibits, ask questions, and draw their own conclusions based on the evidence they see.

Another benefit is that they can be used to promote social learning. Students can learn from each other by working in groups or pairs to explore exhibits and engage with the material and build their communication and collaboration skills. They can be used to build community and foster collaboration among students.

Furthermore, exhibitions can be used to teach a wide range of subjects, from science and technology to history and the arts. Exhibitions can also be designed to accommodate learners of different ages, backgrounds, and abilities, making them a versatile tool for educators.

They can also help make learning more relevant and meaningful for students by providing real-world examples and connections to their lives. For example, an exhibition on sustainable energy might feature interactive exhibits that demonstrate how solar panels work or a history exhibition might include artifacts and primary sources that help students understand the context and significance of historical events.

Finally, this method of learning can be used to foster creativity and encourage students to think critically and analytically. Exhibitions often feature hands-on activities and interactive displays that challenge students to explore new ideas and make connections between different pieces of information. This type of active learning can be particularly effective in helping students develop their critical thinking skills.

How to use exhibitions to benefit students with dyslexia

In terms of making exhibitions inclusive for students with dyslexia, there are a number of strategies that can be employed. For example, exhibits can be designed to be highly visual, with clear graphics and

images that convey information in a way that is easy to understand. Exhibits can also be structured to provide multiple points of entry, allowing students to explore the information in a way that is best suited to their needs.

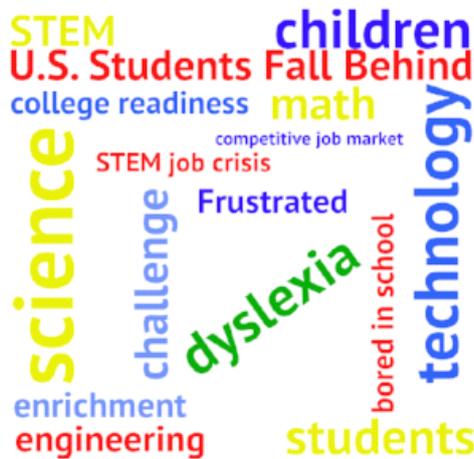


Figure 4: Dyslexia-children-Stem. (From <https://www.sdsquared.org/>)

Additionally, exhibitions can be designed to be highly interactive, with plenty of opportunities for students to engage with the material in a hands-on way. This can be particularly helpful for students with dyslexia, who may have difficulty staying engaged with more passive forms of instruction.

Benefits of exhibitions for students with dyslexia

A benefit of exhibitions as a pedagogical tool for dyslexic students is that they can help to foster creativity and encourage students to think outside the box. Exhibitions often allow students to see things in a new way, explore different perspectives, and make connections between seemingly disparate pieces of information. For dyslexic students, who may struggle with more traditional forms of instruction, this type of creative thinking can be particularly valuable.

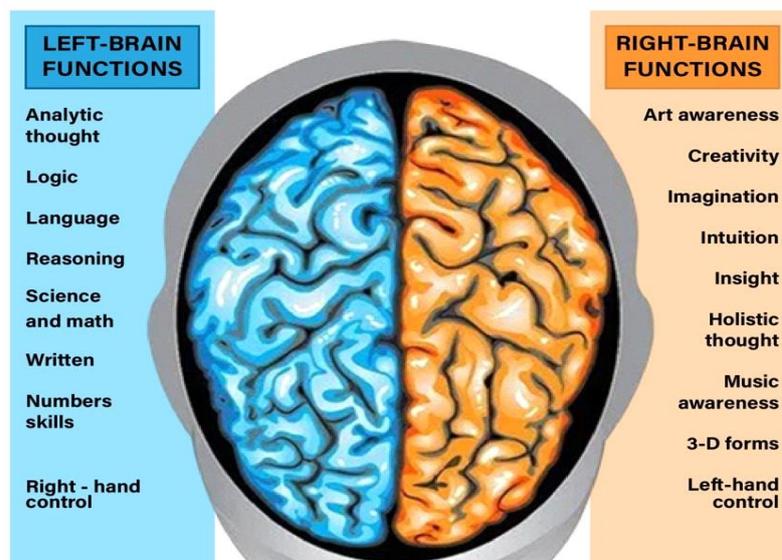


Figure 5: Jobs of the left and right hemispheres of the brain. (<https://www.stepbystepdyslexiasolutions.com/>)

Exhibitions can also help to build confidence and self-esteem in students with dyslexia. Many dyslexic students may feel discouraged or frustrated by their struggles with reading and writing, but exhibitions provide a platform for them to showcase their strengths and talents. By creating exhibits that highlight their unique skills and perspectives, dyslexic students can feel a sense of pride and accomplishment, which can help to boost their confidence and motivation.

In addition, exhibitions can provide dyslexic students with a sense of ownership and control over their learning. By allowing students to take an active role in creating and designing exhibits, they can feel a sense of ownership and responsibility for their learning. This can be empowering for dyslexic students, who may feel like they have little control over their academic experiences in more traditional classroom settings.



Figure 6: This diagram highlights the connection between the identification of dyslexia and Curriculum for Excellence (from <https://www.open.edu/openlearncreate>)

Overall, exhibitions can provide dyslexic students with a highly engaging, interactive, and inclusive learning experience. By tailoring exhibits to the needs and interests of the students, educators can create a learning experience that is both effective and enjoyable for everyone.

It's important to remember that exhibitions are just one tool in the pedagogical toolbox. While they can be highly effective in certain situations, they may not be the best choice for every subject or every student. As with any teaching method, it's important to consider the students' individual needs and learning styles and tailor the instruction accordingly.

Types of exhibitions:

Exhibitions can take many forms, from museum exhibits and science fairs to classroom displays. Here are some examples of how exhibitions can be used as a pedagogical tool:

Museum Exhibits: Many museums have exhibits that are designed specifically for educational purposes. For example, a history museum might exhibit a particular time period or event, while a science museum might exhibit a particular scientific concept. These exhibits can be highly interactive, with hands-on activities and demonstrations that allow students to engage with the material in a fun and educational way.

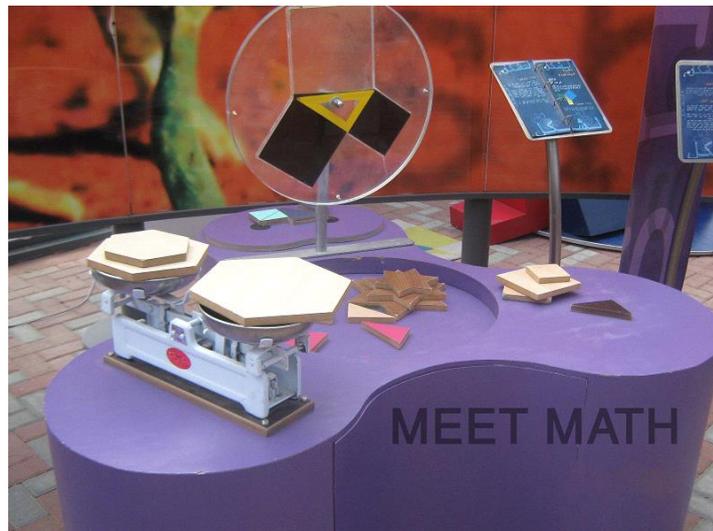


Figure 7: Pythagorean liquid disk, Pythagorean balance and Pythagorean decomposition puzzles at [Meet Math Museum] (<https://www.mathcom.wiki/>)

Science Fairs: Science fairs are a popular way for students to explore scientific concepts and conduct experiments. By creating a display that showcases their work, students can demonstrate their knowledge and engage with others who are interested in the same topics. Science fairs can be particularly effective in promoting critical thinking and problem-solving skills, as students must design and conduct their own experiments and draw their own conclusions based on the evidence they collect.

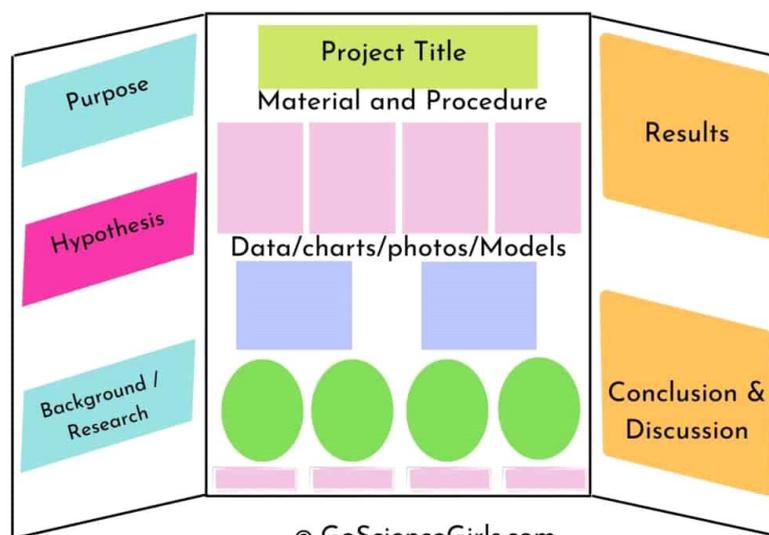


Figure 8: The display board of a science fair project

Classroom Displays: In a classroom setting, exhibits can be used to showcase student work or to provide visual aids that help to illustrate key concepts. For example, a social studies teacher might have a display that highlights different cultures from around the world, while a language arts teacher might have a display that showcases different literary genres. By creating displays that are visually engaging and informative, teachers can help to make the material more accessible and interesting to students.



Figure 9: Exhibition in a Greek school (High school of Proastio Karditsa)



Figure 10: Exhibition in a Greek school (High school of Proastio Karditsa)

Theater: Theatre, as a form of exhibition, brings the magic of storytelling to life through live performances on stage. It is a captivating and immersive experience that engages the senses and emotions of the audience. In a theatrical exhibition, students have the opportunity to witness a dynamic interplay of characters, dialogue, music, and visuals, creating a rich and compelling learning environment. One of the key benefits of theatre as a form of exhibition is its ability to foster imagination and creativity. Through the power of live performances, students are transported to different worlds, time periods, and perspectives. They witness the art of storytelling unfolding before their eyes, which can ignite their own creativity and inspire them to explore new ideas and concepts. The theatre also

cultivates empathy and emotional intelligence among students. By witnessing the struggles, triumphs, and conflicts of characters, students develop a deeper understanding of the human experience. This emotional connection enhances their ability to relate to others, think critically about social issues, and appreciate diverse perspectives. For students with dyslexia, who may rely on visual and experiential learning, theatre provides a unique opportunity to engage with complex emotions and social dynamics. Furthermore, the theatre encourages collaboration and teamwork. The production of a play involves actors, directors, designers, and technicians working together towards a common goal.

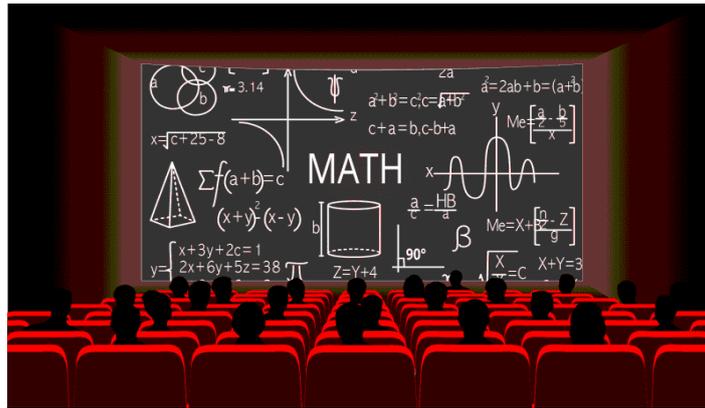


Figure 11: Math's in the stage (<https://leverageedu.com/blog/mathematics-movies/>)

Students participating in theatre productions learn the value of effective communication, cooperation, and problem-solving. These skills are essential not only in the realm of theatre but also in various aspects of life, such as group projects, teamwork, and future careers. For students with dyslexia, theatre offers additional benefits. Dyslexic students often excel in visual and auditory learning, and theatre provides a multisensory experience that caters to their strengths. They can observe the facial expressions, body language, and movements of the actors, which aids in visual understanding. Simultaneously, they hear the dialogue, music, and sound effects, reinforcing auditory comprehension.



Figure 12: group of students participate in a theatrical role «Waiting for a job interview»

This combination of visual and auditory stimulation enhances their learning experience and comprehension of the material. The inclusive nature of theatre also benefits students with dyslexia. Theatre performances often incorporate visual supports, such as costumes, props, and set designs, which

can aid in understanding and memory recall. Additionally, through participation in theatre productions, dyslexic students can build self-confidence, improve public speaking skills, and develop their creativity and self-expression. In summary, theatre as a form of exhibition offers numerous benefits for all students, including those with dyslexia. Its immersive and multisensory nature sparks the imagination, cultivates empathy, and promotes collaboration. For dyslexic students, theatre provides a visually and auditory-rich experience that enhances comprehension, boosts self-confidence, and nurtures their creative abilities. By incorporating theatre into educational settings, educators can harness its power to engage and inspire students of all abilities, fostering a love for the arts and a deeper understanding of the world around them.

Virtual Exhibitions: With the rise of online learning, virtual exhibitions have become increasingly popular. These exhibits can be accessed from anywhere with an internet connection and can be highly engaging, with interactive elements and multimedia content. Virtual exhibitions can be particularly helpful for students with dyslexia, as they can be designed to be highly visual and interactive, with text that is presented in a way that is easy to read and understand.

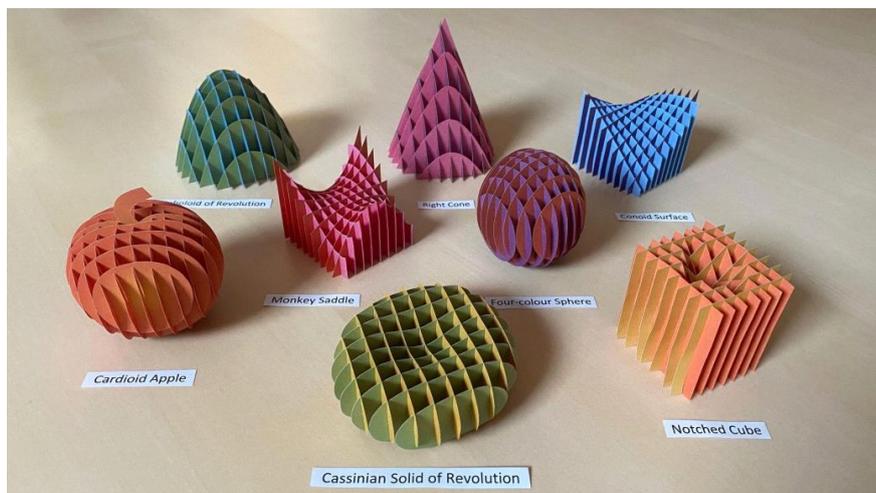


Figure 13: Nadja Vohradsky – Sliceforms (<https://www.maths.ox.ac.uk/about-us/art-and-oxford-mathematics/oxford-mathematics-online-exhibition-2020>)

In all of these examples, exhibitions are being used as a pedagogical tool to engage students in the material, promote critical thinking and problem-solving skills, and encourage social and collaborative learning. By tailoring exhibits to the needs and interests of the students, educators can create a learning experience that is both effective and enjoyable.

The role of art exhibitions and museums in particular

Art exhibitions serve as platforms for showcasing the creative work of students and artists, offering insights into specific time periods or cultures. Through curated displays that highlight diverse styles and techniques, students have the opportunity to delve into the historical and contextual aspects of various art forms. Moreover, art exhibitions can be immersive and interactive, allowing students to engage in hands-on activities, create their own artwork, and explore different artistic techniques and materials.

Over the past two decades, there has been significant progress in the realm of cultural education. Efforts have been made to encourage both children and adults to recognize, explore, and celebrate their cultural heritage. This initiative aims to counter social exclusion and foster individual and collective well-being. Museums, galleries, exhibitions, and numerous non-formal educational activities play a pivotal role in this process by providing spaces for individuals to engage with their heritage, promote inclusivity, and contribute to shared prosperity.

Exhibitions and museums offer opportunities for critical engagement in important subjects, associated with history, memory, and identity.

Engagement, inspiration, and active learning are the priorities for museums and galleries, which try to build relations between the visitors and their cultural heritage.

Such institutions function as an agent, a means of facilitating presentations, engagement in the past, and strengthening mass memory. Museums serve as institutions that preserve, transmit, and examine collective memories and historical narratives. History grants us access to the past as it is interpreted and shared through the collective memory. In times of uncertainty, this shared memory can provide individuals with a sense of belonging and connect them to familiar concepts, helping them navigate the world.

While school field trips to museums and exhibitions are not a novel concept, these spaces are not limited to students alone; they are beneficial to anyone. Regardless of the audience's diversity, engaging in sightseeing and interacting with various collections enhances motivation for informal learning.

Schools play a pivotal role in fostering knowledge and social interactions. They serve as platforms for shaping identities, traits, and personalities, thereby exerting a significant influence on society.

Teachers responsible for art and history education have a vital role to play in developing and implementing activities that expose students to direct engagement with art. They can demonstrate how art can be utilized to convey the past, present, and future, thereby contributing to a comprehensive understanding of history.



Figure 14: National Museum of Mathematics (<https://momath.org/>)

Certainly, it is not solely the responsibility of art and history teachers to connect school groups with the outside world, although it may initially appear as the most obvious choice. Cultural education, which encompasses exploring landmarks, museums, and exhibitions, can prove beneficial across various disciplines. The relationship between art and subjects like mathematics, geometry, biology, physics, geography, as well as humanities, is evident. For instance, visiting a nature museum provides an exceptional opportunity to comprehend nature itself. Similarly, literature classes can gain value from a museum trip where a handwritten version of a particular work is on display. Geometry can be approached as the art of analyzing cubism or seeking analogies between different artistic styles. buildings, such as the Parthenon, famous for its architectonic solutions.

Educators and developers of educational curricula should bear in mind that learning relies not only on the teacher's spoken instructions but also on engaging students' cognitive abilities, personal skills, problem-solving, and hypothesis formation. The teacher assumes the role of a facilitator, directing and supporting students in this process, rather than being the sole focus of learning. Emphasizing learning beyond the confines of the classroom is advantageous, promoting both academic and personal growth in individuals, and thus should be incorporated into school educational programs.

Chapter II: Types of learning (experiential learning; PBL)

Types of Learning Styles in education

It's been well established that that people learn in different ways. Traditional approach to teaching and learning indicated that teacher should known how to teach his/hers students using different strategies

for getting the message into long term memory of students so that they could get it out again at the appropriate exam or test (Fleming, 1995). Over the past two decades we started to talk about different learning styles and models. According to Hawk and Shah (2007) learning style is part of our personality and it consist of some dispositional traits and characteristic adaptations. Ridwan, Sutresna and Haryeti (2019) defines learning style as a strategy of learning that works best for each individual. People learn in different ways and each of us has their own different preferences or learning styles in the way we process, recognize and memorize information (Ridwan, Sutresna, Haryeti, 2019). Every one of us have our own set of strengths, weaknesses and preferred ways of learning. Term in education that describes these preferences is called learning styles. Each learning style outlines the most effective ways that students receive information, interpret it, organize and memorize it (Choudhary, 2021). Today, the main premises in education is that students learn in diverse ways and one approach to teaching does not work for every student (Hawk, Shah, 2007). We are talking about multiple or overlapping learning styles, also called multimodal learning (Choudhary, 2021).

Educators and researchers have identified many models of learning styles over the years. A few that are of most importance are learning styles models by Felder-Silverman, Dunn&Dunn, Kolb, Gregorc, RASI (Revised approaches to studying inventory) and VARK (Hawk, Shah, 2007).

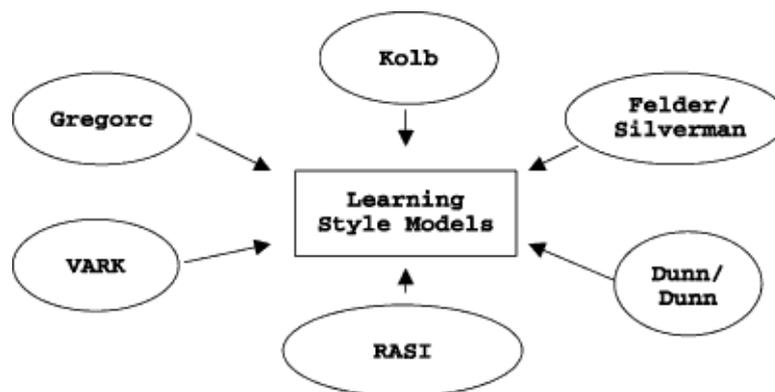


Figure 15: Six prominent learning style models (Hawk, Shah, 2007)

Today, one of the commonly used models is VARK by Fleming (Othman, Amiruddin, 2010). Fleming (2001) defines learning style as “an individual’s characteristics and preferred ways of gathering, organizing and thinking about information” (Hawk, Shah, 2007:6).

VARk learning style model developed by Fleming and Mills, is a sensory model that is an extension of the previous neuro-lingvistic model (Eicher, 1987 cited in Hawk, Shah, 2007) and classify students to four different modes, based on different senses – visual (V), aural (A), reading (R) and kinesthetic (K) (Othman, Amiruddin, 2010). The name VARk is acronym for those four senses (Ridwan, Sutresna, Haryeti, 2019):

VARK Learning Styles

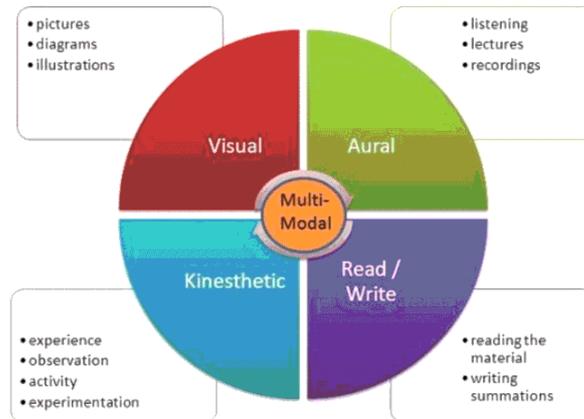


Figure 16: VARK learning styles

• Visual

Students whose dominant learning style is visual are more likely to learn using demonstrations and descriptions. They like to use lists and mental maps to arrange their ideas and mind. Also, visual students like to use figures, pictures and symbolic tools such as graphs, maps, flowcharts, hierarchies, models, brochures, drawings and pictures (Murphy et al., 2004 cited in Othman, Amiruddin, 2010; Hawk, Shah, 2007). While learning they help themselves using highlighters, different colours, pictures, word pictures and different spatial arrangements (Hawk, Shah, 2007). Piping (2005) in his study found that students with visual intelligence are usually rich with imagination, and are likely to be creative and imaginative (Othman, Amiruddin, 2010). Fleming (1995) said that this does not mean that those type of students are restricted merely to picture information, just that they like information to arrive in visual forms. They use their visual memory to retain information for longer periods of time (Choudhary, 2021).

Ways to engage visual learners (Choudhary, 2021):

- Use maps, diagrams, charts, graphs, maps and pictures
- Include technology like projectors, Power point presentations, VR simulations, virtual museums etc.
- Use different colour coding techniques
- Encourage mind maps and sketches

• Aural

Aural students learn dominantly by listening (Drago, Wagner, 2004 cited in Othman, Amiruddin, 2010). In other words, this are the people who tend to understand and retain information by hearing it or saying it out loud (Choudhary, 2021). They learn listening to their teachers and after discuss certain topic which they were taught with classmates. It helps them to clarify their understanding (Othman, Amiruddin, 2010). They like to participate in debates (Choudhary, 2021). According to Miller (2001) aural students

process and memorize information through learning or reading out loud. Students can strengthen their memory by listening audio tape recordings, watching video lectures and by teaching others and discussing topics. They usually read easily, narrate cleverly, often write stories and poetry, learn foreign language fast, have good vocabulary and easily remember names and facts (Othman, Amiruddin, 2010). This type of learners can quickly notice the change in someone's tone (Choudhary, 2021).

Ways to engage aural learners (Choudhary, 2021):

- Reading using different pitches and tones, stressing out the most important things
- Record voice lessons or video lessons
- Encourage class presentations, discussions and debates
- Use peer learning – ask them to teach and help others

- **Reading/writing**

Students which dominant learning style is reading and writing prefer printed word and text as a method to gain information (Othman, Amiruddin, 2010). This type of learners learns best through written material or by writing the material themselves (Choudhary, 2021). They tend to learn by using glossary, textbooks, write essays, definitions, printed handouts, manuals, web pages and lecture notes. They often like to arrange lecture notes into sketch form, paraphrase lessons and notes and have the best results on tests with multiple choice questions (Murphy et al., 2004 cited in Othman, Amiruddin, 2010; Hawk, Shah, 2007). Although they easily learn from textbooks, they prefer learning using their own notes taken in class (Othman, Amiruddin, 2010). They usually possess a wide vocabulary and often help themselves learn by using mnemonics, acronyms, rhymes, tongue twisters and other similar memorizing methods (Choudhary, 2021).

Ways to engage verbal learners (Choudhary, 2021):

- Use mnemonics while teaching, encourage them to memorize facts in that way
- Notes, scripts
- Encourage them to write
- Use word games like crosswords

- **Kinesthetic**

Kinesthetic types tend to learn using experience and practice (Othman, Amiruddin, 2010). They like to experience their learning by using all their senses, including touch, smell, taste and sight (Fleming, 1995). Murphy et al. (2004) said that kinesthetic students should go through some kind of experience to learn something (Othman, Amiruddin, 2010). Drago and Wagner (2004) describes those students as active, with high energy. They prefer to apply touch, movement and interaction to their environment (Drago, Wagner, 2004 cited in Othman, Amiruddin, 2010). Kinesthetic types like field trips, trial and error, laboratories, recipes and solutions to problems, hands-on approaches and using their senses

(Hawk, Shah, 2007). They want concrete, multi-sensory experiences in their learning (Fleming, 1995). According to Armstrong (2004) students that prefer this learning style are fond to move, active and learn physical skills easier. They like to think while moving, they use movement as an aid for remembering, are good at sports and have good coordination (Othman, Amiruddin, 2010). Because of circumstances where students are in class most often passive and sit in their seat, those types of learners are usually unmotivated and passive (Drago, Wagner, 2004 cited in Othman, Amiruddin, 2010). Studying for hours is often very daunting experience for them. They are often described by their teachers as restless, outgoing and energetic (Choudhary, 2021). Educational system as we know it is at least flattering to those type of students. Methods that work best for them are rarely use, so these students have the most difficulties learning.

Ways to engage kinesthetic learners (Choudhary, 2021):

- Encourage movement during lessons like role play
- Ensure enough breaks between lessons to move around
- Use props and interactive models
- Use modern and interactive technology
- Keep them busy like handing out materials, wipe the board ect.

Table 1. Activities that accommodate VARK learning styles (Fleming, 2001 cited in Hawk, Shah, 2007)

Visual	Aural	Read/write	Kinesthetic
Diagrams	Debates, arguments	Books, texts	Real-life examples
Graphs	Discussions	Handouts	Examples
Colours	Conversation	Readings	Guest lecturers
Charts	Audio tapes	Written feedback	Demonstrations
Written texts	Video + audio	Note taking	Physical activity
Different fonts	Seminars	Essays	Constructing
Spatial arrangement	Music	Multiple choice	Role play
Designs	Drama	Bibliographies	Working models

Many researchers came to conclusion that majority of students are all-modal (VARK) preference. Those who do not have the dominant learning style are called multimodal and are the combination of the all four preferences. Students with all-modal learning style do not learn simply sitting in a classroom listening to the teacher, taking notes and memorize assignments. The process of teaching, thus, should be multisensory and filled with variety. To ensure effective learning, teachers should try to provide visual, auditory, reading/writing and kinesthetic activities. According to Shah et al. (2011) it is important that teachers use active learning strategies (Ridwan, Sutresna, Haryeti, 2019). Experimental learning

theories such as Kolb's model and Project based learning theories put students in active role in their education.

- **Experiential Learning Theory in Education**

The experiential theory of learning is a theory that implies a process in which knowledge is gained through a change in experience, so knowledge is a result that consists of existing knowledge and a change in experience that is based on existing knowledge (Kolb, Boyatzis, Mainemelis, 2001). The learning process consists of experience, cognition, perception and the behavior of the learning individual. This learning theory was introduced and developed by the American theorist Kolb (1971) based on the earlier works of Lewin, Piaget and Dewey. The experiential theory of learning is based on assumptions that are based on a holistic learning paradigm, therefore, it places the individual at the center of learning, and education and upbringing are viewed as mutually intertwined and inseparable processes. In the context of education, such an approach to learning implies dependence and correlation of content among educational subjects, reexamination of existing knowledge and continuous transformation of experience. (Lewis, Williams, 1994; Kolb, Boyatzis, Mainemelis, 2001; McCarhy, 2010).

According to these assumptions, the theory of experiential learning represents a model of learning through a circular process consisting of four phases (Kolb, Boyatzis, Mainemelis, 2001). At the same time, it is not enough for an individual to have some experience on which further learning is based, but it is necessary for the existing experience to be objective and to be generalized and formulated in such a way that such experience can then be shaped and applied in new situations. The process and success of learning itself depends on the existing information and the possibilities for its transformation. The acquisition of experience takes place through concrete experience and abstract conceptualization, and the transformation of experience into knowledge takes place in two opposite ways, through reflective observation and active experimentation. (Kolb, Kolb, 2005). Kolb et al. (2001) state that for an individual to learn effectively, he must experience the learning process through all four phases:

- Concrete experience (CE) - during learning, an individual experiences new information and relies on his senses to perceive concrete reality.
- Abstract conceptualization (AC) - during learning, an individual experiences new information in such a way that he thinks about it, analyzes it logically and is guided by reasoning.
- Reflexive observation (RO) - during learning, an individual observes other individuals who are involved in a certain experience, and at the same time thinks about the situation and analyzes what is happening around him and in this way collects information for the expansion of his own experience and knowledge.
- Active experimentation (AE) – during learning, an individual checks and applies new information in concrete practical situations.

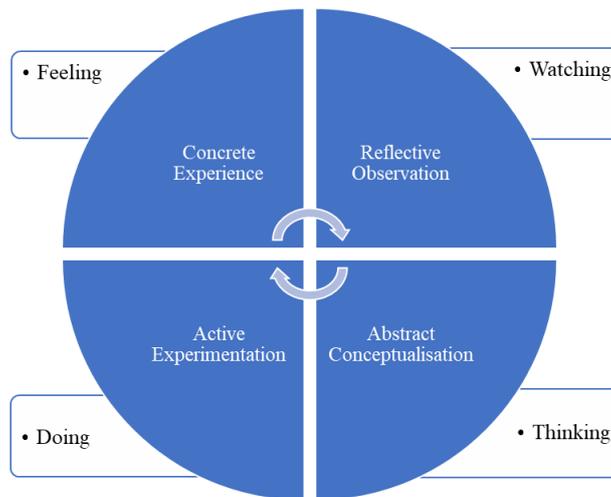


Figure 17: Kolb's model of experiential learning

The learning process can start in any of the mentioned four phases, and it can take place in all phases simultaneously and/or move from one phase to another. Kolb (1985) points out that during the learning process each individual adopts different learning styles in different situations, but in general each individual has a dominant learning style compared to another style. From the above, according to Kolb (1985), four learning styles emerge:

- Divergent learning style is created by a combination of concrete experience and reflective observation. Individuals who belong to this learning style learn by looking at situations from different points of view, and achieve the best learning effect through the creation of new ideas and prefer to learn through working in groups.
- Convergent learning style results from a combination of abstract conceptualization and active experimentation. Individuals who belong to this learning style learn through strong problem-solving abilities with the help of theoretical knowledge, and achieve the best learning results through experimentation with new ideas that could be practically applied.
- The assimilating learning style results from a combination of abstract conceptualization and reflective observation. Individuals who belong to this learning style have a wide range of information that is summarized in a logical structure, and achieve the best learning effect through reading, listening and researching literature.
- An accommodating learning style is created by a combination of concrete experience and active experimentation. Individuals who belong to this learning style learn through direct practical experience with the aim of completing tasks, and achieve the best learning success through collaborative learning, field teaching and project work.

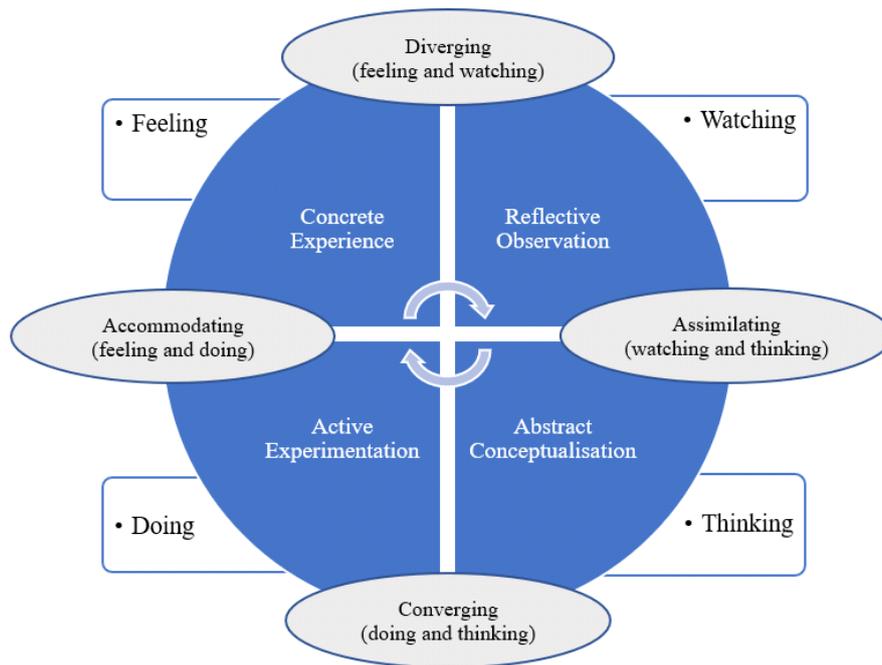


Figure 18: Kolb's learning styles

Subsequently, Kolb and his colleagues refined the existing learning model in such a way that he introduced five additional learning styles: northerner (an individual is successful in CE, good in AE and RO, has problems in AC); westerner (individual is successful in AE, good in CE and AC, has problems in RO); easterner (individual is successful in RO, good in CE and AC, has problems in AE); southerner (individual is successful in AC, good in AE and RO, has problems in CE); balancing (the individual is equally good with the components of gaining experience and with the components of transforming experience into knowledge). The assumptions of Kolb's theory of experiential learning have been tested and confirmed by various scientific and professional authors, and it has also influenced numerous scientists who study learning models and styles (Honey, Mumford, 1989; Gregorc, Ward, 1977; Fleming, Baume, 2006). The model of experiential learning is optimal for use with high school students, students and adults who are learning, and Kolb and Kolb (2005) point out that the model of experiential learning during learning and teaching should consist of all four phases of the model, adjusted according to the individual characteristics and learning style of each individual.

Experiential learning belongs to progressive methods of learning and teaching through which individuals who learn are enabled to gain a deeper understanding of new content that needs to be adopted, and learning outcomes are correlated with benefits for the environment, the environment and the local community. Therefore, through experiential learning, students learn how to apply theories and knowledge in concrete and real life situations (Beaudin, Quick, 1995; Kolb, Kolb, 2005). This type of learning takes place through learn-by-doing, through analyzing and recognizing the positive and negative sides of a situation, through learning through trial and error, and this type of learning requires

the active engagement of the learner. (Beaudin, Quick, 1995). With its learning methods, experiential learning departs from traditional learning and teaching methods in which communication between teacher and student is one-way and in which the student is not at the center of learning and teaching. Experiential learning puts the student at the center of learning, and the teacher is a mentor and advisor in that process (Wurdinger, Carlson, 2010). Therefore, there are different methods of applying experiential learning in education, and some of these methods are as follows:

- small group projects/assignments – it implies collaborative learning in smaller groups, and mutual interaction and the group's common goal are key to success in learning. By applying this method, students develop a positive connection, students are responsible for their work within the group, they reach the goal by working together. Students acquire collaborative skills, develop self-confidence and responsibility towards other group members, and participate in collaborative and critical evaluation of the group's work. The teacher has the role of planning and leading the teaching process and organizes the performance of the lesson and supports the work of groups.
- practicum/field placements – implies learning through practical experience in the field and/or in institutions with the aim of integrating learning from the classroom into a practical environment. Such learning is a mandatory part of the educational curriculum and program that an individual attends with the aim of acquiring competencies for work in the profession. With this method, the student is prepared and familiarized with the labor market and the student acquires concrete practical skills for work, adopts work habits and responsibility towards work, and the student is guided through practical work by an expert as a mentor leader who trains and teaches the student to work in the profession.
- service-learning – implies an educational approach in which the student learns through the planned educational program, and at the same time participates on a volunteer level in the work of various organizations from the local community in order to deepen the understanding of what he learns in the classroom. With this method, students are encouraged to develop experiential learning and the learning process itself moves away from classroom learning. Existing knowledge is supplemented by learning through active participation in the activities of the wider local community. Such an approach to learning develops students' humanistic, social and civic skills, as well as the active involvement of individuals in society and awareness of existing social problems.
- student teaching – implies participation in a selected educational program that includes on-site learning at a specific partner school. This method of experiential learning enables students to put their knowledge and skills into practice through formal and informal learning in a peer environment. This form of learning usually lasts several weeks, depending on the program.
- study abroad – it implies learning abroad, learning through another culture, values and customs in an educational institution that legally regulates acquired competencies. By learning through foreign educational programs, students develop communication and social skills, intercultural

values and norms, organizational skills, and independence. By mastering a foreign program, the student's acquired competencies are recognized in the home institution.

- volunteer experiences – it implies self-initiated learning through charitable volunteer work in the local community. Such work may or may not be directly correlated with the educational program the student attends, and it may take place formally or informally. With this approach to learning, students develop active involvement of individuals in society and awareness of existing social problems.
- apprenticeships – implies training for work after graduation in the context of an internship for a specific occupation and/or workplace with the aim of the individual becoming an expert in the work he/she performs. Learning takes place under the guidance of an expert mentor, and includes the acquisition of new knowledge and practical skills necessary for entry-level work. With this method of experiential learning, the individual is directly involved in the world of work where he undergoes training for specific work, and the completion of the program results in a national credential for the chosen occupation.
- cooperative education experiences – implies cooperative learning methods in which students are actively encouraged to think and work in a team. With this learning method, individuals share and develop knowledge, skills and ideas with each other. Students develop positive interdependence, individual and group responsibility, equality, solidarity and intrapersonal skills. This experiential learning method involves a structured learning and education method that combines classroom education with practical work experience to support individuals in their transition from school to the labor market. Learning takes place full-time during regular education. Learning through this method is structured and focused on student achievement. In cooperative learning, the distribution of roles within the group members is clear, and this is also one of the key conditions for success in learning.
- fellowships – means learning aimed at professional, academic or personal development that is financed by certain organizations, institutions, associations or the government that determines the conditions for obtaining financial resources. This form of learning can last from several weeks to several years, depending on the scholarship program.

- **Project Based Learning in education**

One of the earliest proponents of project-based learning principles was John Dewey, who laid the foundation for project-based education in his thesis on learning through work. Dewey (1938/1997) points out that the purpose of the teacher is not to impose ideas on the students or to shape their habits, but to guide the student as a member of society and community and help him to be able to respond correctly to different situations in life. Based on the stated assumptions, researchers and scientists dealing with upbringing and education advanced the basic assumptions of the original method of

learning through work into project-based learning. Project-based learning is an approach to learning in teaching that allows students to develop their knowledge and skills through various projects, and includes active engagement of students in project work on various topics and issues that students may encounter in the real world. (Barron, 1998; Beckett, Slater, 2019; Bender, 2012; Falk, 2008; Markham, 2011; Polman, 2000).

In a pedagogical sense, project-based learning consists of several processes: defining problems and constraints, generating ideas for solving the problem, working on potential solutions to the problem, testing the results (Dewey, 1938/1997; Falk 2008). These processes can take place over several weeks, and the course of learning depends on the scope and goals of the project. Projects can be complex and long-term, but they can also be simple and shorter. Regardless of the duration and level of complexity, project-based learning has equal educational benefits for the student, and the application of PBL in education generally takes place according to the PBL methodology: choosing a topic and approaching a research question, challenge or task; selection and training of the team; projecting the final content or completion of the challenge; planning; Research; analysis and synthesis; display of results/contents/products; final report on a research question, challenge and/or task; evaluation and self-assessment (Beckett, Slater, 2019; Bender, 2012; Markham, 2011; Polman, 2000).

Project-based learning, like experiential learning, moves away from traditional learning and teaching methods. In traditional learning and teaching methods, students are first presented with content that needs to be memorized, and then assigned a problem through which its solution is illustrated. In project-based learning, the learning process itself is focused on problem-based learning and problem solving (Dewey, 1938/1997; Markham, 2011; Polman, 2000). First, a problem is set in the context of understanding the problematic task according to the student's choice, then the students through cooperation collect and exchange information and research the content and materials they need to solve the problem, and then apply what they have learned to solve the specific problem and present the results in an innovative and interesting way. Thus, during this type of learning, the emphasis is on student engagement, mutual cooperation, and the student is an active subject in the process of learning and mastering educational content, from idea to realization. Students learn in an innovative way, but also look at learning itself in a more positive way. The learning results are a reflection of the students' achievements, knowledge and skills, and the project on which the students work upon completion becomes public material, so other members of the community can also learn from the created educational content. Such learning aims to develop students' creative skills for working on complex problems and improve cooperation among students and all learners. Critical reflection and higher-level cognitive processes are developed, and in this way new knowledge is created in cooperation (Beckett, Slater, 2019; Cook-Sather, Matthews, 2021). Precisely because of the focus on cooperation and creativity, learning in this way is more successful if information and communication technology is used during learning and teaching, which enables effective communication, but also the realization and presentation of the project in a creative way. Through this approach to learning, students are encouraged to develop skills necessary for the 21st century. The use of technology enables the contemporary design of solutions for certain

problem situations from the real world, which contributes to the authenticity of the content, innovation, flexibility and motivation for learning.

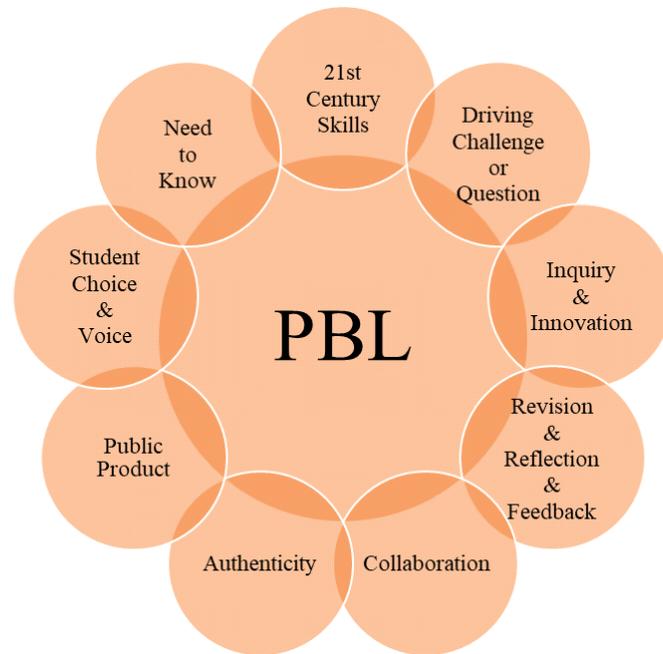


Figure 19: Essential Elements of Project Based Learning

Project-based learning is applicable in its proportions at almost all educational levels and in all educational subjects and areas, and some of the areas can be:

- collaborative classroom projects (includes activities in which a problem is solved collectively in a collaborative way),
- STEM projects (includes taking STEM concepts that students explore in the context of their application to solve real-world problems and/or challenges while developing 21st century skills),
- arts projects (includes project models that lead students in creative and authentic activities),
- community service projects (includes activities that engage students in solving social needs, for the benefit of the local community such as cleaning waste, arranging parks, natural disasters),
- technology projects (includes the integration of technology in learning, development and introduction of innovative production processes through the application of technical knowledge),
- field trips (includes activities for learning and research in a real environment and on the spot) and others.

Project-based learning implies a pedagogic approach, the application of which students create and acquire deeper knowledge through active exploration of challenges and problems of the real world in such a way that they actively participate in significant projects. Through this way of learning, students

develop and create practical solutions to a real problem that is close to them (Beckett, Slater, 2019; Falk, 2008;). According to, learning through projects helps students solve complex problems, especially in the STEM field. This type of learning requires students to have basic skills, such as reading, writing and arithmetic, but also skills of the digital age, which include working in a team and using digital educational content. For success in learning, and especially in the STEM field, it is important to use combined methods of project-based and experimental learning. One of the newer methods is the use of tools, that is, exhibitions in learning and teaching. The use of exhibits in education provides an interactive learning experience through displays and demonstrations that guide students toward solving complex tasks. Their advantage is that they are flexible and can be generated to suit different learning styles.

Conclusion

Experiential learning and project-based learning enable students to develop skills that are important in the knowledge society and that are important for lifelong learning. The emphasis is on the use of technology in learning and teaching. What is characteristic of project-based learning is that students engage in continuous, collaborative research, and this is where the main difference between project-based and experiential-based learning is found. In project learning, the main component for achieving learning outcomes is cooperation between students. For mastering problem tasks in the STEM field, co-creation is one of the most important techniques for achieving success in learning and teaching. Co-creation in science, technology, engineering and mathematics implies a collaborative process in which different researchers, practitioners, educators, community members come together, with the aim of jointly creating solutions to complex problems in the learning and teaching process.

Chapter III: Co-creation in STEM

1. Introduction:

What is co-creation

Co-creation in STEM (Science, Technology, Engineering, and Mathematics) refers to the collaborative process where diverse stakeholders, such as researchers, practitioners, educators, industry professionals, and community members, come together to jointly create and innovate solutions to complex problems.

The co-creation is emerging in education, the concept has been defined by several authors and experts on the topic, and this has allowed the creation of different definitions:

“The concept involves engaging students in their learning process by having them contribute using digital media to the design of learning activities, to the development of marking rubrics and to the

creation of content, thus enabling their agency as 21st-century learners” ((Browne et al. 2017; Gros and López 2016) in Reyna and Meier, 1:2020)

One of the first definitions was given in 2009 by Peter Pfeifer and Martina Merz “*a process of joint value creation, involving interaction between various actors in the innovation process, such as users, customers, suppliers, and employees, as well as external stakeholders such as universities, research institutions, and public authorities*”, while one of the most recent definitions is by Cynthia E. Selin in 2018 as “*a process of creating shared understanding and value among diverse stakeholders, through collaborative engagement in the generation, dissemination, and application of knowledge and technology*”.

This process involves the active participation of all stakeholders in the design, development, and implementation of STEM-related projects, programs, and initiatives. Co-creation in STEM recognizes that diverse perspectives and expertise are necessary to solve complex problems and create innovative solutions.

Co-creation in STEM can take many forms, such as participatory design, collaborative research, community-based participatory research, and citizen science. This approach is becoming increasingly popular in the STEM fields as it promotes more inclusive and equitable approaches to problem-solving and innovation.

2. STEM projects in schools and co-creation application

STEAM projects are a type of experiential learning that integrates multiple subjects such as science, technology, engineering, arts, and mathematics. These projects are designed to encourage students to develop critical thinking skills and creativity. STEAM projects are often interdisciplinary and require students to work collaboratively to solve real-world problems. This approach to teaching emphasizes the importance of hands-on learning and encourages students to apply their skills to real-world situations.

One of the main goals of STEAM projects is to create a learning environment that is engaging and interactive. By combining multiple subjects, students are able to experience a more comprehensive and holistic approach to learning. This approach encourages students to develop a deeper understanding of the material and fosters a love of learning. STEAM projects also provide students with the opportunity to apply their knowledge to real-world problems, which can lead to a sense of accomplishment and pride.

STEAM projects are becoming increasingly popular in schools and classrooms around the world. This is because they offer a unique way of teaching students by integrating science, technology, engineering, art, and math into a single project. STEAM projects are hands-on and provide students with an

opportunity to explore and learn in a creative and fun way. In this article, we will explore why schools and educators use STEAM projects to teach their students.

Co-creation in STEM can be particularly beneficial for schools, as it can enhance student learning and engagement in STEM subjects. Here are some types of co-creation that can be applied to STEM education in schools:

- **Participatory Curriculum Design:** Teachers can involve students in the design of the STEM curriculum. This approach can help to ensure that the curriculum is relevant and engaging for students and meets their learning needs.
- **Student-Led Research Projects:** Teachers can encourage students to conduct research projects on topics of their interest. This approach can help students to develop research skills and gain a deeper understanding of STEM concepts.
- **Industry Partnerships:** Schools can partner with local STEM industries to provide students with opportunities to engage in real-world STEM projects. This approach can help students to understand how STEM is applied in the workplace and gain valuable experience.
- **Community-based Projects:** Schools can collaborate with community organizations on STEM projects. This approach can help to promote community engagement in STEM education and provide students with opportunities to apply their STEM skills to real-world problems.
- **Maker Spaces:** Schools can create maker spaces where students can collaborate on hands-on STEM projects. This approach can help to foster creativity, innovation, and problem-solving skills in students.

3. Designing Successful STEM Co-creation Projects

Designing successful STEM co-creation projects is a crucial aspect of ensuring that the project is effective and impactful. When designing a STEM co-creation project, it is essential to consider the specific goals, objectives, and outcomes of the project. Additionally, it is necessary to identify the appropriate stakeholders who will be involved in the project. The project design should also incorporate the principles of co-creation, which means that all stakeholders should have an equal opportunity to contribute to the project's development.

One of the critical steps in designing a successful STEM co-creation project is to identify the specific goals and objectives of the project. The goals and objectives should be clearly defined to ensure that all stakeholders have a shared understanding of what the project aims to achieve. The goals and objectives should also be measurable, so that progress can be tracked and evaluated throughout the project's lifecycle. This will help to ensure that the project remains focused and aligned with its intended outcomes.

Another important aspect of designing a successful STEM co-creation project is to identify the appropriate stakeholders who will be involved in the project. This includes identifying the target audience or beneficiaries of the project and engaging them in the project's design and development. Additionally, it is essential to identify the key partners and collaborators who will be involved in the project, such as experts from different fields, educational institutions, and community organizations. This will help to ensure that the project is well-rounded and incorporates diverse perspectives and expertise.

Lastly, designing a successful STEM co-creation project requires incorporating the principles of co-creation. This means that all stakeholders should have an equal opportunity to contribute to the project's development, from ideation to implementation. This can be achieved through collaborative workshops, prototyping sessions, and other participatory methods. By involving all stakeholders in the project's design and development, the project is more likely to be successful and impactful, and the stakeholders are more likely to be invested in the project's outcomes.

EXAMPLE ON HOW TO DESIGN SUCCESSFUL STEAM CO-CREATION PROJECTS

1

IDENTIFY THE PROBLEM

This could be a real-world problem, or a challenge related to STEM education.

2

ENGAGE STAKEHOLDERS

Engage diverse stakeholders in the co-creation process, including students, educators, industry professionals, and community members. Ensure that their perspectives are represented and that they are involved in all stages of the project.

3

DEVELOP A SHARED VISION

including goals, objectives, and outcomes. Ensure that all stakeholders are aligned around the vision and that it reflects the needs and preferences of the target audience.

4

DESIGN THE PROJECT

including the activities, timeline, and resources needed. Ensure that the project is feasible and that it addresses the identified problem or challenge.

5

IMPLEMENT THE PROJECT

working collaboratively with stakeholders to ensure that it is successful. Monitor progress and adjust where needed.

6

EVALUATE THE PROJECT

Evaluate the co-creation project to assess its impact on stakeholders and the extent to which it achieved its goals and objectives. Use the findings to improve future co-creation

4. Implementing STEAM Co-creation Projects

STEAM co-creation projects are collaborative efforts between students, teachers, and industry professionals that integrate science, technology, engineering, art, and math. These projects rely on the combined expertise of multiple stakeholders to create meaningful and engaging learning experiences for students. Implementing STEM co-creation projects requires careful planning, coordination, and communication between all parties involved.

One key aspect of implementing STEM co-creation projects is identifying the goals and objectives of the project. This involves understanding the needs and interests of the students, as well as the skills and knowledge that industry professionals can bring to the table. Teachers must also consider the curriculum standards and learning outcomes they want to address through the project. Once these goals are established, teachers can work with industry professionals and students to design a project that is both challenging and achievable.

Another important factor in implementing STEM co-creation projects is creating a supportive learning environment. Students must feel comfortable taking risks and experimenting with new ideas, and teachers must be prepared to provide guidance and support throughout the project. Industry professionals can also play a role in mentoring and coaching students, helping them to develop the skills and knowledge they need to succeed in the project and beyond. By fostering a collaborative and supportive learning environment, teachers can help students develop a sense of ownership and pride in their work.

Finally, implementing STEM co-creation projects requires ongoing evaluation and reflection. Teachers must assess the effectiveness of the project in achieving its goals and objectives, and make adjustments as necessary. This may involve gathering feedback from students, industry professionals, and other stakeholders, and using that feedback to improve the project in future iterations. By continually evaluating and refining STEM co-creation projects, teachers can ensure that they are providing meaningful and engaging learning experiences that prepare students for success in the 21st century workforce.

STEAM Co-creation Projects is an approach that incorporates Science, Technology, Engineering, and Mathematics (STEM) within a collaborative setting. This process enables learners to discover and create solutions to real-world problems. Successful STEM Co-creation Projects require a collaborative approach that involves different stakeholders such as students, educators, researchers, and industries. The idea behind co-creation is to blend different perspectives and knowledge to create innovative solutions that address the needs of the community.

5. Outcomes of Successful STEM Co-creation Projects

The outcomes of successful STEM Co-creation Projects are numerous. Firstly, it enhances the learners' knowledge and skills in STEM fields. This is because the approach fosters a practical learning

environment where learners can apply theoretical knowledge to real-world scenarios. It also provides learners with an opportunity to develop critical thinking and problem-solving skills. Through the collaboration, learners can develop solutions that are creative and innovative, which can be applied to different scenarios.

Another outcome of a successful STEM Co-creation Project is the development of social and emotional skills. Working in teams promotes social interaction, improving communication and leadership skills. The collaborative approach also helps learners develop empathy and understanding of different perspectives. This is important because it helps learners develop a sense of community and responsibility towards other members.

Lastly, successful STEM Co-creation Projects have a positive impact on the community. The solutions developed through this approach are often geared towards addressing community needs. Therefore, the outcomes of these projects have the potential to create a positive impact on people's lives. The solutions developed can be implemented to improve the quality of life, promote sustainable development, or even create job opportunities. This, in turn, creates a sense of achievement and fulfilment for the learners involved.

In conclusion, STEM Co-creation Projects are an effective way of fostering collaborative learning in STEM fields. Successful projects have numerous outcomes that include enhancing learners' knowledge and skills, developing social and emotional skills, and creating positive impacts on the community. Therefore, educators should consider incorporating STEM Co-creation Projects within their curriculum to provide learners with a practical and innovative learning approach.

Types of co-creation projects

- **Participatory Design:** This type of co-creation involves actively involving end-users in the design process of new STEM-related products, technologies, or services. This approach ensures that the final product is tailored to the needs and preferences of the target audience. Some examples of how to apply the participatory design in a classroom that can be included in co-creation:
 - **Project-Based Learning Topics:** Engage students in the selection of project-based learning topics. Provide opportunities for students to brainstorm, discuss, and vote on potential topics of interest. This participatory approach ensures that students have a voice in shaping their learning experiences, fostering intrinsic motivation and engagement.
 - **Lesson Planning:** Involve students in the lesson planning process by seeking their input on activities, resources, and assessment methods. Encourage them to suggest topics, projects, or experiments they find interesting and relevant. By incorporating their ideas, students become active participants in the learning process and have a sense of ownership over their education.

- **Collaborative Research:** Collaborative research involves bringing together experts from different STEM fields to work together on research projects. This approach allows for pooling of resources and expertise, leading to more comprehensive and innovative research outcomes. Some examples of how to apply collaborative research in a classroom that can be included in co-creation:
 - Science Investigations: Divide students into small groups and assign them different research questions or hypotheses related to a specific scientific concept. Each group conducts experiments, collects data, and analyses findings collaboratively. They then present their research outcomes to the class, fostering a shared learning experience.
 - Mathematics Investigations: Form groups of students to explore mathematical concepts beyond the curriculum. Each group selects a specific mathematical problem or topic and collaboratively conducts research, experimenting with different approaches and analysing results. They present their findings and solutions to the class, promoting mathematical reasoning and problem-solving skills.
- **Community-based Participatory Research:** Community-based participatory research involves working with community members to address STEM-related issues that affect their health and well-being. This approach recognizes that community members have valuable knowledge and expertise that can contribute to the research process and ensures that research is responsive to community needs. Here are some examples on how to apply and develop community-based participatory research in a classroom:
 - Sustainable Community Development: Students collaborate with community members, urban planners, or sustainability experts to research and propose sustainable development initiatives. They can explore topics such as renewable energy, green spaces, or waste reduction. Through research and analysis, they develop recommendations and present them to community stakeholders or local government officials.
 - Community Needs Assessment: Students partner with local nonprofit organizations or community service providers to conduct a needs assessment in the community. They collaborate with community members to identify pressing issues or gaps in services. Through surveys, interviews, or focus groups, they collect data to inform decision-making and resource allocation. The students can present their findings to the community organization, advocating for targeted interventions.
- **Citizen Science:** Citizen science involves engaging members of the public in STEM-related research projects. This approach allows for the collection of large amounts of data while also promoting public engagement in science.

- **Light Pollution Mapping:** Students participate in mapping light pollution in their community by measuring sky brightness levels. They can use smartphone apps or light meters to collect data and contribute their findings to citizen science projects focused on studying light pollution and its effects on ecosystems and human health.
- **Bird Migration Tracking:** Students participate in bird migration tracking by observing and recording bird species, behavior, and migratory patterns. They can contribute their observations to regional or national bird monitoring programs, such as eBird or the Great Backyard Bird Count, helping scientists understand bird populations and migration patterns.
- **STEM Education Projects:** Co-creation in STEM education can involve collaborating with educators, students, and industry professionals to develop and implement innovative STEM education programs and initiatives. This approach can help to promote student engagement and interest in STEM subjects, as well as prepare them for future careers in STEM fields.
 - **Robotics and Coding:** Students can engage in robotics projects where they design, build, and program robots to perform specific tasks. They can explore concepts like sensors, motors, and algorithms while developing problem-solving and computational thinking skills.
 - **App Development:** Students can learn the basics of app development and design by creating mobile applications that solve real-world problems. They can explore user interface design, coding, and user experience while developing their own educational or utility apps.

Areas of focus in the co-creation

- **Learning, Teaching, and Assessment:** Co-creation can be applied to the development and implementation of innovative learning, teaching, and assessment strategies. This involves working collaboratively with students, educators, and other stakeholders to design and implement approaches that are tailored to the needs and preferences of the target audience.
- **Curriculum Design and Pedagogic Consultancy:** Co-creation can be used to involve stakeholders in the design and development of curriculum and pedagogic approaches. This approach ensures that the curriculum is relevant and engaging for students and meets their learning needs.
- **Subject-Based Research and Inquiry:** Co-creation can be applied to research projects in specific subject areas. This involves bringing together experts from different disciplines to work collaboratively on research projects that address complex problems.

- **Scholarship of Teaching and Learning (SoTL):** SoTL involves researching and studying teaching and learning practices to improve student learning outcomes. Co-creation can be used to involve students and other stakeholders in the research process, ensuring that the research is responsive to the needs and preferences of the target audience.

6. Conclusion

In conclusion, co-creation in STEM education offers a collaborative and innovative approach to addressing complex problems and fostering meaningful learning experiences. By actively involving diverse stakeholders, such as students, educators, industry professionals, and community members, co-creation projects provide opportunities for shared understanding, value creation, and knowledge generation. Through participatory design, collaborative research, community-based initiatives, and citizen science, co-creation projects empower learners to become active contributors in their education and the broader STEM community.

Implementing STEM co-creation projects in schools requires careful planning, coordination, and the integration of co-creation principles. By involving students in curriculum design, encouraging student-led research projects, fostering industry partnerships, promoting community-based projects, and establishing maker spaces, educators can create engaging and interactive learning environments. Designing successful STEM co-creation projects involves clearly defining goals and objectives, identifying appropriate stakeholders, and ensuring equal opportunities for contribution. Ongoing evaluation and reflection are also crucial for refining and improving these projects over time.

The outcomes of successful STEM co-creation projects are multi-faceted. They enhance learners' knowledge and skills in STEM fields, develop social and emotional competencies, and have a positive impact on the community. Students acquire practical and creative problem-solving skills, collaborate effectively, and gain a sense of ownership and pride in their work. The solutions developed through co-creation projects can address community needs, promote sustainability, and create tangible benefits for society.

Incorporating co-creation projects into STEM education provides a practical and innovative learning approach that prepares students for the challenges of the 21st century workforce. By fostering collaboration, critical thinking, and a sense of responsibility, educators can empower students to become active contributors to their own learning and the betterment of their communities. As the field of STEM education continues to evolve, co-creation offers a promising path towards more inclusive, engaging, and impactful learning experiences.

The chapter IV: Explore Digital, Physical, Phygital and tech and software for digital creation of art

1- Introduction :

In this chapter, we will define and clarify the theoretical concepts of digital, physical, and phygital that will be used for digital co-creation of art that can be exploited for the STEM learning. Also, it will explore the synergy between digital technology and physical experiences for an modern and efficient pedagogical e-book based on art activities. Additionally, we will define the significant role of technological software in this novel ecosystem. Finally, it will discuss the impacts of phygital on the performance of the digital creation of art.

2- The concepts of digital, physical, and phygital approaches

Digital, physical, and phygital methods and approaches can be followed and used by teachers and experts to co-create art content to teach students and children. These terms are mainly used to describe different types of experiences and interactions in this field.

2.1 Physical techniques and pedagogies:

Among these methods, the physical pedagogical approaches provide opportunities for students to explore their creativity, develop technical skills, engage with materials, experiment with different techniques, and express their ideas visually. Art educators often combine these approaches to create a comprehensive and well-rounded art education experience. Physical pedagogy [1] refers to the methods and approaches used to teach and learn art through physical engagement and manipulation of materials. It emphasizes hands-on exploration, experimentation, and skill development. Here are some key physical pedagogical approaches commonly that can be used in art education:

- Drawing is often considered the foundation of visual arts. It involves using various drawing tools like pencils, charcoal, or pastels to represent objects, people, or ideas on paper. Drawing exercises help develop observational skills, hand-eye coordination, and the ability to represent form, perspective, and texture.
- Painting involves applying pigment to a surface using brushes, palette knives, or other tools. It allows artists to explore color theory, composition, texture, and different painting techniques such as glazing, impasto, or wet-on-wet. Learning to mix colors, apply brushstrokes, and create tonal variations are important skills developed through painting.
- Sculpture involves creating three-dimensional artworks by shaping or manipulating materials such as clay, wood, stone, metal, or found objects. Sculpture helps develop spatial awareness,

understanding of form and volume, and the ability to work in three dimensions. Techniques such as carving, modeling, casting, or assembling can be explored.

- Ceramics involve working with clay to create pottery or sculpture. Techniques include hand-building (pinching, coiling, or slab construction) and wheel-throwing. Ceramics teach students about working with a malleable material, glazing and firing techniques, and understanding the properties of clay.
- Printmaking techniques, such as relief printing, intaglio, lithography, or screen printing, involve transferring an image from a prepared surface to another surface, typically paper. Printmaking encourages experimentation, planning, and working in multiples. Students learn to develop technical skills, create textures, explore color options, and engage in the printmaking process.
- Collage involves combining different materials, such as paper, fabric, photographs, or found objects, to create a unified composition. Mixed media refers to the use of various art materials and techniques in a single artwork. These approaches encourage creativity, layering, and experimentation with different textures and materials.
- Performance art (e.g. theater) involves creating artworks and stagecraft skills that are presented through live actions or performances. It can include elements such as movement, body art, sound, and time-based media. Performance art encourages students to explore their bodies, spatial relationships, and audience interaction.
- Mime and physical theater techniques emphasize non-verbal communication, body language, and storytelling through movement. Training in mime helps actors develop precision, control, and the ability to convey meaning through physicality alone. It explores the use of props, space, and physical narratives.
- Kinetic art incorporates movement into artworks, often utilizing mechanical or technological components. It explores the relationship between art and motion, creating interactive and dynamic experiences. Students learn about mechanics, engineering, and the integration of technology with artistic expression.
- Photography involves capturing images using cameras and exploring various photographic techniques, such as composition, lighting, exposure, and post-processing. It encourages students to develop their visual perception, storytelling abilities, and technical skills in image-making.

STEM-Xhibitions recommends the use of the physical pedagogical approaches linked to theater which provide actors with a range of tools and techniques to develop their physical expressiveness, stage presence, and character work. By combining storytelling, body gestures and voice techniques, theater educators create a well-rounded training experience that prepares actors for the physical demands of the stage.

2.2 The digital methods to create art



Figure 20: Picture Art modern (Image credit: Getty Images / lithiumcloud)

Digital techniques refer to technologies that exist solely in the digital realm, such as virtual tools, websites, mobile apps, social media platforms, and other forms of online communication. Digital experiences are usually delivered through electronic devices like smartphones, laptops, or tablets, and can range from simple text-based interactions to complex multimedia experiences that incorporate video, audio, and graphics. When it comes to creating art, digital pedagogy can offer numerous opportunities for exploration, creativity, and collaboration. In the literature, there are some digital pedagogical approaches commonly used in art education:

- The virtual tools integrate virtual and augmented reality technologies into art education. VR allows students to create and experience immersive digital art environments, while AR can overlay digital elements onto real-world surroundings, enhancing traditional art forms or creating interactive installations.
- Incorporation of the use of digital drawing tablets enables teachers proposing students to draw and paint directly on a screen with a stylus. These tablets simulate traditional art media and offer features like pressure sensitivity, allowing for more precise control and a more tactile art-making experience.
- Online collaboration workspaces utilize digital platforms and online communities to facilitate collaborative art projects and peer critique. Teachers, experts and students can collaborate on shared artworks, exchange feedback, and engage in discussions about their creative processes, helping them develop critical thinking and communication skills.
- The exploration of digital storytelling techniques can be used in art creation. Teachers and experts can combine visual art with narrative elements, animation, or interactive elements to create multimedia artworks for students that convey a story or message.
- Digital Exhibitions and Portfolios guide users (e.g., teachers) in creating digital portfolios or online galleries to showcase their artwork. This allows them to share their creations with a broader audience, receive feedback, and develop skills in digital curation and presentation.
- Gamification and Interactive Art Experiences introduce gamified elements and interactive art experiences to engage students. This could involve designing digital art games, interactive

installations, or immersive experiences that encourage exploration, experimentation, and creative problem-solving.

It's important to adapt these digital pedagogical approaches to the specific needs of teachers, experts and students and the resources available. Additionally, regularly evaluate and update the teaching strategies to incorporate new technologies and emerging trends in the digital art field

2.3 The phygital approach

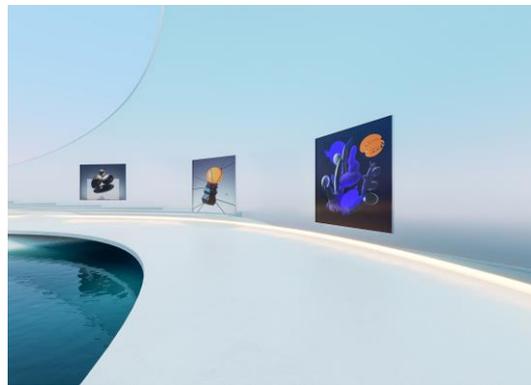


Figure 21: Physical and digital combination of art exhibition (source www.behance.net)

The phygital pedagogy [2] refers to an approach to education that combines physical and digital elements enhance the learning experience (P. Quirke and A. Saeed AlShamsi, 2023). When applied to the creation of art, phygital pedagogy can offer exciting opportunities for artists to explore new techniques, mediums, and interactive experiences. Here's a brief overview of how phygital pedagogy can be used to create art. Also, it is a blending of physical and digital worlds, where physical experiences are enhanced by digital technology and vice versa. In retail, phygital experiences may include digital kiosks that provide product information and recommendations, virtual try-on tools, or personalized promotions delivered through mobile devices while shopping in-store.

The phygital pedagogy in art creation provides artists with expanded possibilities for creativity, experimentation, and audience engagement. By combining the physical and digital realms, artists can create unique and dynamic art experiences that push the boundaries of traditional art forms:

- Blending physical and digital tools encourages artists to combine traditional art materials and techniques with digital tools and technologies. This could involve using physical mediums like paint, clay, or paper in conjunction with digital tools such as graphic design software, 3D modeling programs, or virtual reality (VR) tools.

- Interactive installations and exhibitions promote the creation of interactive art installations or exhibitions that engage viewers in both physical and digital ways. Artists can incorporate elements like motion sensors, touchscreens, or augmented reality (AR) to encourage audience participation and exploration of their artwork.
- Collaborative art projects can facilitate collaborative art projects by leveraging digital platforms and tools. Artists can connect with others from different locations, working together on a shared digital canvas, or using virtual collaboration tools to collectively create artwork. This approach encourages collaboration, feedback, and the exchange of ideas among artists.
- Digital storytelling and multimedia encourage artists to explore the combination of visual art with other media forms, such as audio, video, animation, or interactive narratives. Artists can use digital storytelling techniques to create immersive and engaging art experiences that transcend traditional static artwork.
- Art education through online platforms can also extend to the realm of art education. Online platforms and courses can combine video tutorials, interactive exercises, and virtual classrooms to provide comprehensive art education experiences. This approach allows artists to learn and practice art techniques using both physical and digital tools, and receive feedback from instructors and peers.

In STEM-Xhibitions, phygital experiences may include the use of virtual tools to enhance the learning experience, or the use of online learning platforms that integrate with physical classroom activities. Phygital experiences can also be found in art installations, entertainment, and events. For example, an art exhibit may use augmented reality technology to add digital elements to physical artwork, or a concert may use digital technology to create immersive visual effects.

3-The role of technological software for digital creation of art

This chapter does not suggest that all teachers need to become expert programmers or web developers. Rather, it emphasizes the importance of having an attitude towards and aptitude with technologies, a willingness to use them effectively in the classroom, and an understanding of how and why they should be used. Moreover, technology and software have revolutionized the art world, providing artists with new tools and mediums to create art digitally, and expanding the possibilities for artistic expression. This has also led to greater accessibility and distribution of digital art.

Digital creation of art has become increasingly popular in recent years, with the development of advanced technology and software that enables artists to create stunning digital artwork. The use of digital tools for art creation offers a wide range of possibilities for artists, including greater flexibility, precision, and speed in the creative process.

There are many different software and hardware tools available for digital art creation, each with its own unique features and benefits. Some popular options include Adobe Creative Suite, Procreate, Corel Painter, Sketchbook, Blender, Maya, and ZBrush. These tools provide artists with a wide range of options for creating digital artwork, including painting, drawing, 3D modeling, animation, and more. Besides software, there are also hardware tools specifically designed for digital art creation, such as drawing tablets, pen displays, and 3D printers. These tools provide artists with a more tactile and natural experience while working digitally, allowing them to create artwork that is both precise and expressive. In general, the use of technology and software for digital art creation has revolutionized the art world, enabling artists to explore new mediums and techniques, and creating new opportunities for creativity and expression. In the market, there are various Tools and Software that allow teachers and experts to create digital content specifically designed for creating art, such as Adobe Photoshop, Illustrator, or Procreate. Teach them how to use these tools effectively, including techniques like layering, blending, and manipulating digital brushes.

Furthermore, experts can explore online tutorials, instructional videos, and digital art communities. Platforms like YouTube, Skillshare, or online art forums provide a wealth of resources where students can learn new techniques, gather inspiration, and engage with other artists. Educators face the ongoing challenge of refining their teaching and learning techniques to meet the increasing demands and expectations of students, who are often described as digitally savvy. Students expect that the teaching and learning experiences they encounter throughout their years of formal schooling will be enriched by the use of digital technologies, but many teachers tend to rely on self-taught or peer-taught approaches to develop their technology skills. Consequently, the types of technology they use may not be as current as what their students require, or what is needed for effective teaching.

3.1 Technological software :



Figure 22: Picture digital Art creation (source: <https://www.lifewire.com/best-digital-art-software-4705458>)

Technology and software have become an integral part of pedagogy, transforming the way students learn and teachers teach. From online learning platforms to educational software, technology is being used in a variety of ways to enhance the learning experience. Here are some examples of how technology and software are being used in the art creation context.

- Online learning platforms such as Moodle, Blackboard, and Canvas allow for the delivery of online courses, providing students with access to course materials, assignments, and assessments from anywhere with an internet connection.
- Educational software can be used to provide interactive and engaging learning experiences, such as simulations, games, and virtual reality. Examples of educational software include Minecraft: Education Edition, Kahoot, and Quizlet.
- Technology can facilitate collaboration among students and teachers, allowing them to work together on projects and share ideas in real-time. Examples of collaboration tools include Google Drive, Microsoft Teams, and Slack.
- Technology can be used to create and deliver assessments, such as quizzes and exams, as well as provide feedback to students. Examples of assessment tools include Google Forms, Quizlet, and Turnitin.
- Technology can be used to create and share multimedia content, such as videos and podcasts, to supplement traditional learning materials. Examples of multimedia tools include iMovie, Audacity, and Screencastify.

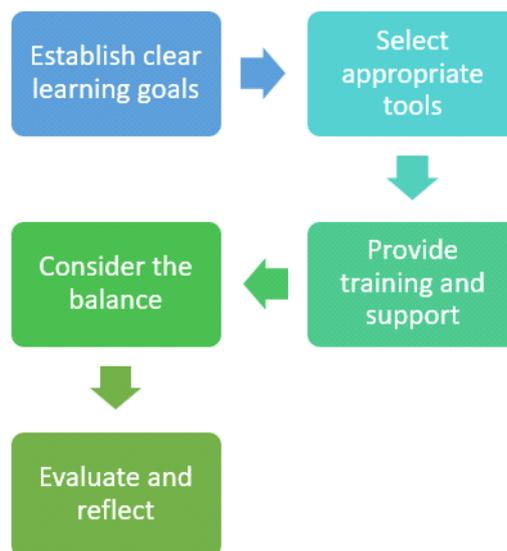


Figure 23: Steps diagram for a successful implementation

Merging technology and software into pedagogy requires thoughtful planning and consideration of the needs and preferences of students, as well as the available resources and infrastructure. In the next subsection, essential steps and key tips are presented that can help facilitate successful implementation of technology and software in the context of pedagogy:

- **Establish clear learning goals:** Identify clear learning goals and determine how technology and software can support those goals.
- **Select appropriate tools:** Select technology and software tools that align with the learning goals and needs of students, and ensure they are accessible to all students.

- **Provide training and support:** Teachers and students may need training and support to effectively use technology and software. Consider providing workshops or online resources to help build skills and confidence.
- **Consider the balance:** Balance the use of technology and software with traditional teaching methods to ensure a well-rounded and effective learning experience.
- **Evaluate and reflect:** Regularly evaluate the effectiveness of technology and software use in pedagogy and reflect on how they can be improved to better meet the needs of students.

Technology and software are being used in a variety of ways to enhance the learning experience in pedagogy. Online learning platforms, educational software, collaboration tools, assessment tools, and multimedia tools are just some examples. Successful implementation of technology and software in pedagogy requires careful planning, appropriate tool selection, training and support, consideration of balance, and regular evaluation and reflection.

3.2 Software inventory

There are various commercialized and accessible tech and software options available for digital creation of art. Among popular references, we present the following software:

- **Adobe Creative Suite:** Adobe Creative Suite is a collection of design software that includes popular programs like Photoshop, Illustrator, and InDesign. These programs are widely used by artists, designers, and photographers for creating digital artwork.
- **Procreate:** Procreate is a powerful digital illustration app that is designed specifically for use on an iPad. It offers a wide range of brushes, textures, and other tools that make it easy to create professional-looking artwork.
- **Corel Painter:** Corel Painter is a digital painting software that offers a variety of realistic brushes and tools for creating traditional media effects. It is a popular choice among professional artists and illustrators.
- **Autodesk Sketchbook:** Autodesk Sketchbook is a drawing and painting app that offers a wide range of brushes and tools for creating digital artwork. It is available on a variety of platforms, including desktop, mobile, and tablet.
- **Blender:** Blender is a 3D modeling and animation software that is popular among digital artists and game developers. It is a free and open-source software that offers a range of features for creating 3D models, animations, and visual effects.
- **Cinema 4D:** Cinema 4D is a 3D modeling, animation, and rendering software that is popular among motion graphics artists and visual effects professionals. It offers a range of advanced features for creating complex 3D animations and simulations.

- **Unity:** Unity is a game engine that is used to create a wide range of games and interactive experiences. It offers a range of tools and features for creating 3D environments, characters, and animations.
- **ZBrush:** ZBrush is a digital sculpting software that is popular among character artists and sculptors. It offers a range of tools for creating detailed and realistic 3D models.

These are the key existing tech and software available for digital creation of art. The best choice will depend on the specific needs and preferences of the artist. In a **pedagogical way**, there are several tech and software options that are suitable for digital creation of art, specially for students and teachers, as follows:

- **Tinkercad:** Tinkercad is a free, web-based 3D modeling software that is easy to use and perfect for beginners. It is a great tool for teaching 3D design and modeling to students in a fun and engaging way.
- **Scratch:** Scratch is a visual programming language that allows users to create interactive stories, games, and animations. It is a great tool for teaching programming and coding concepts to kids and beginners.
- **Canva:** Canva is a graphic design software that is easy to use and perfect for creating visual content such as posters, infographics, and social media graphics. It is a great tool for teaching graphic design to students.
- **Sketchpad:** Sketchpad is a free online drawing and painting tool that is easy to use and perfect for teaching digital art concepts to beginners. It offers a variety of tools and brushes that allow users to create digital artwork quickly and easily.
- **Adobe Spark:** Adobe Spark is a suite of free online tools for creating visual content such as graphics, videos, and web pages. It is a great tool for teaching digital media and storytelling concepts to students.
- **Minecraft:** Minecraft is a sandbox video game that allows players to create and build their own virtual worlds. It is a great tool for teaching architecture, engineering, and design concepts to kids and beginners.
- **Google Arts & Culture:** Google Arts & Culture is an online platform that offers access to high-resolution images of artwork and virtual tours of museums around the world. It is a great tool for teaching art history and appreciation to students.

4. Exploration of approaches and Integrating pedagogy for digital art creation

In the changing world, it is assumed that the term "pedagogy" is familiar to most people and that they have an idea of what it refers to. Pedagogy is the foundation of the teaching profession, and each teacher likely has an idea of what effective pedagogy would look like for their particular subject area or stage

of learning. To clarify, pedagogy can be defined as the study of teaching and the process of being a teacher.

There has been much research and speculation about the use of computers in the classroom, and technology has often been viewed as a tool to assist both teachers and students. However, research has shown that technology not only assists with teaching and learning, but also changes the way we learn and engage in different types of knowledge creation. The use of technology in teaching and learning has informed developments in learning theories. Furthermore, technology has also transformed the traditional view of teachers as all-knowing and all-powerful figures at the front of the class, who simply impart knowledge to empty minds of the students.

Throwing a computer into a classroom does not automatically make learning effective. In order to effectively incorporate technology into teaching, teachers need to understand how to use technology properly, comprehend the learning theories behind its use, and be able to select the appropriate technology to achieve the desired learning outcomes.

There are many benefits to integrating technology and art into the classroom, and this chapter offers comprehensive guidance on different methods of teaching with technology, including exploring digital, physical, and phygital approaches.

4.1 Explore digital:

Exploring digital technologies in the context of pedagogy can involve a wide range of activities and approaches. The following illustrations highlight the possible exploration of these technologies:

- **Digital content creation:** Experts and teachers can explore digital tools such as graphic design software, video editing tools, and web development platforms to create multimedia content for learning purposes. For example, they can create infographics, animations, and videos to communicate their understanding of a topic
- **Virtual and augmented reality:** Exploring virtual and augmented reality technologies can provide students with immersive learning experiences that simulate real-world scenarios. For example, they can use virtual reality to visit historical sites, explore scientific concepts, or practice language skills.
- **Online collaboration:** Digital technologies can enable students to collaborate and communicate with each other and with teachers in new ways. For example, they can use online discussion forums, collaborative documents, and video conferencing tools to share ideas, receive feedback, and work on group projects.
- **Digital citizenship:** Exploring digital technologies can also help students develop digital citizenship skills, such as online safety, privacy, and responsible use of technology. For example,

they can learn how to use social media responsibly, how to protect their personal information online, and how to evaluate the credibility of online sources.

Exploring digital technologies in the context of pedagogy can help students develop digital literacy skills, engage with new modes of learning, and prepare for a digital future.

4.2 Explore physical approach:



Figure 24: Types of physical activities (source: <https://newsinhealth.nih.gov/2020/07/personalized-exercise>)

Physical pedagogy is the study of education and the process of teaching and learning. Physical education, also known as PE or gym class, is a type of education that focuses on physical activities and fitness. The inclusion of physical education in pedagogy is important because it provides students with knowledge and skills related to physical fitness and health. Physical education is a vital component of pedagogy as it contributes to the overall development of students, not just physically but also mentally, socially, and emotionally. The following are some of the ways in which physical education is beneficial to students.

Experts in art can explore and deepen their understanding of the physical pedagogy of art-making through various means. Here are some ways they can engage in this exploration:

- Artists can pursue formal education in art by enrolling in art schools, universities, or specialized programs. These institutions offer structured courses and workshops that focus on developing technical skills and exploring different artistic approaches. Participating in workshops led by experienced artists or attending specialized classes can also provide valuable insights and hands-on training.
- Seeking mentorship from established artists who excel in a particular medium or technique can be highly beneficial. Working closely with a mentor allows artists to receive personalized guidance, feedback, and demonstrations.

Combining physical education into pedagogy requires a comprehensive approach that takes into account the needs of individual students, as well as the cultural and environmental factors that may affect their participation in physical activity. This may involve adapting physical activities to accommodate students with disabilities, creating safe and inclusive environments for all students, and providing opportunities for students to participate in a variety of physical activities that cater to their interests and abilities.

In summary, physical education is an important component of pedagogy that contributes to the overall development of students. It helps to promote physical fitness, improve academic performance, develop social skills, reduce stress, and instill healthy habits. A comprehensive approach that considers the individual needs of students is essential for incorporating physical education into pedagogy.

4.3. Explore phygital:

As defined previously, phygital is a term that combines "physical" and "digital" and refers to the blending of physical and digital experiences [3]. In the context of pedagogy, phygital learning involves integrating digital technologies into traditional physical learning spaces to enhance the learning experience (Mele, C., Spina, T.R. 2023). This can include using digital tools for instruction, assessment, and collaboration, as well as incorporating physical activities into digital learning environments. The next steps showcase how can the phygital learning can be beneficial in the context of art creation [4]:

- **Increased engagement:** Incorporating digital tools and technologies into physical learning spaces can increase student engagement by providing interactive and immersive learning experiences.
- **Personalization:** Digital tools can help personalize learning by providing tailored instruction and assessment based on individual student needs and preferences.
- **Accessibility:** Digital tools can make learning more accessible for students with disabilities, such as providing text-to-speech or screen-reading software for students with visual impairments.
- **Collaboration:** Digital tools can facilitate collaboration among students, allowing them to work together on projects and share ideas in real-time.
- **Flexibility:** Phygital learning allows for greater flexibility in teaching and learning, as digital tools and resources can be accessed and used anytime, anywhere.

Incorporating phygital learning (Anna Lindemann, 2017) into pedagogy requires thoughtful planning and consideration of the needs and preferences of students, as well as the available resources and infrastructure. The following iterations present the strategies that can help facilitate successful implementation of phygital learning:

- **Start small:** Begin by introducing one or two digital tools or resources at a time to allow students and teachers to become familiar with the technology.
- **Provide training and support:** Teachers and students may need training and support to effectively use digital tools and technologies. Consider providing workshops or online resources to help build skills and confidence.
- **Ensure accessibility:** When selecting digital tools and resources, consider the accessibility needs of all students and ensure that they are able to access and use the technology.
- **Foster collaboration:** Encourage collaboration and communication among students by providing opportunities for them to work together using digital tools and resources.
- **Evaluate and reflect:** Regularly evaluate the effectiveness of phygital learning strategies and reflect on how they can be improved to better meet the needs of students.

The exploration of phygital learning is a way to integrate digital tools and technologies into physical learning spaces to enhance the learning experience. It can increase engagement, personalize learning, improve accessibility, facilitate collaboration, and offer greater flexibility in teaching and learning. Successful implementation of phygital learning requires careful planning, training and support, and consideration of the needs of all students.

5- Phygital creation of Art best practices:

Creating art digitally can be a great way for students to explore their creativity and develop their artistic skills. And has a different step to go through as the following points:

- **Choose the right software:** There are many software options available for digital art creation, such as Adobe Photoshop, Adobe Illustrator, Procreate, Sketchbook, and more. Choose the software that best fits your teaching goals and student skill levels.
- **Teach the basics:** Start with the basics of digital art creation, such as using layers, brushes, and color palettes. Teach students how to use the software and its various tools.
- **Incorporate art theory:** Teach students about the elements of art and principles of design, such as composition, color theory, and perspective. This will help students to create more aesthetically pleasing and meaningful art.
- **Provide inspiration:** Show students examples of digital art created by professionals or other students to inspire them and give them ideas for their own creations.
- **Encourage experimentation:** Encourage students to experiment with different tools, techniques, and styles to find their own unique artistic voice.
- **Give feedback:** Provide constructive feedback on student work to help them improve their skills and continue to develop as artists.

- **Showcase student work:** Showcase student work in a digital gallery or on social media to give students a sense of pride in their accomplishments and to inspire others.

6. Conclusion:

Based on the findings of this chapter, STEM-Xhibitions will use mainly phygital approaches to create art content to be used for learning and teaching STEM fields. Also, using open and accessible software will ensure the sustainability of the project outputs and the replication of art creation in other STEM fields. Moreover, the pedagogy constraints and techniques have to be considered while co-creating art or virtual tools for STEM learning.

Chapter V: Best Practices from Similar EU Settings

Introduction:

Exhibitions have been used in education as a widespread educational practice to enhance learners' critical thinking, problem-solving and reflection in a variety of subjects. Although visiting exhibitions has often provided students with positive learning values in a diversity of settings and on a large variety of topics, it is a learning process that often remains fairly passive.

The experience is usually focused on following the path created by another source, the curator of every exhibition. This passive aspect is not ideal as a learning process and creates differences in the understanding and processing of the lesson imparted by the exhibitions. This leads to some students, often the ones more familiar with art-oriented forms of teaching, to engage more successfully and benefiting from the learning experience, while many others are left behind, especially the ones following STEM-oriented subjects (VXDesigners project, 2020). Therefore, it is important to understand this when it comes to designing STEM exhibitions and how to adjust them to the experiences and teachings that both STEM and non-STEM students have had.

When designing a project such as STEM xhibitions, it is vital to think about similar EU projects that have tackled using exhibitions in STEM learning. Looking at other EU projects and how they are structured, where they have found success, and where they have found failure, helps us navigate our project to avoid making similar mistakes and focus on the most efficient ways of building our content and guiding our project goals.

PERFORM – PERSEIA :



Figure 25: PERFORM project logo taken from the project website (<http://www.perform-research.eu/>)

Between 2016 and 2018, as part of the European Union’s Horizon 2020 Research and Innovation Programme, the PERFORM (Participatory Engagement with Scientific and Technological Research through Performance) project was run in France, Spain, and the UK. It aimed to investigate the effects of innovative science education methods based on performing arts in fostering young people’s motivations and engagement with science, technology, engineering, and mathematics (STEM) in selected secondary schools in France, Spain, and the United Kingdom (PERFORM project, 2016).

PERSEIA (PERformance-based Science Education Innovative Activities), as part of the project’s work packages, aimed to incorporate drama-based activities in STEM teaching for young students. This was implemented in secondary schools in the UK and Spain as case studies. In Spain, stand-up comedy was used to deliver education and science busking (street theatre) in the UK (Villanueva, Marimon & Gonzalez, 2018, p. 5).

Science busking showed less favourable results than stand-up comedy, with the latter being more successful in promoting positive attitudes toward STEM subjects. It was more appealing because it provoked more emotional engagement than science busking. However, it is important to note that street theatre can target a bigger audience. Due to its nature, it was easier for the audience/class to participate, showing more general engagement with the participants (Villanueva, Marimon & Gonzalez, 2018, p. 22-23).

Therefore, it is highly significant to consider the results found from this project as they show how theatre can engage a large audience, as seen in science busking. Still, when applying this method for STEM education, it is important to remember to engage students emotionally as well, as it promotes more favourable results, as seen from the stand-up comedy case study.

I-STEM:



Figure 26: I-STEM project logo taken from the project website (<https://istem-project.eu/>)

I-STEM is an EU-funded multinational collaboration between universities, science experts, performing arts industry professionals, post-primary school teachers and young people that has been run from 2020 until the day of writing. It aims to make STEM subjects more accessible and attract more creative-based students by making STEM more “fun” (I-STEM project, 2020). It offers a more artistic approach to STEM to make it more understandable and engaging for students who wouldn’t otherwise have been interested in it.

An EU Commission Report released in 2015 shows that, at the moment, Europe needs higher numbers of science-centred people at all levels of society and the economy. More and more students finish formal education with science qualifications. However, we have not seen an interest in pursuing science-related careers nor witnessed enhanced science-based innovation or any increase in entrepreneurship. STEM subjects are considered not engaging enough by many students. As a result, artistic minds, desired in the science industry, often find science to be “boring” or “too technical” for them.

This project includes free teacher masterclasses and an e-book containing techniques created by the I-STEM project to make STEM more engaging. It uses case studies, teaching scenarios for teachers, workshops for students, student-created animations, student mobility between countries and a platform for sharing knowledge (I-STEM project, 2020). Hence, it is important to consider how STEM subjects can be made more attractive to promote engagement, and the performing arts play a significant role in doing so, which is vital to consider when creating STEM-centred exhibitions.

STE(A)M IT:



Figure 27: STE(A)M IT Project logo taken from the project website (<https://steamit.eun.org/>)

STE(A)M IT is an EU-funded project that aimed to create and evaluate a conceptual reference framework for integrated STE(A)M education. Based on this framework, it also sought to develop a capacity-building programme for primary and secondary STEM teachers, focusing on the contextualisation of STEM teaching, primarily through industry-education cooperation. Finally, it aimed to ensure the contextualisation of integrated STEM teaching by establishing a network of guidance counsellors/career advisors in schools, promoting the attractiveness of STEM jobs to their classes (STE(A)M IT project, 2021).

The project's integrated [STEM framework](#) included a Master Learning Scenario, guiding teachers on how to teach in an integrated way. Furthermore, it had 7 Example Learning Scenarios for Secondary education (12-16 years old) and 4 for Primary education (6 to 11 years old) with real case scenarios, based on the Master Learning Scenario. To continue, it has created a Capacity building programme for Secondary and Primary School teachers on teaching in an integrated way and a network of teachers to exchange on integrated STE(A)M teaching. Finally, a report on developing and using this teaching methodology in real case scenarios, including tips and guidelines for integration at Ministries of Education level and by schools (STE(A)M IT project, 2021).

The integration of Art practices in STEM subjects has been becoming more and more common in education as it opens up new methods for better teaching and comprehension of subjects. The STE(A)M IT project highlights this with the implementation of its framework in teaching students how to integrate Art methods in their teaching. Therefore, it is vital to take into advisement these types of frameworks when developing exhibitions to enhance the quality and accuracy of the teaching that aims to be conveyed through them.

STEAMBUILDERS:



Figure 28: STEAMBUILDERS logo taken from the project website (<https://steambuilders.eu/>)

STEAMBUILDERS is another EU-funded project that run from December 2020 till the end of November 2022 and aimed at creating a more hands-on approach to STEAM that engaged students more and made them more interested in pursuing STEAM careers in the future. It aimed to do this by showing students how STEAM is present in every aspect of life. STEAMBUILDERS argued that the older a pupil in school gets, the less their interests are stirred and the more their attitude is towards school in general, especially in subjects such as Mathematics, Arts and Science, which leads to their interest deteriorating (STEAMBUILDERS project, 2020).

Its objective was to provide teachers, educators, and education professionals with the tools, pedagogy, and necessary theory to implement this innovative, cross-curricular approach to STEAM, intending to increase the levels of achievement and interest in Science, Technology, Engineering, and Mathematics (STEM) of pupils aged 10 to 15. In order to do this, the following resources were developed:

- [A Pedagogical Guide](#)
- [A Non-formal education in STEAM booklet](#)
- [35 manipulations and their blueprints](#)
- [35 Pedagogical sequences](#)
- [A Best Practice Booklet](#)

With the STEAMBUILDERS project having made the argument that the older a pupil gets the less their interests are stirred towards school in general, it is important to take into consideration the outputs provided by this project when designing an SCE as STEM teachers, experts and students can find common ground in how to create effective exhibitions.

VX DESIGNERS:



Figure 29: VX Designers logo taken from the project website (<https://vxdesigners.eu>)

VX Designers was another EU-funded project that was implemented from October 2020 to September 2022. It aimed to create a learning methodology to make the most of exhibitions as a pedagogical tool. Its target groups were secondary school pupils, teachers, and any people who would benefit from learning through designing and curating exhibitions (VXDesigners project, 2020). It highlighted the development of technological means such as the multiplication of and the publication of classical artwork online. Learners can become co-designers of their own exhibitions, using digital tools in a meaningful and innovative non-formal approach to learning.

It aimed to answer the questions:

- How can exhibitions become part of an active learning experience?
- How can we place learners at the centre of exhibition creation?
- What about focusing on digital and inclusive aspects in exhibition design?

To do so it focused on creating a pedagogical tool incorporating exhibitions in teaching. Creating an “Exhibitions Generator Platform” enabled teachers and students to create exhibitions easily and the platform was designed considering users with different learning needs (VXDesigners project, 2020). Clicking on the picture below allows you to visit the VX Designers platform they produced to interact with and learn more about.



Figure 29: VXDesigners platform link taken from the project website (<https://vxdesigners.eu/>)

Other than the platform the VX Designers project offered the following free resources as well:

- [Exhibition and school guide](#)
- [User guide for virtual exhibitions creation](#)
- [Pedagogical guide](#)
- [Exhibitions design and their pedagogical sequences](#)

Taking from this project the platform that can create virtual exhibitions, as well as its other outputs that provide more information on how to create effective exhibitions, teachers and experts can focus on creating exhibitions for STEM subjects with targeted aims, enhancing their efficacy.

DLaB (Digital Learning across Boundaries):



Figure 30: DLaB project logo, taken from <https://dlaberasmus.com/>

The Digital Learning across Boundaries (DLaB) project is an Erasmus+ Project that addresses the need to align European educational practices with digital technology and the ways in which it’s changing how and what people learn (DLaB project, 2016). With a consortium from Belgium, Denmark, England, and Norway the project adopted [three ‘learning across boundaries’ themes](#) across three years:

- **Technology outdoors**: bridging formal and informal learning by extending learning beyond traditional classroom spaces and supporting learners with disadvantaged backgrounds by managing transitions positively through collaborative outdoor learning experiences
- **Stem to SteAm**: adding the Arts to the integrated study of Science, Technology, Engineering and Maths, creating inter-disciplinary challenge-based online learning resources.
- **Technology Enabled CLIL**: using curriculum contexts to teach language competencies and cultural sensitivity with the aim of meeting the language needs of a diversity of learners, including learners for whom English is an additional language (EAL/EFL)

Its sub-themes were:

- **Learning STEM through creative expression**: This focused on linking STEM to the creative arts (music, dance, drama/theatre, crafts, creative writing, photography) and exploring explicit connections between art and science.
- **The maker movement**: Focused on craft and computing, electronics, 3d printing, laser cutters, sensors, robots
- **Inquiry driven STEAM**: Focused on creating pedagogical approaches, challenge or problem based learning and real-world problem approaches in order to peak children's interests and educate them.

Focusing on the second theme, DLaB, worked on adding the Arts subjects to STEM in order to create inter-disciplinary challenged-based online learning resources. In order to build STEAM literacy, DLaB focused on teaching children, ways to increase their critical literacy skills, critical thinking and collaboration between them. Furthermore, this theme focused on establishing a secure and supportive learning environment where children could take intellectual risks and learn from their experiences. To continue, its focus on "learning STEM through creative expression: is vital, when it comes to creating STEM exhibitions that incorporate artistic methods such as learning through music, crafts or even theatre as it helps make connections between the two sectors of education and promote a different way of teaching. Teachers and STEM experts can greatly benefit from this.

STEAMonEdu:



Figure 31: STEAMonEdu project logo taken from <https://steamonedu.eu/>

STEAMonEdu is an Erasmus+ project that ran from January 2020 to December 2021. It was comprised of a consortium from Romania, Spain (Catalonia), Greece, Germany, Italy, and Belgium. It aimed to increase the adoption and impact of STE(A)M education by investing in the community of stakeholders and the professional development of educators. (STEAMonEdu project, 2020)

It adopted a bottom-up participatory approach and delivered:

- [A training plan/handbook](#)
- [A STE\(A\)M education framework](#)
- [A STE\(A\)M competence framework and educator profile](#)
- [A blended course, including a MOOC targeting STE\(A\)M educators](#)
- [A Guide of STE\(A\)M educational practices](#)
- [A Guide on STE\(A\)M Education policies](#)
- [A STE\(A\)M educational objects meta-data profile](#)
- [A Guide for STE\(A\)M education policy makers](#)
- [SELFIE](#) (Self-reflection on Effective Learning by Fostering the use of Innovative Educational technologies)

STEAMonEdu was able to produce a STE(A)M education framework through research and the incorporation of creative arts techniques, including competences, policies, methodologies and educational projects.

Focusing on investing on community stakeholders and the professional development of educators is critical for the implementation of exhibitions in STEM subjects. It leads on more readily available experts for creating STEM exhibitions and allows for a higher level of engagement with participants and audiences, increasing the reach that exhibitions have on educating people.

CHOICE:



Figure 32: Choice project, source <https://www.euchoice.eu/>

CHOICE is an Erasmus+ Programme that ran from January 2020 until December 2022. Its consortium was made up of organisations from Italy, Cyprus, Greece, Spain and Belgium. CHOICE aimed to promote and improve STEM education at schools by designing innovative Open Educational Resources (OERs) collected in a MOOC that would increase the professional competences of teachers by equipping them with a STE(A)M approach of teaching. (CHOICE project, 2020)

During its 36-month run, the project produced the [following results](#):

- **National reports** that gathered findings on local and regional initiatives connected to the reform of STEM education, best practices, students' attitudes and teachers' approaches at local and EU levels.
- **A State-of-the-art Study** that was a comparative analysis of the findings across the involved countries.
- **A Reflective Practice Case Study Compendium**: a collection of case-studies discussed during the reflective groups with experts from companies, Higher Education Institutions and local authorities conducted in 4 countries.
- **A framework for Reforming Curricula**
- **Working Guidelines** to guide partners in the delivery of the design and development of workshops at local levels.
- **Training for Teachers on the use of STE(A)M approaches** in the form of a MOOC
- **A Good practice tool called CHOICE@SCHOOL**, guiding schools, directors, and teachers in integrating the CHOICE approaches and tools to their curricula and STEM teaching practices.

Once again, the CHOICE project, highlights the importance of educating teachers and experts on a STEAM approach of teaching to increase their professional competences. This in turn, helps provide them with the integrated approach when it comes to creating exhibitions to increase the audiences they attract and the efficacy that have in educating them in their exhibitions' subjects.

Conclusions:

Studying similar EU projects allows for identifying frameworks that can help this project move forward.

Seeing the practical side of the PERFORM project's case studies with Spain and the UK, the importance of theatre as a form of an exhibition and how it can engage a large audience while, at the same time, how important it is to remember to engage students emotionally as well, as it promotes more favourable results.

To continue, the I-STEM project highlighted the need to keep STEM subjects attractive by ensuring the content remains entertaining and more accessible to students of different disciplines to increase the audience we can pool for the project.

Thirdly, with the STE(A)M IT project, a reference framework was created to integrate STEM subjects with art subjects. It also sought to develop a capacity-building programme for primary and secondary STEM teachers, allowing students to transition to this integrated format of learning more easily, a crucial point when incorporating teachings in exhibitions as it allows for students and audiences to understand the topics presented to them more easily.

STEAMBUILDERS gives insight as to how to incorporate the changes that students' attitudes towards STEM courses and schools in general, as they age and how to ensure that they maintain an interest and motivation in following STEM-oriented career paths, once again very important when considering how to design exhibitions to maintain your audience engaged.

With the inclusion of VX Designers project, we can see the practical application of designing and presenting an exhibition. Keeping access open for both teachers and students allows for creativity and design to not be limited. Furthermore, the VXDesigners open tool for designing virtual exhibitions can provide insight to teachers and experts when designing and presenting an exhibition.

To continue, through the DLaB project we can see the importance of, when designing STEM exhibitions, to remember to align educational practices with digital technology. DLaB also provides more insight into how to go about with incorporating creative arts such as music, dance and even theatre into STEM subjects and how to express them, which can be crucial to designing exhibitions focused on creative arts such as theatre and knowing what their strengths and weaknesses can be.

With the STEAMonEdu project, a STE(A)M education framework was produced, showing how the incorporation of Arts in STEM subjects has an impact on the professional development of educators but also on the community of stakeholders. When creating exhibitions, it is important to take this in consideration as it affects the efficacy of teachers in delivering a well-structured exhibition as well as the engagement from their audience.

Finally, with the CHOICE project we can see how STEM education can be promoted and improved upon in schools through Open Education Resources that allow for innovation to take place through adopting Arts subjects in STEM. This in turn, helps provide audiences with an integrated approach in learning when it comes to creating exhibitions to widen the background of the audience they attract and how effective they are in educating them in their exhibitions' subjects.

Following the examples that previous similar EU projects have presented allows for this project to avoid making similar mistakes and focus on the most efficient ways of building its content and guiding its project goals. Hence, it shows the importance of ensuring that exhibitions that will be created in this project will take into consideration the adjustments needed to make their format more accessible to their audience.

References of Chapters

References of introduction to exhibitions in education and exhibitions in STEM :

- Connett Wendy, *Hard Skills: Definition, Examples, and Comparison to Soft Skills*, March 31 2023 <https://www.investopedia.com/terms/h/hard-skills.asp> (last accessed 15/05/2023)
- *Exhibitions as active learning experiences.* (n.d.). SchoolEducationGateway. <https://www.schooleducationgateway.eu/en/pub/latest/news/exhibitions-active-learning.htm> (last accessed 24/04/2023)
- *Experifun Educational Solutions Pvt. Ltd.* (n.d.). Experifun Educational Solutions Pvt. Ltd. <https://experifun.com/> last accessed (24/04/2023)
- Gillis Alexander S., *Definition: Hard Skills*, March 2023 <https://www.techtarget.com/searchcio/definition/hard-skills#:~:text=Hard%20skills%20are%20specific%20abilities,required%20for%20a%20specific%20job.> (last accessed 15/05/2023)
- Hauan Nils Petter & Kolsto Stein Dankert, *Exhibitions as learning environments: a review of empirical research on students' science learning at Natural History Museums*, 2014
- Kampschulte, Lorenz & Parchmann, Ilka. (2015). The student-curated exhibition - A new approach to getting in touch with science. *Lumat: International Journal of Math, Science and Technology Education*. 3. 462-482. DOI: 10.31129/lumat.v3i4.1017
- Kenton Will, *What are Soft Skills? Definition, Importance, and Examples*, 31 March 2023, <https://www.investopedia.com/terms/s/soft-skills.asp> (last accessed 15/05/2023)
- Lai, C. (2018). Using inquiry-based strategies for enhancing students' STEM education learning. *Journal of Education in Science, Environment and Health (JESEH)*, 4(1), 110-117. DOI:10.21891/jeseh.389740
- Myhill Richard, London International Youth Science Forum (LIYSF), *What is STEM Education?*, 2020, <https://www.liysf.org.uk/blog/what-is-stem-education> (last accessed 15/05/2023)

- Sheffield Rachel, Koul Rekha, Blackley Susan, Fitriani Ella, Rahmawati Yuli & Resek Diane, *Transnational Examination of STEM education, International Journal of Innovation in Science and Mathematics Education* 26(8), 2018
- Arteria Foundation, *The usage of an exhibition in the learning process: types of exhibitions, methods of using exhibitions in the learning process, its benefits*, 2020, <https://fundacja-arteria.org/the-usage-of-an-exhibition-in-the-learning-process-types-of-exhibitions-methods-of-using-exhibitions-in-the-learning-process-its-benefits/> last accessed (24/04/2023)
- Vainikainen, Mari-Pauliina, Hannu Salmi, and Helena Thuneberg. "Situational interest and learning in a science center mathematics exhibition." *Journal of Research in STEM Education* (2015).
- Wahono, B., Lin, PL. & Chang, CY. Evidence of STEM enactment effectiveness in Asian student learning outcomes. *IJ STEM Ed* 7, 36 (2020). <https://doi.org/10.1186/s40594-020-00236-HYPERLINK> "<https://doi.org/10.1186/s40594-020-00236-1>"-1

Reference of Chapter I: Benefits of Exhibitions as a learning and pedagogical tool

- Design Desk - India's Leading Exhibition Build & Design Specialists. (2020). *Virtual Exhibition benefits for marketing • VirtuLab*. [online] Available at: <https://designdesk.in/unique-benefits-of-virtual-exhibitions/> [Accessed 12 May 2023].
- Virtulabadmin (2020). *12 Benefits of Virtual Showroom and Why Your Business Needs One*. [online] Virtulab. Available at: <https://virtulab.online/virtual-showroom-benefits/>.
- Arteria Foundation. (2021). *The usage of an exhibition in the learning process: types of exhibitions, methods of using exhibitions in the learning process, its benefits*. [online] Available at: <https://fundacja-arteria.org/the-usage-of-an-exhibition-in-the-learning-process-types-of-exhibitions-methods-of-using-exhibitions-in-the-learning-process-its-benefits/>.
- Leverage Edu. (2021). *30+ Must Watch Mathematics Movies*. [online] Available at: <https://leverageedu.com/blog/mathematics-movies/> [Accessed 17 May 2023].
- www.maths.ox.ac.uk. (n.d.). *Oxford Mathematics Online Exhibition 2020 | Mathematical Institute*. [online] Available at: <https://www.maths.ox.ac.uk/about-us/art-and-oxford-mathematics/oxford-mathematics-online-exhibition-2020> [Accessed 17 May 2023].
- Anon, (n.d.). *National Museum of Mathematics*. [online] Available at: <https://momath.org/>.

Reference of Chapter II: Type of learning

- Barron, B. (1998). Doing with understanding: Lessons from research on problem and project-based learning. *Journal of the Learning Sciences*, 7 (3-4), 271-311.
- Beaudin, B. P., Quick, D. (1995). *Experiential Learning: Theoretical Underpinnings*. Colorado State University: HI-CAHS.
- Beckett, G. and Slater, T. (2019). *Global Perspectives on Project-Based Language Learning, Teaching, and Assessment: Key Approaches, Technology Tools, and Frameworks*. Oxon: Routledge.
- Bender, W. N. (2012). *Project-Based Learning: Differentiating Instruction for the 21st Century*. Thousand Oaks, CA: Corwin Press.

- Choudhary, M. (2021). 10 Types of Learning and How to Teach Them: A Complete Guide to Learning Styles. <https://www.classcardapp.com/blog/10-types-of-learning-and-how-to-teach-them-a-complete-guide-to-learning-styles>
- Cook-Sather, A. and Matthews, K. E., (2021). Pedagogical partnership: engaging with students as co-creators of curriculum, assessment, and knowledge. In (eds) *University Teaching in Focus: A learning-centred approach*. Routledge, 243-259.
- Dewey, J. (1938/1997). *Education and Experience*. New York: Touchstone.
- Falk, B. (2008). *Teaching the way children learn*. New York: Teachers College Press.
- Fleming, N. (1995). I'm different; not dumb. Modes of presentation (V.A.R.K.) in the tertiary classroom. *Research and Development in Higher Education*, 18, 308-313.
- Fleming, N, and Baume D. (2006). Learning Styles Again: VARKing up the right tree!. *Educational developments* 7(4), 4-7.
- Gregorc A. F. and Ward H.B. (1977). Implications for learning and teaching: a new definition of individual. *National Association of Secondary School Principals*, 61, 20-23.
- Hawk, T.F. and Shah, A.J. (2007). Using Learning Style Instruments to Enhance Student Learning. *Decision Science Journal of Innovative Education*, 5 (1).
- Honey, P., and Mumford, A. (1989). *Learning styles questionnaire*. Organization Design and Development, Incorporated.
- Kolb, D. A. (1971). *Individual learning styles and the learning process*. Cambridge, MA: Massachusetts Institute of Technology.
- Kolb, D. A. (1985). *Learning style inventory*. Boston, MA: McBer and Company.
- Kolb, D. A, Boyatzis, R. E., and Mainemelis, C. (2001). Experiential learning theory: Previous research and new directions. Perspectives on thinking, learning, and cognitive styles. *The educational psychology series*, 227-247.
- Kolb, A. Y. and Kolb, D. A. (2005). *The Kolb Learning Style Inventory*. Boston, MA: Hay Resour Direct.
- Lewis, L. H. and Williams, C. J. (1994). Experiential Learning: Past and Present. *New Directions for Adult and Continuing Education*, 62, 5-16.
- Markham, T. (2011). Project-Based Learning. *Teacher Librarian*, 39(2), 38-42.
- McCarhy, M. (2010). Experiential Learning Theory: From Theory To Practice. *Journal of Buisness & Economics Research*, 8(5), 131-140.
- Othman, N. and Amiruddin, M.H. (2010). Different Perspectives of Learning Styles from VARK Model. *Procedia Social and Behavioral Sciences*, 7, 652-660.
- Polman, J. L. (2000). *Designing project-based science: Connecting learners through guided inquiry*. New York: Teachers College Press.
- Ridwan, H., Sutresna I. and Haryeti P. (2019). Teaching styles of the teachers and learning styles of the students. *Journal of Physics*, doi:10.1088/17426596/1318/1/012028
- Sharlanova, V. (2004). Experiential learning. *Trakia Journal of Sciences*, 2(4), 36-39.
- Wurdinger, S. D. and Carlson, J. A. (2010). *Teaching for experiential learning: Five approaches that work*. Lanham, MD: Rowman & Littlefield Education.

References of Chapter III: Co-creation

- Bell, P., Lewenstein, B., Shouse, A.W., & Feder, M.A. (Eds.). (2009). *Learning Science in Informal Environments: People, Places, and Pursuits*. Washington, DC: The National Academies Press.
- Blikstein, P. (2013). Digital fabrication and 'making' in education: The democratization of invention. In J. Walter-Herrmann & C. Büching (Eds.), *FabLab: Of Machines, Makers and Inventors* (pp. 203-218). Bielefeld: Transcript Verlag.

- Falk, J.H., & Dierking, L.D. (2016). *The Museum Experience Revisited*. New York: Routledge.
- King, H., & Robinson, L. (2018). Co-creation in education: A systematic literature review. *Educational Research Review*, 25, 1-17.
- Loh, C.S., & Kan, E. (2014). Co-creation of STEM curriculum with industry. *Journal of Engineering Education*, 103(4), 624-648.
- National Academies of Sciences, Engineering, and Medicine. (2018). *Science and Engineering for Grades 6-12: Investigation and Design at the Center*. Washington, DC: The National Academies Press.
- National Science Foundation. (2019). STEM+C Program Solicitation. Retrieved from https://www.nsf.gov/funding/pgm_summ.jsp?pims_id=505031
- Sanders, E.B.-N., & Stappers, P.J. (2014). Co-creation and the new landscapes of design. *CoDesign*, 10(1), 5-18.
- UNESCO. (2017). Education for Sustainable Development Goals: Learning Objectives. Retrieved from <https://unesdoc.unesco.org/ark:/48223/pf0000247444>
- Zimmerman, E., & Bodzin, A. (2017). Co-design in a STEAM curriculum: Student and teacher experiences with engineering design and the arts. *International Journal of STEM Education*, 4(1), 1-11.
- Reyna, J. and Meier, P. (2020). Co-creation of knowledge using mobile technologies and digital media as pedagogical devices in undergraduate STEM education. *Research in Learning Technology* from <https://journal.alt.ac.uk/index.php/rlt/article/view/2356/2683>

References of Chapter IV: Explore Digital, Physical, Phygital and tech. software for digital creation of art

- [1] Physical Or Digital? At theVOV's Phygital Exhibitions, It's Both
- [2] WHAT IS PHYGITAL: BRIDGING PHYSICAL ART & DIGITAL
- P. Quirke and A. Saeed AlShamsi, (2023) 'Perspective Chapter: Peer Observation of Teaching in Phygital Communities of Inquiry', *Higher Education - Reflections From the Field* [Working Title]. IntechOpen, Jan. 03, 2023. doi: 10.5772/intechopen.109380.
- [3] Explore the Future of Art: How Phygital Exhibitions Will Transform the Way We Experience Art
- Mele, C., Spina, T.R., Marzullo, M. et al. The phygital transformation: a systematic review and a research agenda. *Ital. J. Mark.* (2023). <https://doi.org/10.1007/s43039-023-00070-7>.
- [4] Sharné McDonald "The History and Future of Digital Art" <https://www.vectornator.io/blog/digital-art/>
- Anna Lindemann, 2017, Assistant Professor, "Animating Science: Digital Arts in STEAM Education" *Digital Media and Design*, School of Fine Arts, University of Connecticut, 2017.

Reference of Chapter V: Best practice

- CHOICE project, <https://www.euchoice.eu/>
- Digital Learning across Boundaries (DLaB) project, <https://dlaberasmus.com/>

- I-STEM project description, <https://istem-project.eu/>
- PERFORM project, *Project description*. (n.d.). Perform. <http://www.perform-research.eu/about/project-description/>
- STEAM IT project description, <https://steamit.eun.org/about-the-project/our-objectives/>
- STEAMBUILDERS Project description, <https://steambuilders.eu/the-project/>
- STEAMonEdu project, <https://steamonedu.eu/>
- Villanueva Baselga, Sergio, Marimon Garrido, Oriol, González Burón, Helena, *Drama-based activities for STEM education: encouraging scientific aspirations and debunking stereotypes in secondary school students in Spain and the UK* <https://diposit.ub.edu/dspace/bitstream/2445/163678/1/701246.pdf>
- VXDesigners project, *The project* <https://vxdesigners.eu/the-project/> (last accessed 25/04/2023)