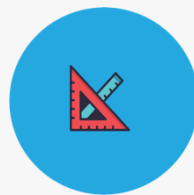


GUIDELINES FOR INTRODUCTION OF TRANSVERSAL SKILLS IN NON-FORMAL STEAM EDUCATION



Co-funded by
the European Union

The sole responsibility for the content of this document lies with the authors. It does not necessarily reflect the opinion of the European Union.





Title of project	DOTS... Development of transversal skills in STEM
Full title of project	DOTS... Development of transversal skills in STEM
Title of this document	Guidelines for introduction of transversal skills in non-formal education
Versioning history	v.1
Author	DOTS partner consortium
Executive summary	The guidelines aim to guide educators from non-formal frameworks and teachers in early primary school education and non-STEM teachers on how to introduce and perform activities that increase the individual ownership of transversal competencies.





TABLE OF CONTENTS

1.	<i>ABOUT THE DOTS PROJECT</i>	3
1.1.	INTRODUCTION	3
1.2.	RESULTS	4
2.	<i>ABOUT THE GUIDELINES</i>	5
3.	<i>STEAM, NON-FORMAL EDUCATION AND TRANSVERSAL SKILLS</i>	6
3.1.	UNDERSTANDING THE DEFINITION OF STEM	6
3.2.	UNDERSTANDING THE DEFINITION OF NON- FORMAL EDUCATION	7
3.3.	UNDERSTANDING THE DEFINITION OF TRANSVERSAL SKILLS	8
3.4.	TRANSVERSAL SKILLS IN STEAM	10
4.	<i>DEVELOPMENT OF TRANSVERSAL SKILLS IN STEAM (NON-FORMAL EDUCATION)</i>	11
4.1.	PEDAGOGICAL APPROACHES	11
4.2.	DESIGNING A STEAM ACTIVITY: KEY POINTS TO CONSIDER	14
4.3.	DESIGNING A SPACE FOR STEAM ACTIVITIES BEYOND TRADITIONAL CLASSROOM	20
5.	<i>CONCLUSIONS</i>	21
6.	<i>BIBLIOGRAPHY</i>	22
	<i>ANNEX A: TRANSVERSAL SKILLS TABLE</i>	0

TABLE OF FIGURES

<i>Figure 1. Results of DOTS project.....</i>	4
<i>Figure 2. Transversal skills by UNESCO.....</i>	9
<i>Figure 3. Experiential learning. Source: Brock University.....</i>	12
<i>Figure 4. PBL, PrBL and IRL learning. Source: https://www.learningbyinquiry.com/.....</i>	13
<i>Figure 5. EDP process. Source: www.study.com.....</i>	15
<i>Figure 6. Graphic organiser to assist in planning integrated STEAM activities</i>	19





1. ABOUT THE DOTS PROJECT

1.1. INTRODUCTION

The project "DOTS... Development of transversal skills in STEM" was implemented within the Erasmus+ programme. The overall objective of the project was to improve the transversal skills of both STEM teachers and other teachers and coaches for innovative approaches to teaching.

The specific objectives of the DOTS project were:

- developing methods, materials and tools that support the learning and teaching of transversal skills
- training teachers to apply the developed methods, tools and materials in teaching.

The project sought to encompass highly motivated teachers who will undergo a series of coaching training courses to enable them to further disseminate the acquired knowledge in their environments. In addition, the project allowed teachers to exchange good practice examples from European countries and the wider international community.

In addition to teachers' specific, subject-related STEM skills, the project also developed transversal skills that contributed to open communication and collaborative work within the school collective and between the teacher and the students. Some transversal skills include presentation, communication, critical thinking, teamwork, and others.

Through the project, the partners developed a set of practical materials, tools, guidelines and a manual that will contribute to the application of new teaching methods in teaching STEM subjects. In addition, training sessions were organised in all partner countries to develop cooperation and devise new, innovative methods, tools and materials for learning and teaching.

Overall, the DOTS project has gathered professionals in the field of STEAM (Science, Technology, Engineering, Arts and Mathematics) to fulfil the existing gap between the educational system and societal needs. Bringing in international expertise of project partners and enabling them to analyse, reshape and co-create teacher training methods to move teachers above certain specific fields of STEAM - exploring the landscapes of transversal skills which could be taught within the STEM classroom environment.

It is a strong belief of the DOTS project that a teacher with an understanding of the role of transversal skills and the ability to design a learning experience that fully incorporates them will be able to empower students to become active and autonomous learners and positive actors in their school, the local community and eventually in the whole of society. Transversal skills allow educators to expand pupils' scientific literacy, critical thinking, ethical intelligence and global perspective and help them grow into confident lifelong learners and active citizens.





For more information about the project, please visit the project's website here: <https://www.dots-project.eu/>

1.2. RESULTS

The DOTS project has developed four intellectual outputs:

- 1) **SMALL ACTIVITIES, BIG IMPACT - TRAINING MATERIAL**: The document presents the approach and the main training material that has been produced for the training courses of the project. The training material includes several cases and STEM fields covering transversal skills. It also includes a structure for the training courses for teachers, that can use the material to enhance their transversal skills.
- 2) **EDUCATIONAL TOOLKIT AND TOOLBOX** - a digital handbook with open access to detailed activities for enriching STEM teaching practices and methods while transversely boosting student transversal competencies. It incorporates multimedia content with detailed explanations on executing activities, which STEM concepts are tackled with them, and how to simultaneously develop transversal skills.
- 3) **REVERSE TEACHING SCENARIOS** - provides teaching scenarios for specific STEM lessons with detailed and in-depth instructions on how to guide the students, how to introduce them to the challenge, what STEM topics are acquired and needed to solve it, what are the indicators and types of evidence sufficient proof of the desired result and much more.
- 4) **GUIDELINES FOR INTRODUCTION OF TRANSVERSAL SKILLS IN NON-FORMAL EDUCATION** – the guidelines will explain how to guide activities and directly teach skills which are shown like a needed strategy in the acquisition by students.

All the results are available in English, Croatian and Greek languages and can be found in the project's website here: <https://www.dots-project.eu/activities-and-results/>

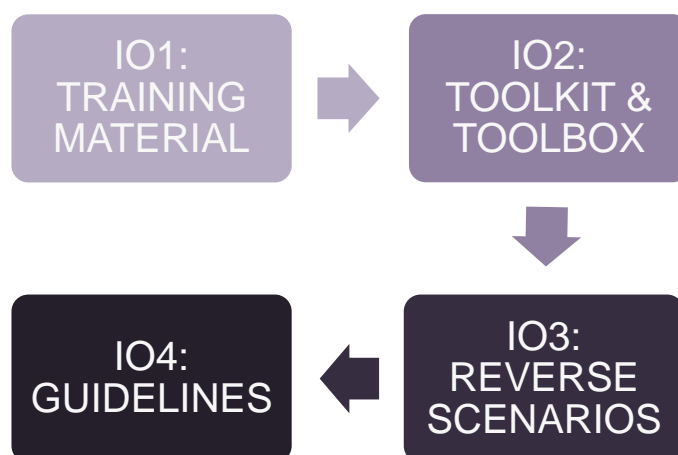


Figure 1. Results of DOTS project





2. ABOUT THE GUIDELINES

The main aim of the guidelines is to provide information and deepen the understanding of transversal skills. Teachers in all education levels must be aware of the importance of transversal competencies and should help students develop them alongside the professional competencies.

The guidelines also aim to guide educators from non-formal frameworks and teachers in early primary school education as well as non-STEM teachers on how to introduce and perform activities which are increasing the individual ownership of transversal competencies in a non-formal education setting.

The guidelines are composed of several parts:

- Introduction to the project
- Defining STEM
- Defining transversal skills
- Understanding pedagogical approaches in STEAM
- Discovering key points to consider when designing STEAM activity
- Discovering how to create STEAM learning spaces beyond the traditional classroom approach

With such guidance, educators, trainers and non-STEM teachers, especially in early primary educational frameworks, can start to develop pre-scientific competencies, which include skills, knowledge, and values. Furthermore, they can also begin developing their STEAM activities focused not only on specific scientific knowledge but also on the development of transversal skills.





3. STEM, NON-FORMAL EDUCATION AND TRANSVERSAL SKILLS

3.1. UNDERSTANDING THE DEFINITION OF STEM

Simply put, STEM stands for Science, Technology, Engineering and Maths. The core idea of STEM is to use all of these disciplines to solve daily or societal problems, making the learning of science, technology, engineering and mathematics more relevant and contextual.

STEM literacy has been defined as (R. W. Bybee, 2013):

- Knowledge, attitudes, skills and values to identify questions and problems in real-life situations. Explain the natural and designed world, and draw evidence-based conclusions about STEM-related issues;
- Understanding of the characteristic features of STEM disciplines as forms of human knowledge, inquiry, and design;
- Awareness of how STEM disciplines shape our material, intellectual, and cultural environments;
- Willingness to engage in STEM-related issues with science, technology, engineering, and mathematics ideas as a constructive, concerned and reflective citizen.

The need to shift from traditional education to innovative educational approaches has led to the growth of STEAM - Science, Technology, Engineering, Arts, and Mathematics education. It started as an extension of the acronym STEM and all that it encompassed, with the addition of Arts. The term was introduced by Georgette. Adding Arts to STEM to create STEAM incorporates creative thinking and applied arts in real situations.

Including the "A" as a representative of the arts is a way to invite those students who are not comfortable in these disciplines and, at the same time, a way to carry out a strategy to improve their self-efficacy (Zimmerman & Campillo, 2003).

While there are many definitions and variations of STEM concepts, they often depend on the perspective from which it is viewed within the education system. For example, many people view STEM as four separate disciplines.

In the context of the DOTS project, STEAM is viewed as a holistic, interdisciplinary approach which removes the learning and development barriers between the four disciplines of Science, Technology, Engineering, Arts and Mathematics. Thus, when designing STEAM activities, it is essential to consider cross-disciplinary concepts and approaches while at the same time acknowledging the specificities and characteristics of each STEAM discipline.

Research suggests that interdisciplinary or integrated activities provide opportunities for more relevant, less fragmented, and more stimulating experiences for learners, including improving student motivation to learn; enhancing attitudes and interest; making students better problem solvers, innovators, inventors, self-reliant, logical thinkers, and technologically literate (UNESCO, 2019).





The goal of such STEAM educational approach is to develop well-informed and highly competent citizens in the age of the 4th industrial revolution – able to cope with changes and adapt to new workforce requirements.

3.2. UNDERSTANDING THE DEFINITION OF NON-FORMAL EDUCATION

Non-formal education refers to planned, structured programmes and personal and social education processes for young people designed to improve a range of skills and competencies outside the formal educational curriculum.

Non-formal education happens in places such as youth organisations, sports clubs and drama and community groups where young people meet, for example, to undertake projects together, play games, discuss, go camping, or make music and drama (Council of Europe).

It is essential to emphasise that non-formal education, together with formal and informal education, are all elements of lifelong learning.

To consider education a non-formal education, it has to have these essential features (Council of Europe, 2001).

- balanced co-existence and interaction between cognitive, affective and practical dimensions of learning
- linking individual and social learning, partnership-oriented solidary and symmetrical teaching/learning relations
- participatory and learner-centred
- holistic and process-oriented
- close to real-life concerns, experiential and oriented to learning by doing, using intercultural exchanges and encounters as learning devices
- voluntary and (ideally) open-access
- aims above all to convey and practice the values and skills of democratic life

UNESCO also emphasises the flexibility of non-formal education and how it allows for more personalised learning to be developed for each person.

Over the past decades, civil society, governments, and European institutions have increasingly recognised the importance and relevance of non-formal education. As a result, non-formal learning and education have been viewed as key priorities and work areas of education-related organisations and institutions.

Still, despite growing interest and is considered a key priority area in Europe Union, most of the time, non-formal education does not lead to qualifications recognised by relevant national education authorities or to any qualifications in general. To validate the qualifications of non-formal education, Europe Union has used two types of certificates: Youthpass¹(for youth and youth workers) and Europass²(for adults). However, the disadvantage of these documents is

¹ <https://www.youthpass.eu/en/>

² <https://europa.eu/europass/en>





that they aim to recognise international learning experiences gained during some educational experience abroad and do not cover the local educational activities.

3.3. UNDERSTANDING THE DEFINITION OF TRANSVERSAL SKILLS

Before we proceed with the guidance on introducing transversal skills in your STEAM activities, we have to have a common understanding of transversal skills.

Transversal skills are those typically considered as not specifically related to a particular job, task, academic discipline or area of knowledge but as skills that can be used in a wide variety of situations and work settings (IBE 2013). These skills are increasingly in high demand for learners to successfully adapt to changes and to lead meaningful and productive lives (UNESCO 2014c)³.

The term 'transversal' refers to how these skills' cut across' different tasks and roles, just like a transversal line in geometry.

UNESCO has proposed six domains to categorise transversal skills and competencies", which are:

- 1) **Critical and innovative thinking** (e.g., creativity, resourcefulness, decision making, etc.);
- 2) **Interpersonal skills** (e.g., presentation and communication skills, organisational skills, teamwork, etc.);
- 3) **Intrapersonal skills** (e.g., self-discipline, enthusiasm, perseverance, self-motivation, etc.);
- 4) **Global citizenship** (e.g., tolerance, openness, respect for diversity, intercultural understanding, etc.);
- 5) **Media and Information literacy** (e.g., the ability to locate and access information, as well as to analyse and evaluate media content) ;
- 6) **Others.** The domain " others" was created as a way for researchers to include competencies, such as physical health or religious values, that may not fall into one of the other" domains.

The glossary with definitions of these skills prepared by the DOTS project consortium with examples can be found in Annex A.

You can find the graphic created by UNESCO with six domains and accompanying skills/competencies below.

³ TVETipedia Glossary, URL: <https://unevoc.unesco.org/home/TVETipedia+Glossary/filt=all/id=577>





Figure 2. Transversal skills by UNESCO



3.4. TRANSVERSAL SKILLS IN STEAM

The importance of STEM teaching arises from the fact that our global economy is changing at a very fast pace. A lot of existing jobs are vanishing daily, and a lot of them are replaced by new, highly automated jobs as a result of the usage of advanced technology. The demand for these types of jobs is not the only thing that is changing. New learning approaches, connections and interaction among students are required because of these advancements. Observing it from a statistical point of view, the current marketplace is 50% in shortage of STEM-connected fields. Furthermore, around 75% of the arising jobs require STEM skills, while approximately 90% of the existing jobs on the market will need digital skills in the following few years (Government of WA, 2020).

Employers point out that being well-rounded and able to work successfully in various teams and with others calls for a variety of skills. At the same time, employers believe it is more challenging to develop transferable skills. The capacity to acquire these abilities can be offered by STEM education and can benefit both career and personal growth (Gurudev, 2022).

Solutions to the challenges that we are facing today will require a new multidisciplinary scientific workforce equipped with a skill set of new technology and interdisciplinary thinking that may "require the integration of multiple STEM concepts to solve them" (Wang, Moore, Roehrig, & Park, 2011, p. 1). Thus, it is essential to prepare a diverse STEM-literate workforce with the capability to understand and comprehend the technological world (Merchant & Khanbilvardi, 2011).

STEM educational methodology is specially shaped with the purpose of fitting the gaps that occur within different study programmes. Furthermore, the combination set of skills and knowledge serves the purpose of preparing the future labour force for the upcoming challenges and issues while performing their daily job requirements.

However, judging only by the acronym, STEM interdisciplinary learning indicates the education of students only in technical and scientific areas and preparing them for those job positions that require a specific type of knowledge. In practice, STEM provides support to students in developing portable abilities necessary to overcome digital and similar changes. As a result, students will be able to adjust to a changing workforce where new job kinds replace dated ones thanks to the adaptability of these skills. Furthermore, as new market demands emerge, these transferrable abilities will be crucial in assisting students in managing transitions between various industries and jobs (Hallinen, 2022).

The inclusion of transferable skills within the STEAM-connected subjects represents a starting point for a competitive way of learning. The current and future generations of students will be required to possess competences and skills that can be used in various situations and work settings. This particular set of skills can be exploited through STEAM activities either in a formal or non-formal setting. The goal of the STEAM methodology with respect to the transversal type of skills is to motivate a more learner-centred and experiential way of gaining knowledge instead of just transferring information from teachers to students.





4. DEVELOPMENT OF TRANSVERSAL SKILLS IN STEAM (NON-FORMAL EDUCATION)

4.1. PEDAGOGICAL APPROACHES

In today's rapidly evolving world, setting learners up for future success means exposing them to STEAM disciplines holistically in order not only to develop specific knowledge useful across the disciplines but also to equip them with transversal skills. These skills are key to preparing students for future jobs and lives where creativity and innovation are becoming the norm.

There are several different pedagogical approaches that educators can use to promote the acquisition of transversal competencies through STEAM activities:

- 1) **Start with student centred approach.** This approach, as can be understood from the title, shifts the focus of activity from the educator to the students - students taking an active role in the learning process rather than being passive recipients of information from the educator. In other words, students are encouraged to participate fully and take responsibility for their learning. The student-centred approach in STEAM focuses on students' individual needs and different learning styles and keeps them engaged in the learning process. For this approach to work, the educator needs to accept students' autonomy and create a supportive relationship and environment in which the students are valued and can freely express themselves. Other essential elements of this approach are students' choice, collaboration, and reflection. Research about the student-centred approach in STEAM demonstrates outcomes consistent with developing 21st-century skills, including transversal skills and STEAM mastery (Keiler, 2018). The student-centred approach allows students to build independence, communicate effectively, learn through inquiry, and develop transferable skills.
- 2) **Focus on real-world problems in context students can relate to.** Learning about real-life challenges and looking for solutions is an excellent way to engage students, fuel their curiosity and get them excited about STEAM as they realise that the solutions developed could potentially have an impact beyond the classroom walls. The best STEAM lessons invite students to address compelling social, economic, and environmental issues in their lives and communities. Keep in mind that the real-life problem chosen should be relatable, doable (students have the necessary knowledge and skills set to design solutions), as well as have multiple acceptable approaches and solutions. Some examples of real-life problems that STEAM lessons could focus on are - preventing soil erosion, improving the lives of people with disabilities, water pollution, renewable energy, etc.
- 3) **Experiential learning is a key.** Experiential learning has been recognised as a means to improve retention in STEAM education and create knowledge through experience transformation. The experiential learning approach allows acquiring knowledge and building skills through active engagement in relevant activities followed by processing and reflection, leading to continued learning and more reflection into the future.



To put it simply, using this approach, lessons are tailored to be relevant to the students – they draw on students' past experiences and interests to introduce them to new ideas and concepts. Throughout the learning process, students are actively engaged in posing questions, analysing and investigating, experimenting, solving problems, making decisions and constructing meaning. Students also develop their transversal skills – communication, collaboration, creative problem solving and many more. Using this approach, educators' primary role is to set relevant experiences, pose problems/challenges, set boundaries, support learners and facilitate learning progress. It is important to emphasise that the design of the whole learning experience includes the possibility to learn from successes as well as failures and mistakes.

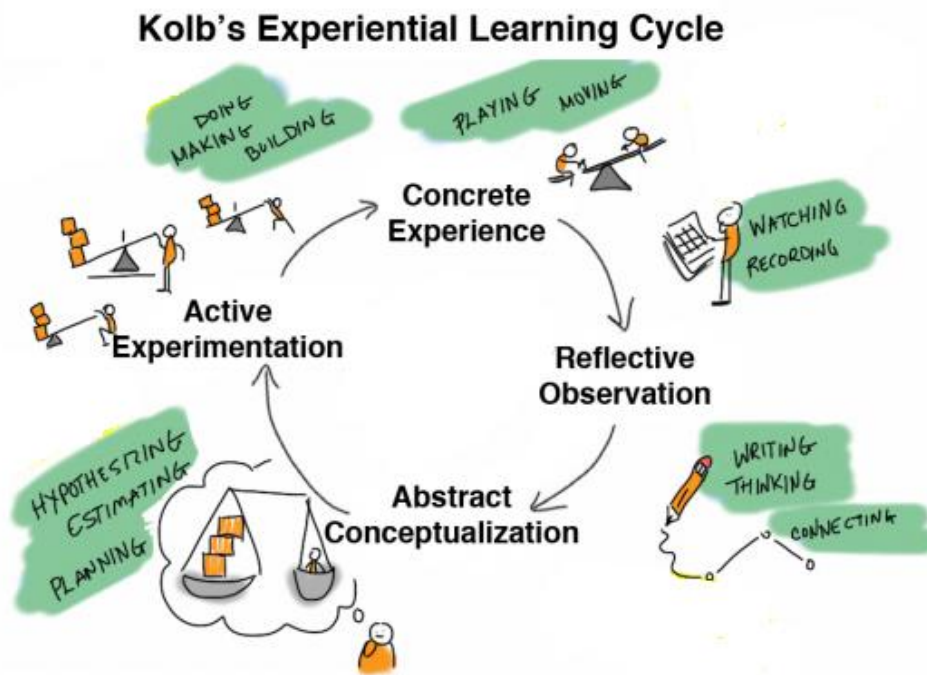


Figure 3. Experiential learning. Source: Brock University

- 4) **Use Problem-based learning (PBL).** PBL as a strategy is a top-down process that requires learners to solve problems, analyse, synthesise, think critically, and communicate knowledge from several disciplines promoted by constructivism (Terhart, 2003). You can use PBL to allow the student to conduct research and apply knowledge and skills to develop a viable solution to a defined problem. Transversal skills like collaboration, communication, creativity, critical thinking, problem-solving, etc., are part of any STEAM PBL activity. Thus, using problem-based learning in STEAM activities can add the intentionality needed to teach and assess the 21st-century and transversal skills embedded in STEAM. Keep in mind that the success of STEAM PBL activity depends on well-selected, ill-structured problems (often interdisciplinary) and the availability of support to guide the learning process and to debrief at the end of the learning experience. While it is essential for educators to support the process, it is also essential for them not to provide information related to the problem or solutions to their students (UNESCO, 2019).

- 5) **Employ Project-based learning (PrBL).** Besides problem-based learning, you can also employ project-based learning. The best analogy to describe the difference between the two approaches is that in Project-based Learning, students have to produce an artefact to demonstrate their mastery of content, while in Problem-Based Learning, students have to present a solution to a clearly defined authentic problem. However, PBL and PrBL both begin with and are framed around real-world problems. Both of these approaches are cross-disciplinary, incorporating a variety of concepts into a single learning experience. Like problem-based learning, project-based learning also supports students, encourages a deeper understanding of the content, enables meaningful connections and aids students in their transversal skills development. Project-based learning can work for all students, developing a wide range of transversal skills - critical thinking and problem-solving skills, collaboration, communication, self-reflection and many others. In this approach, the role of the educator, as both a facilitator of learning and a provider of information, is stronger, whereas the learner's role in setting the goals and parameters for the investigation is less defined.
- 6) **Utilise Inquiry-based learning (IRL).** Inquiry-based STEAM learning focuses on hands-on experiences and creative ways to solve problems. It mirrors the thinking and processes employed by scientists, engineers and innovators in the real world. Using this method, students learn how to gather, critique, analyse, and interpret information, create working theories, pose new questions and integrate new ideas – while simultaneously developing their transversal skills. Reasoning, reflective thinking, gathering and critically evaluating data available, creativity, communication and teamwork skills – are just some examples of transversal skills inquiry-based learning helps to develop. In this approach, the educator's role is to monitor students' progress, provide structural support when needed, and ensure that the main focus stays on students' questions and observations.

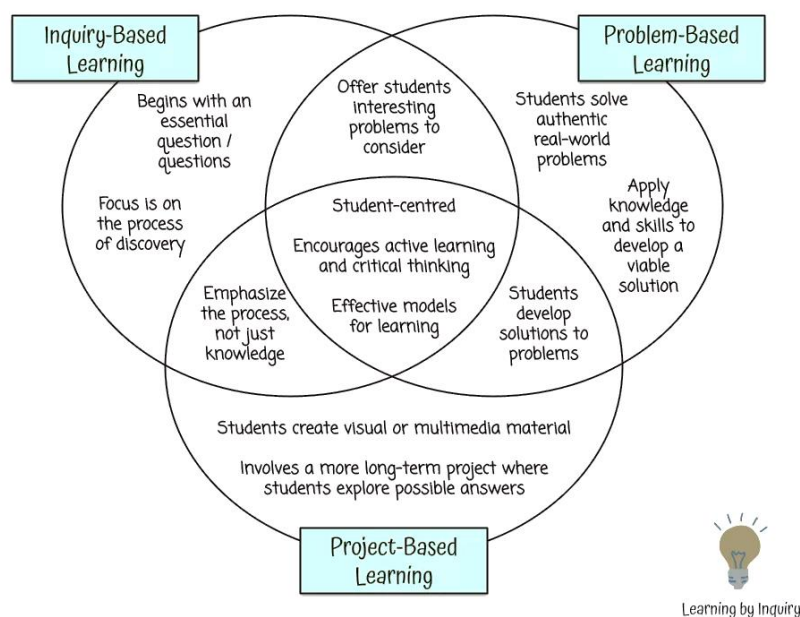


Figure 4. PBL, PrBL and IRL learning. Source: <https://www.learningbyinquiry.com/>



- 7) **Make learning fun and engaging using Game-based learning (GBL).** GBL is an innovative learning tool that bridges physical and digital learning environments. Gamification elements can be used to increase student focus, knowledge retention and motivation. Gamification elements can also be used to go from a traditional classroom environment into a space that encourages interaction and exploration. The research done by two researchers at Clemson University in South Carolina found that students either learned more or showed more improvement in transversal skills such as critical thinking and problem solving when game design elements of competition, collaboration, and role-playing were incorporated.

If implemented correctly, these approaches can help students make personal meaning of their learning experiences, increasing the probability that what is learned will be retained and transferred for later use.

4.2. DESIGNING A STEAM ACTIVITY: KEY POINTS TO CONSIDER

There are several vital questions educators should ask themselves when designing their STEAM activities (Liston, 2018):

1. Does the lesson present a real problem?

Working on solutions to real-world problems is the heart of any STEAM investigation. Focusing on real-life challenges that students can relate to can help you tap into their investigative curiosity and encourage them to ask and investigate questions they care about. It is also a great way to engage students and keep them motivated to continue with their discoveries in STEAM. You can invite students to address social, economic, and environmental issues they face in their daily lives in their communities. For example, a workshop focused on developing solutions to clean up oil spills.

2. Will students relate to the problem?

The level of student engagement and motivation highly depends on the relevance of the problem presented to them. Thus, it is essential to choose a problem that focuses on real-life situations and issues, not a scenario that is made up. It is best to focus on the problem that affects the community/region the students are from. This way, we can also develop students' empathy - a sense of being able to place themselves in someone else's shoes and understanding that there is something worth dedicating their efforts to. If you struggle to choose the problem your students could relate to, just ask them – giving them autonomy to identify problems they want to solve. You might start by asking students what problems they face in their homes, school, or community. You can also go the other way around and instead of focusing on the problem, ask them what needs to happen to make life better for people in their community.

3. Does the lesson allow students multiple acceptable and creative approaches and solutions for successfully solving the problems?

The STEM environment should offer rich possibilities for creative solutions. Thus, chosen real-life problems should always be not only doable (students have the necessary knowledge and





skillset to design solutions) but also have multiple acceptable approaches and solutions. The way the STEAM activity is designed should allow students to research and select different approaches and solutions as well as develop their creativity. For example, a bridge might be successfully constructed using many different designs and from many different materials.

4. Does the lesson integrate and apply important science and math content?

To reach the desired impact, STEAM activities, by design, should develop students' understanding of important science and math concepts. Therefore, you should purposely connect and integrate content from math and science subjects into your STEAM activities. You do not necessarily have to be a math or science educator. Instead, you can collaborate with educators from these areas to gain insight into how these subjects can be seamlessly integrated into your activities. This way, students will start to see maths and science not as separate subjects but as knowledge and skills that are needed for everyday life solutions. For example, maths equations can ensure students' design works properly, or knowledge of physics will help them understand how to create some structure and designs.

5. Does the lesson use the engineering design process as the approach to solving problems?

"E" in STEM stands for engineering – a key component differentiating STEAM from regular science, technology, and math approaches. Therefore, STEAM activities should engage students in using an engineering design process (EDP).

As a separate process from STEAM, the engineering design process indicates a series of procedures to guide the engineers and engineering teams on how to solve real-life problems. Observed from the STEAM point of view, the design engineering process application encourages the ability to self-learning, working collaboratively with others, among other transversal skills, and a deeper understanding of how science, art, math, engineering and technology go hand in hand.

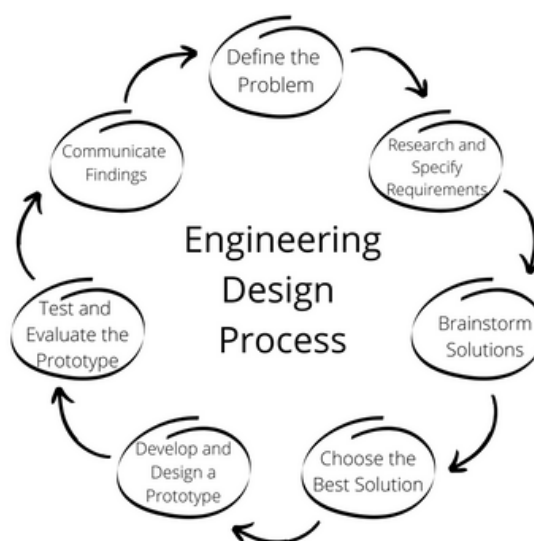


Figure 5. EDP process. Source: www.study.com





There are several steps involved in EDP:

- *Ask - define the problem.* You can begin by asking your students questions about the challenge they will aim to address. Encourage students to answer the following questions: What problem is being solved? Who is this product being designed for? Why is a solution to this problem important? Set criteria and constraints should be introduced in this stage.
- *Research.* In this stage, students should use available resources to gather needed information about the chosen problem. The research can involve talking to the educator, researching online, watching videos, etc. The research stage is essential as it can help students discover what similar products or solutions already exist and encourage them to think about how to improve them or find new solutions/products.
- *Imagine.* Divide your students into smaller teams and ask them to brainstorm as many ideas to solve the problem as possible. Encourage creative and out-of-the-box ideas. Remember, this should be a collaborative process where everyone has a chance to present their ideas in no judgement zone. You may use many brainstorming techniques—brainwriting, mind maps, rapid ideation, starbursting, etc.
- *Plan.* During this step, students must choose the best idea they will work on. To do this, they should consider their original questions, the research carried out, and ideas from the brainstorming process. Then, students should choose the idea they think will work best and start deciding on their prototype design. Choosing and sketching the prototype is suggested as part of the planning step. The planning stage could be challenging for students, thus, additional support from the educator might be required.
- *Create.* During this stage, students build the prototype they selected. This is the time to get creative and use a hands-on approach. At this point, students will also be able to see if their design is functional and meet original requirements. If the design is not what they expected, they can do additional planning and redesigning. This stage does not require much intervention from the educator's side – the educator should just observe and encourage students when needed.
- *Test and evaluate.* Students test their prototypes to see if they work. This usually involves going through a few tests with a few modified prototypes due to some additional problems coming up that weren't thought of in the planning and creation stage. The test results should be recorded, and prototypes should be evaluated based on the criteria established in the first stage and their problem-solving ability. Students can use various rubrics and checklists for evaluation purposes.
- *Redesign.* Based on the test and evaluation results, students decide on changes they will make and justify the revisions. Then they start working on redesigning the prototype. They also have to identify the changes. Redesigning is an integral part of EDP. Sometimes, the entire STEAM activity can be focused on improving the existing device or prototype.
- *Communicate.* As the final step, students share the information about the problem they tackled and their design solutions. They could share it with other teams/their peers, but it could also be shared with various audiences using various communication methods (e.g., posting it online, sharing it in the science fair, etc.).





During all these stages, many transversal skills are developed - resourcefulness, creativity, communication skills, teamwork and collaboration, critical thinking and ability to obtain information, reflective thinking, reasoned decision-making application skills, and empathy, among others. Depending on the topic of the problem chosen, students can also develop global citizenship skills, e.g., respect for the environment, ethical and intercultural understanding, tolerance for diversity, etc.

6. Does the lesson use a student-centred, hands-on teaching and learning approach?

Successful STEAM activities encourage students to explore and solve problems through a hands-on and collaborative approach where decisions about solutions are student-generated. Students carry out hands-on investigations, generate ideas, explore, make decisions, and test their ideas as possible solutions without fear of failure. In such activities, the learning path is open-ended, within some constraints (e.g., time frame, available materials), and failure is a part of learning. The activities include flexibility and choice, where educators act as facilitators – providing just enough guidance and monitoring.

7. Does the lesson lead to the design and development of a model or prototype?

In most cases, STEAM activities involve the creation of a model or prototype. Sometimes, it can be the creation of some system to solve a chosen problem instead of the prototype. Nevertheless, models and prototypes are introduced as a critical element to understanding, exploring and expressing almost all big concepts in science and engineering. Moreover, students are more motivated and engaged when they use the knowledge and skills they have in practice to construct tangible solutions.

8. Is technology involved in the activity? If yes, is the role of technology in the activity clear to the students?

Technology can play an important role in the STEM learning process. Technology can help students with their research and investigation well as prototype design. Depending on the resources available, students may use coding to create digital technology to solve a problem. In such cases, students not only use technology to solve a problem but also create a technology. While technology can help to facilitate creative, flexible and purposeful thinking and knowledge construction, not all activities require the use of technology. Whether you decide to use it or not, during the activity, technology's role should always be clear to students.

9. Does the STEAM activity develop students' transversal skills?

The main goal of implementing a STEAM activity is gaining specific knowledge and skills easily transferable from one scientific area to another, meaning that the students can use them as an advantage further in life (e.g., successfully entering the labour market). If the STEAM activities are planned with this in mind, besides the specific scientific knowledge, students also develop transversal skills such as increased problem-solving abilities, critical thinking, collaboration, independent thinking and taking initiative, digital literacy, communication abilities and many more. Thus, when designing activities and writing down the outcomes, always think about what transferable skills students will develop as a part of the outcomes.





Here is a very simple example of a STEAM activity mixing different scientific fields and producing transferable skills.

Building a geometrical tower

Required materials for the activity:

- A4 papers (if you are working with young children, you can use paper with already printed geometric shapes and how to cut them)
- Scissors
- Glue
- Strong paper material (e.g., carton)

The students are divided into teams, and their goal is to cut the paper with the geometrical shapes on it, glue it to the stronger paper material and then, in the end, make the 3D geometrical shapes themselves by glueing the edges. After different geometrical shapes are made, the idea is to build the biggest tower by using various geometrical shapes and placing them in the right position and order (Crockett, 2021).

This particular STEM activity aims to provide a mathematical understanding of the geometrical shapes while simultaneously motivating the group to figure out how physics works and explore their engineering abilities. The transferable soft skills that this activity can trigger are critical thinking, communication and organisational skills, teamwork, creativity, and application skills, among others.

10. Does the lesson include testing the solution, evaluating the results, and redesigning to improve the outcome?

STEM activities in practice are not linear, meaning that the educator encourages students for them to generate different types of ideas or approaches on how to tackle the issue and guide them to choose one approach, test it and evaluate the results.

As mentioned earlier, prototype testing and evaluation are essential for STEAM activity. Students should be able to present gathered testing data graphically and draw conclusions. Then, based on the results, they should be able to make informed decisions about redesigning their prototype to improve it.

11. Does the lesson involve students in communicating about their design and results?

There can be many ways to involve students in communicating their achievements. It could include blogging, creating videos or creative poster shows, posting on social media, sharing with their peers in science fairs, etc. This is a part where students could also use their creativity, art and design skills.

Being able to share their achievements should be incorporated in every activity, even in a simple way as sharing results with the other students or student teams or parents. Sharing results can help to maintain students' engagement and motivation, boost their confidence,





make them feel that their work is valued and meaningful, as well as develop their transversal skills. Being able to present their work shows them they have a voice and are capable of producing meaningful, authentic, high-quality work that can have an impact outside of the classroom.



Figure 6. Graphic organiser to assist in planning integrated STEAM activities

Keep in mind that while successful STEAM activity should include all these key points, sometimes it just doesn't, and that is okay. The most important thing is that throughout their STEAM experience and activities, students would eventually immerse themselves in all the STEAM activity components. Therefore, if you are using available STEAM plans, ensure that all these components are covered throughout the whole experience. If it is not, you can redesign them to fit your ideas and needs.





4.3. DESIGNING A SPACE FOR STEAM ACTIVITIES BEYOND THE TRADITIONAL CLASSROOM

Due to STEAM's interactive, collaborative and hands-on nature, most of the activities involve using some sort of materials. Depending on the resources available, they can be sophisticated materials or just simple ones that we use in our everyday lives. The same goes with the space for activities -it can range from simple space to special areas in the room or other designated spaces, depending on the budget and other available resources.

In the past couple of years, we have seen the emergence of so-called "Makerspaces" or "STEAM labs" – collaborative workspaces specifically designed to provide hands-on, creative ways to encourage students to design, experiment, build and invent as they immerse in STEAM activities.

A makerspace should not be confused with a simple lab, as usually it is a space that contains elements of different spaces such as a science lab, computer lab, art room, etc. and is designed to accommodate a wide range of activities, equipment and materials.

Some educational institutions at different levels of education, both formal and non-formal, have chosen to incorporate makerspaces within multiple spaces, each equipped with specific equipment and materials. However, not all educational institutions and educators have the resources to create and maintain such spaces. Nevertheless, there are several strategies you can employ to create a space suitable for hands-on, collaborative and engaging STEAM activities:

- 1) Create "Tinker Tubs". Think of tinker tubs as a simpler version of makerspaces. Tinker tubs essentially are boxes/containers with materials necessary for STEAM activities that are brought out to the space for certain STEAM activities. Each box may have one type of material (building blocks, toy car parts, various crafts materials, etc.) or mixed materials needed for a specific activity.
- 2) Use investigation stations. Creating investigation spaces typically involves setting up a space in a room/area with necessary materials, tools and resources students can use to investigate, study, design and test. Different steps of STEAM activity will be done in different stations. For example, students in the "engineering station" could be building a tower using geometrical paper figures and glue, but to measure the towers constructed, they will need to move to the "math station" that stores measuring tools. You can create as many investigation stations as necessary for your activity using the previously mentioned tinkering boxes. The stations can be easily formed by moving tables and chairs to different places of the space you are using. Some stations can also be created outside, depending on your working space. After the activity, the materials can be stored again, chairs and tables moved to their initial positions, and place can be used for other activities.





- 3) Use public spaces. You can use public areas such as parks, museums, public libraries, etc. Research suggests active exploration wires the brain and helps students to develop knowledge and meaningful connections central to STEAM subjects. Successful STEAM activities involve engaging hands-on exploration, fun projects, and learning through experience. Taking STEAM activities to public spaces can add a creative, playful side to your activities and help to keep students engaged.

5. CONCLUSIONS

The 21st-century workplace demands lifelong learners with innovative and forward-thinking mindsets who can quickly adapt to changes. Furthermore, 21st-century skills or transversal skills such as teamwork, communication, creative problem solving, and leadership are in as much demand from STEM employees as their technical know-how.

To keep up with the technological, fast-changing world and its new demands, our education approaches have to change and adapt as well to be able to prepare such learners. STEAM activities are perfect for stimulating the development of knowledge and skills needed for an ever-changing world. However, to achieve that, our STEAM education should not be only focused on developing technical know-how but also transversal skills that are useful across disciplines and stick with the students through life.

Unfortunately, when it comes to designing STEAM activities that also focus on transversal skills development, there's no single, die-cut approach that everyone is or should be using. STEAM activities can come in many different shapes and sizes: they can be complex or simple; they can be done in a designated space, or materials can just be brought out for the occasion; they can be embellished with deep questioning or left to simple discovery; it can be a full-blown project, or it can be a one-off challenge; it can involve sophisticated machines or simple tools; it can take a whole lesson or 10 minutes of it. Whatever the budget, space and materials you have access to, STEAM can be done (Hillyard, 2020)

As an educator, when creating activities, you first have to analyse the needs of your students and the existing skills and knowledge gaps and then consider the resources available as well as existing constrictions. To engage and motivate the students, activities should be based on real-life challenges they can relate to and designed using a mix of various different pedagogical approaches (student-centred, experiential, PBL, PrBL, IRL, GBL and other approaches). If implemented correctly, these approaches can help students make personal meaning of their learning experiences, increasing the probability that what is learned will be retained and transferred for later use.





6. BIBLIOGRAPHY

1. ArtIntegration. (2022, July 21). What is steam education? The Institute for Arts Integration and STEAM. URL: <https://artsintegration.com/what-is-steam-education-in-k-12-schools/>
2. Bauld, A. (2022, May 23). What is steam education? Rethink Together. URL: <https://xgsuperschool.org/rethinktogether/what-is-steam-education/>
3. Bybee, R.A. 2013. The Case for STEM Education, Challenges and Opportunities, National Science Teachers Association (NSTA)
4. Callaghan, C. (2021, June 29). What is stem? Top Universities. URL: <https://www.topuniversities.com/courses/engineering/what-stem>
5. Council of Europe Symposium on Non-Formal Education: Report (2001).
6. Crockett, L. (2021, September 19). 36 resources for STEM Project-Based Learning Activities. Future Focused Learning Insights. URL: <https://blog.futurefocusedlearning.net/36-stem-project-based-learning-activities>
7. Elvis, C. (2021). Assessment of transversal skills in STEM. University for Continuing Education Krems. URL: https://www.donau-uni.ac.at/en/research/project/U7_PROJEKT_4294969787
8. Government of WA. (2020). What is stem? Department of Education. Retrieved August 5, 2022, from <https://www.education.wa.edu.au/what-is-stem>
9. Government of WA. (2020). What is stem? Department of Education. URL: <https://www.education.wa.edu.au/what-is-stem>
10. Gurudev, S. (2022, March 16). Stem skills: Transferable and flexible. Eco Ambassadors. URL: <https://ecoambassadors.ca/stem-skills-transferable-and-flexible%EF%BF%BC/>
11. Hallinen, J. (2022). Stem education. Encyclopædia Britannica. URL: <https://www.britannica.com/topic/STEM-education/STEM-education>
12. Hillyard, S. A Pocket Guide to STEAM. 2020
13. Jakobson, E. (2022, June 9). 5 methods for steam classroom learning. SAM Labs. URL: <https://samlabs.com/us/teaching-steam-classroom-5-ways-create-authentic-learning-experiences/>
14. Jolly, A. (2017) STEM by Design by Anne Jolly.
15. Jolly, A. (2019). 12 steps to designing Great Stem Lessons. MiddleWeb. URL: <https://www.middleweb.com/4328/12-steps-to-great-stem-lessons/>
16. Keiler, L.S. Teachers' roles and identities in student-centered classrooms. IJ STEM Ed 5, 34 (2018). <https://doi.org/10.1186/s40594-018-0131-6>
17. Kurt, D. (2022, July 21). The college degrees you should have gotten. Investopedia. 2022, URL: [https://www.investopedia.com/financial-edge/0711/the-college-degrees-you-should-have-gotten.aspx#:~:text=STEM%20\(science%2C%20technology%2C%20engineering,and%20a%20more%20lucrative%20career](https://www.investopedia.com/financial-edge/0711/the-college-degrees-you-should-have-gotten.aspx#:~:text=STEM%20(science%2C%20technology%2C%20engineering,and%20a%20more%20lucrative%20career) .
18. Liston, M. (2018). Designing Meaningful STEM Lessons, Science, 53 (4) pp 34-37





19. STEM. (2022). What is stem? STEM Education. URL: <https://stem.edu.gr/en/what-is-stem/>
20. TeachEngineering. (2022). Popular topics. TeachEngineering. URL: <https://www.teachengineering.org/populartopics>
21. Terhart, Ewald. (2003). Constructivism and teaching: A new paradigm in general didactics?. Journal of Curriculum Studies - J CURRICULUM STUD. 35. 25-44. 10.1080/00220270210163653.
22. TWI. (2020). What is the Engineering Design Process? A complete guide. URL: <https://www.twi-global.com/technical-knowledge/faqs/engineering-design-process>
23. UNESCO. (2016). Tvetipedia Glossary. URL: <https://unevoc.unesco.org/home/TVETipedia+Glossary/filt=all/id=577>



ANNEX A: TRANSVERSAL SKILLS TABLE

DOMAIN	KEY SKILLS, COMPETENCIES, VALUES AND ATTITUDES	DESCRIPTION	EXAMPLE OF USE IN DOTS ACTIVITIES
CRITICAL AND INNOVATIVE THINKING	Creativity	Creative thinking and critical thinking are distinctly separate phenomena which nonetheless share a common focus on decision making (Wechsler et al., 2018). Creativity masters a process of making or producing, criticality a process of assessing or judging.	Empowering the teachers (and consequently the students) to make creative enrichment in their teaching/learning practices. Example: creating DIY and low budget teaching accessories like poles for sticky finger activity or enabling different forms of expression while presenting various content.
	Resourcefulness	Resourcefulness—the ability to find and use available resources to achieve goals. By finding innovative and creative means for problem-solving while optimising the processes and improvising with limited resources.	By imagining multiple outcomes, setting objectives, experimenting with new approaches, and negotiating challenges, teachers (and consequently the students) make important connections between knowledge and goal achievement.



CRITICAL AND INNOVATIVE THINKING	Application skills	<p>In order to have a meaningful learning experience, any learner should be able to discern where can she or he apply the skills that he learned in life. Application skills enable us to use our knowledge in everyday situations.</p>	<p>Guiding teachers (and consequently the students) to set up experiments or measuring devices in a kitchen science format (materials which can be easily found in the household).</p> <p>Empowering the teachers (and consequently the students) for creating opportunities to apply knowledge and skills in everyday situations.</p>
	Reflective thinking	<p>Reflective thinking is a part of the critical thinking process referring specifically to the processes of analysing and making judgments about what has happened. Dewey (1933) suggests that reflective thinking is an active, persistent, and careful consideration of a belief or supposed form of knowledge, of the grounds that support that knowledge, and the further conclusions to which that knowledge leads.</p>	<p>Learners are aware of and control their learning by actively participating in reflective thinking – assessing what they know, what they need to know, and how they bridge that gap – during learning situations.</p>
	Reasoned decision-making	<p>Decision-related surprises arising from the decisionmaker often involve changes in the decision maker's beliefs, preferences, or criteria for decision making. Many real-world planning and decision problems are far too uncertain,</p>	<p>Empowering the teachers (and consequently the students) with skills and tools to bypass accountability demands from others in their networks or groups while analysing biases, beliefs, and data while evaluating processes and estimating outcomes.</p>



		too variable, and too complicated to support realistic scientific models.	
INTERPERSONAL SKILLS	Communication skills	Communication skills can be defined as the transmission of a message that involves the shared understanding between the contexts in which the communication takes place (Saunders and Mills, 1999). Successfully conveying a message is an everyday task in our lives, and has more depth to it than we acknowledge.	Activities which promote the presentation of accomplished work and which require communication to be accomplished. Activities which emphasise the importance of communication and presentation to the teachers, and empowers the teachers to develop activities which require their students to communicate their work to the rest of the class.
	Organisational skills	The ability to use your time, energy, resources, etc. in an effective way so that you achieve the things you want to achieve (Cambridge dictionary).	Empowering the teachers to create activities which engage the students to think how to work through them from start to finish. Activities which will make the students try different setups in order to finish them. Activities which require the students to delegate different roles in completing the task.
	Teamwork & collaboration	Both teamwork and collaboration involve a group of people working together to complete a shared goal. The key difference between the collaboration and teamwork is that whilst teamwork	Guiding the teachers to activities which involve the participants to act simultaneously to achieve the wanted learning outcome, whether by working as a team, or when collaborating.





		combines the individual efforts of all team members to achieve a goal, people working collaboratively complete a project collectively.	
INTRAPERSONAL SKILLS	Flexibility and adaptability	Adaptability enables the decisionmaker to persist in the pursuit of specified goals despite ignorance and in response to surprise and the discovery of error.	By empowering the teachers to improvise on the spot and learn from their mistakes.
	Ability to learn independently	Independent study consists of various forms of teaching-learning arrangements in which teachers and learners carry out their essential tasks and responsibilities apart from one another, communicating in a variety of ways for the purposes of freeing internal learners from inappropriate class paces or patterns, of providing external learners with opportunities to continue learning in their own environments, and of developing in all learners the capacity to carry on self-directed learning (Wedemeyer, 1971.).	Having the learners engage in activities which will leave them with the possibility of continued learning even after the wanted outcomes have been reached. Such activities should encourage the possibility of working without the additional help from the teacher. Also, activities which emphasise the importance of independent learning. Activities which emphasise independent learning should encourage the teachers to produce their own innovative activities.
	Perseverance and self-motivation	Self-motivation is enthusiasm for doing something, and perseverance is the continued effort and determination (Cambridge dictionary) to do so. While you can have one without the other,	Teaching the teachers to make their students relate to the goal which they've set. Activities which will make the teachers relate to the current task and understand why they are



		having both will aid a person greatly in tackling the tasks laid before them.	doing it. Emphasising that they should do the same for their students.
	Self discipline	The ability of students to monitor and control their own behaviors. Students who are highly self-disciplined may be able to better focus on long-term goals and make better choices related to academic engagement. In addition, the concept of self-discipline focuses on students' own ability to engage in (or refrain from engaging in) particular behaviors, rather than reliance on external motivations, rewards, or punishments.	Making activities which raise the teachers awareness about the importance of self discipline. Providing the teachers and students with learning situations in which the importance of self discipline is emphasised.
MEDIA AND INFORMATION LITERACY	Ability to critically evaluate information and media content	In the present day, information and media content on the internet are highly unreliable. A good teacher knows this and will try to raise the awareness of their students about the dangers of taking information from the internet for granted.	Raising the awareness of teachers about the presence of misinformation on the Internet by presenting them with activities which clarify this. An example activity could be providing the teachers with an article with a title named "Scientists have proven (...)" and telling them to try and find the source article of the research.
GLOBAL CITIZENSHIP	Responsibility and ability to resolve conflict	Classrooms are highly social and involve complex relationships between the students and the teacher. In order to maintain a healthy and productive	Putting the teachers in hypotetic situations which require them to take different opinions into account in order to de-escalate a possible quarrel.





		<p>environment, teachers should be able to teach their students the importance of taking responsibility for their actions, and should be able to resolve conflicts.</p>	
<p>GLOBAL CITIZENSHIP</p>	<p>Tolerance and respect for diversity</p>	<p>Recent studies show that intolerance and social exclusion are increasing, with some migrant groups feeling alienated. This is leading to incidences of social tensions and unrest. Education has a key role to play in preparing societies for dealing with these phenomena. It also plays a vital role in the political socialisation of European citizens from cradle to grave</p>	<p>Having activities which will raise the teachers awareness of the benefits of multiculturalism in tackling challenges laid before them. Such an activity could have the participants reflect on their own cultural backgrounds and hearing from others how their experience differs in academic and societal contexts.</p>
	<p>Awareness and openness</p>	<p>In the context of education, "open(ness)" has become the watermark for a fast growing number of learning materials and associated platforms and practices from a variety of institutions and individuals. "Open" in education is currently mostly debated in the context of the technological developments that allowed it to emerge in its current forms. (Peter, Deimann, 2013)</p>	<p>A well informed teacher should be aware that she or he has a multitude of tools and resources at their disposal, especially on the Internet. An activity exemplifying this should demonstrate to the teachers the vast number of open resources, and, consequently, raise their students awareness of being able to utilise these resources for their own development.</p>