Competence development of STE(A)M educators through online tools and communities

STEAMonEDU – 612911-EPP-1-2019-1-EL-EPPKA3-PI-FORWARD

D7.2: STE(A)M education framework

Work package: 3
Type: Report
Dissemination level: Public
Version: 1.0
Delivery date: 31/12/2021

Keywords: STE(A)M education, educators' competences, instructional design

Abstract: This framework attempts to bring together some of the defining elements of STE(A)M education, in order to present a synthetic overview, that would enable policy makers and other stakeholders to better design STE(A)M education programmes.

Author: Mihai Iacob, Cornelia Popescu – EOS

Contributors Achilles Kameas, Athanasios Iossifides, Ekaterina Clifford, Katrin Schuberth, Jutta Schneider, Natalia Spyropoulou, Panagiotis Papadouris, Esther Subias, Paolo Russo, Pep Oliveras, Spyros Papadakis

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

This project has been funded with support from the European Commission. This publication reflects the views only of the author, and the Commission cannot be held responsible for any use which may be made of the information contained therein.

Table of contents

Abstract 5

Introduction 6

1 What is STE(A)M education? 8

1.1 How it started 8

1.2 STE(A)M education as a project 9

2 Mapping the educator's position 12

2.1 The policy context 13

2.2 The educator's roles 14

2.3 Partners of the education systems 15

3 Understanding competences 17

3.1 Educator's competences 17

3.2 Students' competences 18

4 STE(A)M instructional meta-methodology 21

4.1 Learning design principles and curricular approaches 21

4.2 Analysis of teaching method suitability 22

4.2.1 Ranking of teaching method suitability 22

4.2.2 Description of selected teaching methods 24

4.2.3 Reflections on appropriate teaching methods for STE(A)M education 25

5 Body of Knowledge (BoK) 27

5.1 Introduction 27

5.2 Organisation and regulation 27

5.2.1 Policies 27

5.2.2 Stakeholders 29

5.3 STE(A)M elements 33

5.3.1 Science 33

5.3.2 Technology 33

5.3.3 Engineering 34

5.3.4 Arts 35

5.3.5 Mathematics 36

5.4 STE(A)M Perspectives / roles of educators 37

5.4.1 Educator as teacher-trainer-tutor 37

5.4.2 Educator as Learning designer and creator 37

5.4.3 Educator as Orchestrator and manager ... 37
5.4.4 Educator as Community member ... 37
5.4.5 Educator as Professional ... 37
5.5 STE(A)M Learning Design Principles ... 37
5.5.1 Equal treatment of STE(A)M elements ... 38
5.5.2 Appropriate disciplinary and pedagogical approaches ... 38
5.5.3 Use of real-world contexts ... 38
5.5.4 Equity ... 38
5.6 Instructional design and assessment ... 38
5.7 Resources ... 41
5.7.1 Educational resources ... 41
5.7.2 Other resources ... 43
5.8 Professional development ... 47
5.8.1 Validation of STE(A)M competences ... 47
6 STE(A)M-ready OER Specification ... 50
6.1 Introduction ... 50
6.1.1 What are Open Educational Resources (OER)? ... 50
6.1.2 UNESCO Recommendation on OER (2019) ... 50
6.2 STE(A)M OER SPECIFICATIONS - EXAMPLES FROM PROJECT PARTNERS ... 51
6.2.1 STE(A)M OER specification Romania ... 51
6.2.2 STE(A)M OER specification Greece ... 52
6.2.3 STE(A)M OER specification - Italy ... 53
6.2.4 STE(A)M OER specification Germany ... 55
6.2.5 STE(A)M OER specification Spain ... 56
7 Educator's professional development ... 60
7.1 STE(A)M education and continuous professional development ... 60
7.2 Educator's agency in continuous professional development ... 61
References ... 63

List of tables

Table 1. STE(A)M Education Framework and its corresponding STEAMonEdu outputs 7
Table 2. Analysis of STEAM education (Perignat & Katz-Buonincontro, 2019) 10
Table 3. Policy and advocacy 14
Table 4. STEAMComp Profile (Spyropoulou & Kameas, 2020c) 18
Table 5. Raking of instructional methods by teachers (Zendler, Seitz & Klaudt,2018; Zendler, 2018) 23

Abstract

This report attempts to bring together some of the defining elements of STE(A)M education, in order to give a synthetic overview of its evolution and possible development, that could enable interested parties (e.g. policy makers, educators) to better design and implement STE(A)M education programmes. After a brief introduction in which we present the objectives of the STEAMonEdu project and its outputs, we take a look at how STE(A)M education has evolved, trying to make sense of the different iterations that can be found concurrently in educational practices and policies.

In the second chapter we consider three of the elements that shape STE(A)M education – policies, the expected roles that an educator is expected to perform and the agendas of the partners of the educational systems. A STE(A)M educator needs to map his/her own position in relationship to them, in order to be able to conduct practice in a responsible and effective manner, but the relationship needs to go both ways - with the educator able to influence the other actors.

There is a growing movement at European level to offer students and educators the opportunity to assess their competences in different areas, in order to facilitate the self-direct learning. Based on the DigCompEdu model, the STEAMonEdu Project has undertaken the production of STEAMComp competence framework. Chapter three presents the proposed model, along with other competence frameworks related to STEM and STE(A)M education. Separate consideration is given to educators' competences and students' competences.

The rationale behind chapter four, which contains what is termed a meta-methodology, is to give to the STE(A)M education framework a practice-oriented outlook and to facilitate its deployment in educational contexts. It was developed based on a literature review, as well as the review of STE(A)M education practices and policies collected by the STEAMonEdu partnership. The review has explored existing methodologies, while trying to understand possible developments connected to technological and pedagogical changes.

The Body of Knowledge that covers chapter five in this document provides a tool that supports educators and policy makers to quickly map out areas pertaining to STE(A)M education, while the scope of chapter six is to enable educators to quickly identify the suitability of OERs for teaching specific STE(A)M subjects using specific techniques.

The educators' professional development has emerged as a recognised area of research, due to its importance for the learning process and its influence on student achievement (Borko, 2004). Chapter seven presents some of the elements that currently define the continuous professional development of educators, such as competence frameworks and the use of MOOCs.

STE(A)M education is still undergoing development, both in terms of theory and practice. What was initially an educational marketing tool, has taken on the shape of a vibrant pedagogical approach, that interrogates both its own nature and the articulation of educational systems across the world.

Introduction

The rationale behind the STE(A)M education framework has two aspects: an inward-looking aspect, that tries to bring together the multifaceted approach of the STEAMonEdu Project, as well as an outward-looking aspect, that engages with similar[1] research and practices in order to initiate a dialogue.

For project members and beneficiaries, this document is meant to map out the numerous components and to allow seamless transition between the intellectual outputs, but its relevance should extend beyond the timeframe and the reach of the Project and create bridges towards other research and the development of practices. The objectives of the STEAMonEdu Project cover a large of number of actions and outputs, such as:

- to attribute to the community of STE(A)M education stakeholders a central role in designing, implementing and assessing STE(A)M education policies,
- to develop online tools in order to support this community,
- to collect and assess practices based on local and regional initiatives that support STEM and STE(A)M education,
- to collect, analyse and index evidence to substantiate innovative policies and practices,
- to design a core STE(A)M education framework containing a STE(A)M instructional meta-methodology, the STE(A)M body of knowledge, a special focus on diversity issues (including gender and social inclusion issues), STE(A)M learning activity and course templates,
- to develop and test STE(A)MComp, the competence framework for STE(A)M educators, along the example of DigComp for Edu,
- to design the STE(A)M educator profile in an ESCO compatible manner,
- to design a STE(A)M evaluation readiness test for Schools following the example of SELFIE,
- to test STE(A)MComp by delivering an online course for the professional development of STE(A)M educators,
- to produce the STE(A)M Policy Influencer Toolkit containing recommendations for the uptake of STE(A)M education in Europe.

For ease of use, we have presented in Table 1 the correspondence between the different outputs of the project and the chapters of this document.

[1] For exemple, other projects have proposed frameworks for STEM (Butler et al., 2020) or they have taken a more practical approach to a STE(A)M framework (Sotiroiu et. al, 2021).

Table 1. STE(A)M Education Framework and its corresponding STEAMonEdu outputs

Chapter	Title		Corresponding outputs
1	A practical understanding of STE(A)M education		• MOOC: Module 1 • STEAMonEdu platform • Collection of STE(A)M education practices
2	Mapping the educator's position	The policy context	• MOOC: Module 5 • Policy influence toolkit • Guide on STE(A)M education policy • STEAMonEdu platform
		The educator's role	• STE(A)M educator's competence framework
		Partners of the education systems	• Policy influence toolkit
3	Understanding competences	Educator's competences	• STE(A)M educator's competence framework • STE(A)M Educator's profile • MOOC: Modules 2, 3, and 4 • STE(A)M educators' community
		Student's competences	• Not covered by the STEAMonEdu Project
4	STEAM instructional meta-methodology	Learning design principles	• MOOC: Modules 3 and 4 • Collection of STE(A)M education practices • LAMS
		Curricular approaches	
		Teaching methods	
5	Professional development and communities of practice		• MOOC: Module 6 • STE(A)M educators' community

As evident from the table, the project has aimed to touch a very wide array of issues pertaining to STE(A)M education, from the standpoint of the educator.

This document is a synthetic report that draws upon three sources of information: a) academic texts dealing with STEM and STE(A)M education, b) research and development undertaken by the STEAMonEdu partnership in regard to STE(A)M policy and competences, and c) examples of practices collected with support from educators.

1 What is STE(A)M education?

In this chapter we take a look at how STE(A)M education has evolved, trying to make sense of the different iterations that can be found concurrently in educational practices and policies. The first part looks at the beginnings of STE(A)M education, while the second part problematises between the different options for promoting the acquisition competences related to sciences and the arts.

1.1 How it started

STE(A)M - the acronym for Science, Technology, Engineering, Arts and Maths education - is a concept to which researchers, policy makers and educators have assigned a variety of meanings over time. It has evolved under the impulse of a large number of stakeholders, which have sought to develop support mechanism that encourage learners to take up studies in areas that were seen as key to economic growth. For example, the New York State Education Agency Directors of Arts Education defines STEAM as *„an intentional, collaborative pedagogy for teachers that empowers learners to engage in real-world experiences through the authentic alignment of standards, processes, and practices in science, technology, engineering, the arts, and mathematics*" (Huser et al., 2020).

STE(A)M and its previous iteration, STEM, do not constitute new subjects that need to be included in the curriculum, but rather an integrated approach to teaching the subjects under its umbrella. This means that, while a certain regional or national context may lack explicit mentions of STE(A)M education policies, this might not be the case at the level of educational practice[2].

Before diving deeper into its meanings, let's consider what were the drivers behind the creation of STE(A)M. The economic and political landscape of the world has changed considerably during the past few decades, under the pressure of globalization and technological changes. During this time, we have witnessed the globalization of the science curriculum (Stacey et al., 2018) that entailed "*the growing use of information technologies and the increasing influence of intergovernmental organizations in education*". This has meant that international large-scale assessments have been, in part, responsible for driving changes and reforms in the science curricula of many participating countries.

There is also a manifest technological pressure, not only in our professional lives, but also within our personal environment, which we must learn to navigate. Keane and Keane (2016) have argued that because of this reliance on technological skills "*all students need opportunities to develop mathematical, scientific and creative capacities*".

Another driver for espousing new ways to make students engage with technical subjects was market pressure. This has provided the impetus to seek ways of bridging the gap between the qualifications on offer and those that were sought by learners.

[2] This opens up a debate about intentionality, as mentioned above in the definition provided by Huser et al. (2020). While we consider that there must be a conscious effort for promoting what is called the STE(A)M approach, not all who apply it use this term to describe their practice.

Markedly absent from the list of drivers above, are the pedagogical factors. This is not to say that educators were not involved, but the point of reference was outside of the educational field, with the success of STEM/STE(A)M education tied to its economic value. The result is a complicated landscape in which the position of the arts within STEM education has been a source of ample debate.

1.2 STE(A)M education as a project

STEM was a step forward in building a scaffolding that would enable a transdisciplinary approach for the fields it targeted, while also questioning the relevance of the qualifications obtained through schooling. The first references to this paring of subjects were made in the 90s, but it took off as a pedagogical approach about 20 years ago.

After the initial push for the adoption of STEM education, a growing movement started to promote the inclusion of arts. This was done in response to its perceived limitations of not engaging with the creative and aesthetic side of our nature. It was also a way to reinstate the learner's agency, who is not just a product to be assembled and delivered to the labour market.

It should be noted that the advent of STE(A)M education as a conceptual framework did not detract from further development of STEM education, as evident from a growing body of knowledge (e.g. Butler et al., 2020; Li et al., 2020). Projects[3] similar in scope to STEAMonEdu, that are being implemented more or less synchronously, take STEM as their reference and treat arts only as an area of possible further development.

STE(A)M and STEAM are used interchangeably in academic literature. Our option is to use the "STE(A)M", in order to reflect the process and the tensions associated with its development. Putting the A in STE(A)M between parenthesis reflects a stage of development which acknowledges the difficulties of building an integrated approach and treats the field as an ongoing project, that continuously poses the question of how the elements are coming together. In this line of thought, STEAM would represent the ideal, fully developed approach. Throughout this document we will use this spelling, unless quoting other studies which have used the "STEAM" spelling.

It is the treatment of arts that holds the key to understanding and practicing STE(A)M education. The position of the arts, not just among STEM subjects, but also within the larger field of education has come under sustained scrutiny during the past two decades, with increasing numbers of academics emphasizing the intrinsic benefits of arts education (Bamford, 2006; Winer, Goldstein & Vincent-Lancrin, 2013) as opposed to the benefits of instrumentalizing it.

STE(A)M education did not take a linear approach when defining what position the arts should have or how they can be deployed in the learning process. This gave rise to a whole spectrum of understandings that were afterwards embedded in education practices. They ranged from the reduction of arts to creative thinking, to a fully integrated approach, where arts come with

[3] For example: STE(A)M IT (http://steamit.eun.org/) or CHOICE (https://www.euchoice.eu/).

their own means of knowledge production and educational outcomes (e.g. Smyrnaiou et al., 2017).

The difficulties in achieving a balanced approach is evidenced by a literature review (Perignat & Katz-Buonincontro, 2019) of how STE(A)M is in practice and research. Special consideration was given to the position of arts among the other elements. The analysis was based on six the reference points for STE(A)M education: 1) the purpose, 2) the definitions of STE(A)M, 3) the definition of arts within STE(A)M, 4) creativity as an outcome, 5) arts education and 6) arts education learning outcomes (see Table 2).

Table 2. Analysis of STEAM education (Perignat & Katz-Buonincontro, 2019)

No.	Reference	Main findings
1	Purpose of STEAM Education	*"There were two dominant approaches to defining the purpose of STEAM education. The first approach emphasizes the importance of advancing learning in STEM disciplines [...]. The second approach emphasizes the significance of integrating domain general skills such as perspective-taking, creative and problem-solving skills, knowledge transfer across disciplines, and/or encouraging students to explore and experience new ways of knowing."*
2	Diverse STEAM Definitions	*"... four main types of disciplinary integration surfaced: transdisciplinary, interdisciplinary, multi-disciplinary, and cross-disciplinary"*
3	Defining the "A" in STEAM	*"This review identified three main categories: Arts Education, Arts as any non-STEM discipline, Arts as a synonym for project-based learning, problem-based learning, technology-based learning, or making."*
4	Creativity as a STEAM Outcome	*"The concept of creativity is connected to the arts and is characterized as one of the benefits or learning outcomes of STEAM education."*
5	Arts education	*"Each article included at least one aspect of arts education. The terms design or making are two aspects included in arts education."*
6	Arts education learning outcomes	*"... there is an overall lack of explanation of arts education learning outcomes (24 articles) despite the description of such outcomes in the articles' introductions. This points to a critical gap in the STEAM education literature."*

The main aims and objectives of the STE(A)M education approach are (Papadouris, 2021):

- to prepare active and functioning citizens in a scientific and technological based society.
- education based on activities focusing on designing, experiential learning and problem solving.
- to support the development of transversal, soft skills such as critical thinking and communication.
- to strengthen students' personal and social abilities in order to familiarize students with the new demands of the labour field and create better opportunities with their futures in mind.

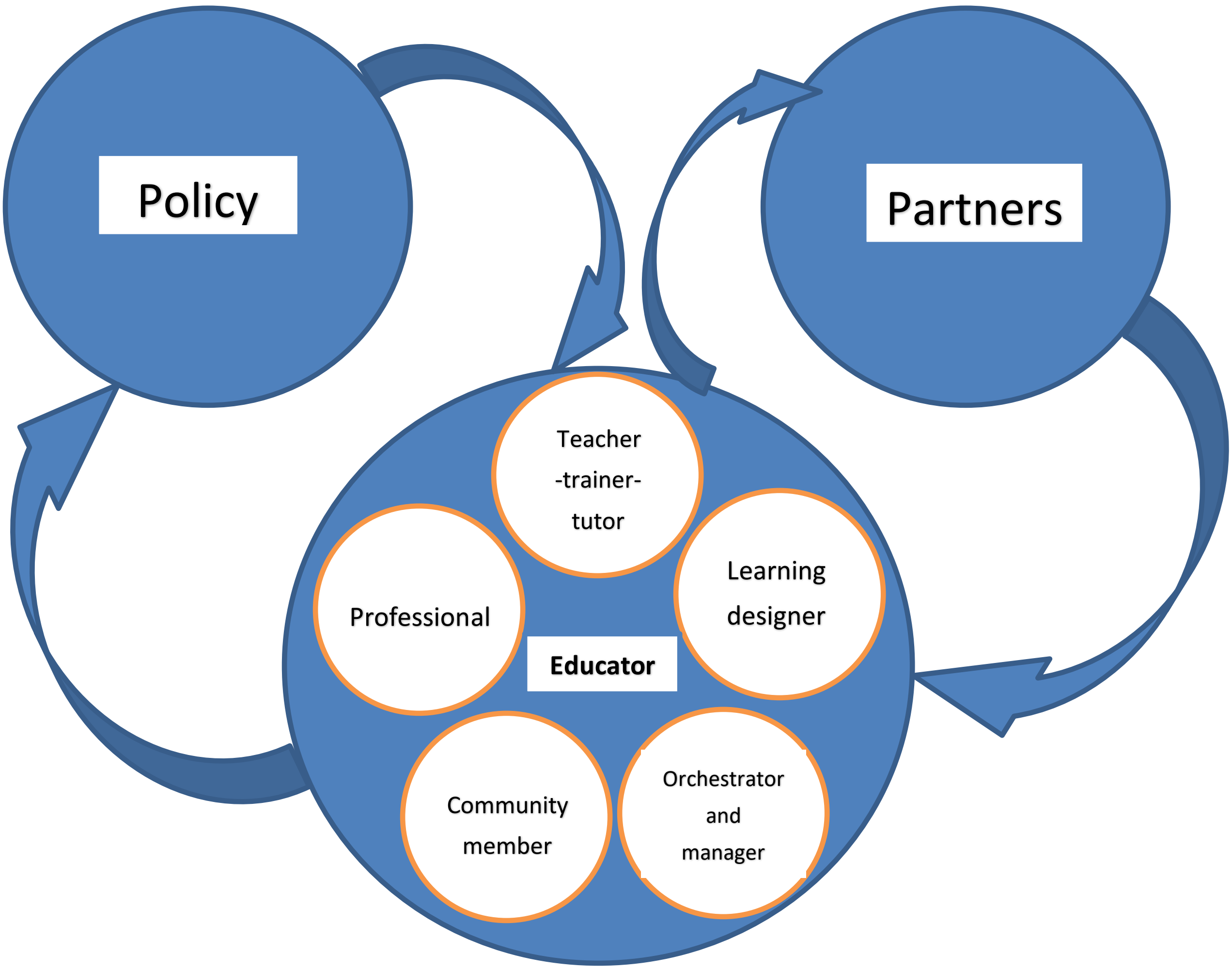
As noted by Huser et al. (2020, p. 4), STE(A)M is not merely equivalent to arts integration. STE(A)M is seen as a practice that recognizes the real-world role of the arts. Throughout its outputs and activities, the STEAMonEdu Project has taken an integrated approach to STE(A)M education, with arts as an integral part of the instructional process[4].

[4] For a more detailed discussion of curricular approaches to STE(A)M education that were highlighted in academic literature see Chapter 4.

2 Mapping the educator's position

STE(A)M educators, both in the formal and non-formal education contexts, find themselves in a complicated entanglement of regulations and stakeholders - each with their own needs, agendas and expectations – that shape their daily practices. In order to make sense of the situation, educators need to be empowered with a sense of agency, that will, in turn, enable them to engage with the other actors of the network. STE(A)M educators need to map their own position in relationship to them, in order to be able to conduct practice in a responsible and effective manner.

In this chapter we will consider three of the elements that shape STE(A)M education and can help us map the educator's position – the context created by policies, the roles an educator is expected to perform and the agendas of the partners of the education system.



All of the relationships between these actors are reciprocal. Educators' work is framed by policy, but they also contribute to their development. The partners of the education system benefit from the competences acquired by the students, but they also have a say in how education is organized.

2.1 The policy context

The STE(A)M movement started in the USA, but it has since become a global phenomenon, with policy makers looking for ways to promote it. At EU level, consultations between policy makers led to the publication of official recommendations (Council of the European Union, 2018) and communications that encourage progress on adoption and implementation of STE(A)M education, by calling for better research, knowledge sharing and awareness raising.

The updated Digital Education Action Plan (2021-2027) published by the European Commission expressly refers to STE(A)M disciplines by envisaging a more consistent participation of women in STE(A)M education practices, in order to foster gender equality and women's enhanced access to education and the labour market. More explicitly, the Commission aims to "*encourage women's participation in STEAM with the European Institute of Innovation and Technology (EIT) and support the EU STEM Coalition to develop higher education curricula which attracts women to engineering and ITC based on the 'STEAM' approach*".

The "Science with and for Society" Programme has been established by the Commission as a vehicle to address the relevant European societal challenges tackled by Horizon 2020, by developing actions focused on building capacities and conceiving innovative methods to connect science to society. The ambition is to make science more appealing to young target groups, fostering innovation and broadening the field of educational research work.

An analysis conducted by the STEAMonEdu partnership of policies at EU level and in their respective countries highlighted several aspects:

- **Quantity and quality of STE(A)M policies.** The research performed within the project identified only 20 policies at EU level and in the five countries of the project partners. The quantity and the quality of STE(A)M policies is still very low.
- **STE(A)M vs STEM**. STE(A)M is largely unknown as a concept, and, as a consequence, it is not addressed by policy makers at **national** level, as the large majority of policy initiatives are related to STEM only.
- **Integration of STEM.** Significant policy support for integration of STEM in education can be found at EU level. STEM education is thus currently recognised as an effective, integrated and multidisciplinary approach.
- **Efficiency of STE(A)M policies.** Most of the identified policies are still ongoing or do not include a monitoring and evaluation framework, thus it is very difficult to assess the efficiency and impact of these policies
- **STE(A)M educators' needs.** The research identified a large and diverse set of needs for the STE(A)M educators, from lack of infrastructure to teach STE(A)M disciplines to low levels of confidence and competences, and to difficulty to assess and evaluate.

A more detailed discussion of STE(A)M related policies at EU level, as well as developments in the countries participating in the STEAMonEdu Project, can be found in the *Guide on STE(A)M education policies and educators' needs* (Educating for an Open Society Foundation, 2020).

In order to support a practical approach to policy development, the STEAMonEdu Project has produced a Policy Influence Toolkit (Colectic & ALL DIGITAL, 2020) which addresses organisations working in the field of STE(A)M education, in both formal and non-formal contexts. The document aims to provide the project partners and interested parties with a set of tools to develop their policy influence strategy and implement advocacy work at local/regional, national and European level.

Educators are expected to take an active role in policy development. A synthesis of policy making tools, monitoring activities and the stages of the advocacy process are presented in Table 3.

Table 3. Policy and advocacy

Policy making tools	Monitoring activities	Advocacy
Open public consultations	Peer review	Context analysis
Public relation direct contacts	Multiplier events	Planning
Participation to working groups		Delivering your message
High level meetings and debates		Assessing the outcome
Research / survey		
Policy papers / statements		
Public hearings: exchange of views		
Good practices promotion		
Production of autonomous data analysis		

2.2 The educator's roles

The *Competence framework for STE(A)M educators* (Spyropoulu & Kameas, 2020a), which is the reference point for the STEAMonEdu Project, envisages five positions that an educator can assume:

- "**Teacher-trainer-tutor**" which refers to implementing the educational procedure. Competences under this heading are distributed across six areas:

a) pedagogy, b) content knowledge, c) instruction, d) use of content and tools, e) feedback and assessment, f) learner empowerment.

- "**Learning designer and creator**" which refers to designing and producing outputs. Competences under this heading are distributed across three areas: course / curriculum / activity design, content and tools design and development, learner development.
- "**Orchestrator and manager**" which refers to coordinating procedures and outputs. Competences under this heading are distributed across two areas: a) educational procedure management, b) resource management.
- "**Community member**" which refers to interacting with the environment. Competences under this heading are distributed across two areas: a) community building, b) application of policies.
- "**Professional**" which refers to developing and applying competences. Competences under this heading are distributed across two areas: a) transferable skills, b) digital skills, c) professional development.

This mapping of roles is anchored in a particular conceptual framework and research process, which means that other sources may consider a different number of roles and might label them differently. While they will be somewhat similar in scope (e.g. author-creator, manager, coach), they will not be entirely overlapping with the STEAMonEdu mapping.

2.3 Partners of the education systems

Education should reflect the interests of the local community surrounding the school or educational centre. They can be the parents, grass roots initiatives, local businesses, cultural organizations, or the local government. There is a lot of interest on their side to connect STE(A)M education to local needs.

A key question that schools and other providers of educational services need to answer is "*How should the voice of parents and the community be incorporated in educational practice?*". Educational programmes need to consider the environment in which they take place, in order to incorporate equity and stakeholder engagement in their design. For example, the Texas Education Agency has proposed a STEM framework[5] with quality indicators covering six domains, with three of them directly relevant to these issues: equity of programming, school climate and culture, and stakeholder engagement.

Regional government, especially in countries with a more decentralised system of governance, will watch how well connected are the qualifications offered and the labour market. They might be interested in awarding grants or other forms of support for STE(A)M activities and educators.

[5] https://tea.texas.gov/sites/default/files/Texas_STEM_Framework_v20200728.pdf

Universities are interested in giving a practical use to the research they conduct, especially as they have a solid system of training and certification. They might be interested in joining a consortium dedicated to training STE(A)M educators.

Practices regarding parent engagement differ from country to country, but they are unified by principles that favour involvement in decision making, design and choice of educational activities, as well as respect for diversity.

STE(A)M education is not confined only to formal settings. On the contrary non-formal education providers, such as NGOs, students' unions, public and private training centres play an essential role in supporting and developing STE(A)M programmes and training opportunities. This in turn affects teaching practices of STE(A)M subjects, as classroom settings incorporate experiences from outside the school's walls. For example, in Romania many STEM and STE(A)M education initiatives are developed in partnership between NGOs and schools, such as the Măgurele Summer School - MSCiTech[6], the grant programme "Fondul Științescu"[7], or the "Lecțiile patrimoniului" Project[8] which used built heritage to teach a variety of STE(A)M subjects.

At European level, a recent collaboration[9] between the European Schoolnet – an NGO that brings together the Ministries of Education from across the continent – and the Europeana Library has seen the creation of teaching resources and a of a community of practitioners interested in STE(A)M education.

A recurring project that has a worldwide reach is the Global Science Opera[10], which started in 2014 as a collaboration between three converging initiatives dedicated to science and arts. Each year, students from all over the world are invited to contribute to what will become an artistic production that explores a different scientific topic.

From its inception STEM education was designed to have a strong connection to the needs of the labour market, making engagement with relevant stakeholders – such as trade unions, corporations, labour market policy makers – a key aspect to its relevance. However, this does not directly address issues of equity and it even risks exacerbating existing issues of inequality, by promoting the agenda driven by market needs, rather than the needs of students. That is why educational services providers need to take concrete steps to ensure that STEM and STE(A)M programmes retain their educational values and ideals.

[6] https://msciteh.educatiepentrustiinta.ro/
[7] https://stiintescu.ro/
[8] https://culturaineducatie.ro/proiecte-2/lectiile-patrimoniului/
[9] https://teachwitheuropeana.eun.org/learning-scenarios/ls-topic/ls-steam/
[10] https://globalscienceopera.com/

3 Understanding competences

There is a growing movement at European level to offer students and educators the opportunity to assess their competences in different areas, in order to facilitate the self-direct learning. Digital competences (Iacob & Proietti, 2020), entrepreneurial competences (Mccallum et al., 2018), personal and social competences (Sala et al., 2020) have been mapped in a way that enables learners to plot a path towards competence areas they feel they have not yet mastered.

Based on the DigCompEdu model, the STEAMonEdu Project has created the STEAMComp competence framework. Below we present the proposed model, along other competence frameworks related to STEM and STE(A)M education. Separate consideration is given to educators' competences and students' competences.

3.1 Educator's competences

Educator's competencies are descriptions of what a qualified teacher/educator should know and be able to do (Spyropoulou & Kameas, 2020c). A review of existing literature on STEM educator's competences (Butler et al., 2020) has identified 243 specific competences, which were grouped under eight STEM core competences: a) problem-solving; b) innovation and creativity; c) communication; d) critical-thinking; e) meta-cognitive skills; f) collaboration; g) self-regulation; h) disciplinary competences.

The STEAMonEdu project has developed a specific competence framework for STE(A)M educators using the Delphi method, which entails multiple rounds of surveys with groups of participants. Educators were considered as the pillars of the research (Spyropoulou & Kameas, 2020c).

The development of the framework is a response to challenges that educators encounter. Spyropoulou and Kameas (2020d) have identified thirteen challenges that STE(A)M educators are facing: 1) inadequate equipment/infrastructures, 2) time constraints, 3) lack of suitable educational material and lesson plans, 4) diversity of students (skills, age, number), 5) shape collaboration and teamwork culture, 6) lack of adequate training for STEM education, 7) classroom management for STEM education programs, 8) Wide range of required knowledge from different fields, 9) parents' perceptions and stereotypes about education, 10) preparation time, 11) lack of support from colleagues and educational institutions, 12) lack of students' interest and 13) difficulties in using the equipment – technical issues.

Competency-based strategies provide flexibility and personalized learning opportunities with a better learner engagement. The design of the STE(A)M competence framework for educators, had two aims (Spyropoulou & Kameas, 2020a): a) to be usable by educators for self-evaluation and self-regulation purposes as a self-assessment tool; b) to allow for both the support and professional development of STE(A)M educators, both as a guide for the formulation of the learning outcomes of specific training programs and as an assessment tool for the evaluation of the training program.

The framework (Table 4) was conceived after an online research with 59 Greek STEM educators (Spyropoulou & Kameas, 2020b), and has been further evaluated during the lifespan of the STEAMonEdu Project, with educators from the five partner countries.

Table 4. STEAMComp Profile (Spyropoulou & Kameas, 2020c)

No.	Areas	
1	Content	1.1 Understand STE(A)M Education 1.2 Content knowledge 1.3 Selecting content 1.4 Creating and modifying content 1.5 Managing and sharing content
2	Teaching and learning	2.1 Teaching 2.2. Design 2.3 Guidance 2.4 Collaborative learning 2.5 Self-regulated learning
3	Organization and Management	3.1 Classroom management 3.2 Content management 3.3 Teaching organization
4	Professional Engagement	4.1 Communication and cooperation 4.2 Professional collaboration 4.3 Reflective activities
5	Assessment	5.1 Assessment strategies 5.2 Feedback and Planning
6	Empowering Learners	6.1 Accessibility and inclusion 6.1 Active engagement of learners 6.2 Differentiation and personalization

3.2 Students' competences

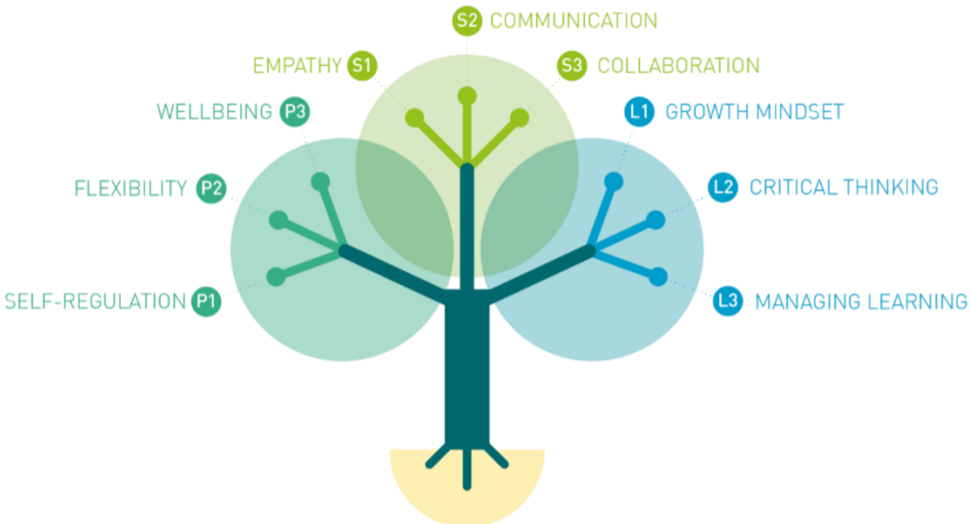
In our review, we have not found any references to specifically developed frameworks of students' STE(A)M competences, but there are many frameworks that are being used as a benchmark and guide when developing STE(A)M projects, such as: key competences, national standards, 21st century competences, digital competences, entrepreneurial competences, etc.

21st century competences have had many iterations, meant to account for the social and technological changes that have occurred during the past few decades. They were found to fit (Finegold, D., & Notabartolo, 2010) under five categories: analytic skills, interpersonal skills, ability to execute, information processing, and capacity for change/learning.

The first version of the *Digital Competence Framework* (DigComp) was made available in 2013. It's second version includes five domains of competence (digital content creation, safety, information and data literacy, problem solving, communication and collaboration). They act as an umbrella for 21 competences, which are described on a scale of eight proficiency levels.

DigComp 2.0 (Image source: Joint Research Centre, 2016)

Lifecomp (Sala et al., 2020) offers a conceptual framework for three competence domains: personal, social and learning to learn, with each of them being subdivided into three "branches".



LifeComp Tree (image source: European Union, 2020)

A systematic review of the impact of arts in education (Winer, Goldstein & Vincent-Lancrin, 2013) has gathered the available information at that time about how they support the acquisition of competences in different domains. While the report makes a compelling case for the impact of arts in many areas, the authors caution against approaches that do not see art for its intrinsic benefits.

More recently, evidence has started to build up that STE(A)M education can have a positive impact on students' acquisitions: Diego-Mantecón et al. (2021) show that STE(A)M education can have a positive impact on the acquisition of key competences, as defined by the Council of the European Union (2018); STE(A)M education improves students' critical thinking (Rahmawati et al., 2020); Integration of arts improves performance in maths (Inoa, R., Weltsek, G. & Tabone, C., 2014); STE(A)M education can improve cognitive performance (Chapman & Kirkland, 2013).

4 STE(A)M instructional meta-methodology

The rationale of this chapter is to give to the STE(A)M education framework a practice-oriented outlook and to facilitate its deployment in educational contexts. It was developed based on a literature review, the experience of the LAMS community[11], as well as the review of STE(A)M education practices and policies collected by the STEAMonEdu partnership.

A meta-methodology is a "*form of meta-level research where the subject matter is other research methods*" (Edwards, 2014). The review has explored existing methodologies, while trying to understand possible developments connected to technological and pedagogical changes. Not all references are centred on STE(A)M education, as the available literature is still limited, with some of the selected literature is based on STEM education. The analysis goes from principles, to curricular approaches and on to specific methods, with some final considerations on how a learning activity can be organized.

4.1 Learning design principles and curricular approaches

Any approach to STE(A)M education needs to consider its specificity as an intersectional practice, that goes beyond what any one educator can deliver alone: „*STEAM pedagogy cannot be the domain of only one teacher instructing in all content areas*" (Huser et al., 2020).

In terms of learning design principles, we can turn to STEM to see how the science and maths are seen as being best approached. Butler et al. (2020) propose a list of six such principles: problem solving design and approaches[12], disciplinary and interdisciplinary knowledge, engineering design and practices, appropriate use and application of technology, use of real-world contexts, appropriate pedagogical practices. Similar suggestions were promoted by the CHOICE Project, which, when designing STE(A)M workshops, advocates for "*active participation of the learners, promote rather a non-formal frame of learning, collaborative approach and focus on the development of transversal skill and competencies applicable in a real-world context*" (La Monica Grus, 2020).

Margot & Kettler (2019) suggest some pedagogical practices to support STEM integration, such as:

- using hands-on, practical applications of content in order to solve their challenges,
- introducing students to STEM professions,
- using a project-based approach,
- helping students apply content knowledge to solve problems,
- utilising the engineering design process in the classroom to make real-connection to the world.

[11] https://www.lamscommunity.org

[12] „a problem-solving attitude refers to both the learning process and the individual's ability to handle obstacles and change. It includes the desire to apply prior learning and life experiences and the curiosity to look for opportunities to learn and develop in a variety of life contexts." (European Commission, 2019, p. 11).

Others suggest inquiry-based teaching method (Thibbaut et al., 2018) or project-based teaching method (Kennedy & Odell, 2014; Pitt, 2009; Ritz & Fan, 2015).

An important discussion focuses on the extent to which the individual components of STE(A)M need to be integrated. In their review of STEAM education Perignat and Katz-Buonincontro (2019) found five types of disciplinary integration:

- transdisciplinary: several fields of knowledge come together in a way that disregards boundaries.
- interdisciplinary: several fields of knowledge come together, but each retains its boundaries.
- multi-disciplinary: collaboration between several disciplines that do not merge together.
- cross-disciplinary: the practice of observing one disciple through the eyes of another.
- arts-integration.

A UNESCO document (Ng, 2019) references an integrative approach, called neo-disciplinary, which "*disregards traditional subject boundaries altogether 'to create new categories of skills and knowledge networks'*". When digging deeper for the initial proposal[13] regarding such an approach not many details can be found, but what can be gleaned from it, make it an interesting avenue to pursue, that could fit STE(A)M education.

4.2 Analysis of teaching method suitability

Our analysis is based on three sources of information: a) a series of articles ranking the suitability of teaching methods in several subjects; b) examples of STE(A)M education practices collected through the STEAMonEdu project; c) the practices of the LAMS community in developing learning activity templates.

We have used the ranking and the examples collected by the STEAMonEdu project to select the descriptions of several teaching methods' that were available on the LAMS community website.

4.2.1 Ranking of teaching method suitability

Zendler, Seitz & Klaudt (2018) reviewed the opinions of computer science teachers and mathematics teachers, while Zendler (2018) reviewed the opinions of English language teachers regarding 20 instructional methods. It should be noted that teaching English covers grammar, as well as literature, which makes it, at least in part, relevant to arts teaching. The evaluation was made on a six-point scale, defined as:

- **build**: acquiring knowledge, new practical and cognitive abilities as well as attitudes;

[13] https://delaforce.info/?tag=stem

- **process**: establishing, deepening, structuring and connecting what has been learned;
- **apply**: using what has been learned in new tasks corresponding with the framework conditions of the learning situation;
- **transfer**: using what has been learned in new situations in which the framework conditions differ from those of the learning situation;
- **assess**: classifying what has been learned in regard to its usefulness, scope, benefits and limits;
- **integrate**: integrating what has been learned outside of the actual learning situation in connection with one's own knowledge.

Table 5 shows the ranking of the instructional methods by the three categories of teachers relative to their perception of contribution to the knowledge building process.

Table 5. Raking of instructional methods by teachers (Zendler, Seitz & Klaudt,2018; Zendler, 2018)

No.	Computer science teachers	Maths teachers	English language teachers
1	problem-based learning	problem-based learning	project work
2	learning tasks	direct instruction	jigsaw
3	discovery learning	learning (at) stations	problem-based learning
4	computer simulation	learning tasks	learning tasks
5	project work	project work	learning (at) stations
6	direct instruction	discovery learning	presentation
7	models method	learning by teaching	reciprocal teaching
8	programmed instruction	jigsaw	learning by teaching
9	learning by teaching	presentation	discovery learning
10	case study	experiment	role-play
11	learning (at) stations	models method	direct instruction
12	presentation	programmed instruction	concept mapping
13	experiment	computer simulation	case study
14	role-play	concept mapping	web quest
15	jigsaw	case study	portfolio method
16	concept mapping	portfolio method	leittext method
17	leittext method	leittext method	experiment
18	web quest	web quest	programmed instruction

No.	Computer science teachers	Maths teachers	English language teachers
19	reciprocal teaching	role-play	computer simulation
20	portfolio method	reciprocal teaching	models method

They present easily observable distinctions between all three categories, with more similarities between computer science teachers and mathematics teachers.

4.2.2 Description of selected teaching methods

Based on the above ranking and the methods present the STEAMonEdu collection of practices we have chosen to present and analyse several teaching methods, using, where available, descriptions provided by the LAMS community. The choices were: a) methods that are ranked high (rank 7 and above) by all three groups (problem-based learning, project work), b) methods that were ranked high by one group, but mid or low by others (jigsaw, reciprocal teaching), c) methods that were ranked low by all groups (portfolio).

Problem-based learning (PBL) is a student-centred method that challenges the learners to solve an open-ended problem, based on a series of materials they are provided.

> Stages[14]: 1) introduction to the PBL process 2) description of the problem; 3) reflection on existing ideas and knowledge; 4) each student analyses the problem and describes their ideas and sees the answers of other students; 5) general discussion of students' existing knowledge and ideas about approaching the problem; 6) individual/small group research; 7) students discuss their research findings; 8) each student describes his/her solution; 9) feedback resources on the problem; 10) comments from the teacher on student solutions.

Project work (Knoll, 1995) is a method that encourages students to plan and develop a project as far as possible on their own, either individually or in groups, over a given period of time. The focus is on the practical implementation of knowledge, rather than on its acquisition.

> There are two approaches to project work, depending on when the instructional part takes place: a) the skills needed for the project are systematically taught before the project is assigned; b) the teaching is done as the project is being implemented. Students present their work and afterwards reflect on the process.

Jigsaw (Aronson et al., 1978) is a teaching method that aims to make the success at a given task dependant on collaboration between students that are divided small groups. The solution is developed in pieces by each group and needs to be assembled like a jigsaw puzzle.

> Stages[15]: 1) divide the problem into subproblems, 2) assign roles and material to each student, 3) form group of experts, 4) experts study the material and plan how to teach

[14] Adapted from: PBL template, by James Dalziel (https://www.lamscommunity.org/lamscentral/sequence?seq%5Fid=1125655)

[15] Adapted from: Planning collaboration using the "Jigsaw" method within LAMS by Maria Kordaki, https://lamscommunity.org/lamscentral/sequence?seq%5fid=820536

their colleagues, 5) create heterogeneous groups, 6) experts teach in their groups, 7) assess students.

Reciprocal teaching (Palincsar, 1986) is a method aimed at promoting students' reading comprehension, through a series of strategies that are meant to support the construction of meaning in a text.

The four strategies that define reciprocal teaching are: predicting (what will happen next?), questioning (what were the themes?), clarifying (what was unclear or unfamiliar?) and summarizing (what was the main message?). Participants take turns at assuming the teacher's role.

Role-play is a teaching method that invites the learners to assume roles they might not be familiar with and perform them based on a series of trigger materials.

Stages[16]: 1) overview of role play method; 2) presentation of the scenario; 3) description of the task structure; 4) defining role groups; 5) random allocation of students to role groups; 6) individual reflection on roles; 7) proper role play; 8) students step out of role and decide their own view for or against; 9) students reflect privately on what they have learned; 10) debriefing.

The portfolio is a method that originated in the practice of artists gathering their works in a way that could be presented to potential customers. It encourages the learners to put together evidence about their work in a particular domain and organize it in a way that facilitates self-reflection and presentation. It is often used by educators as a tool for evaluation.

The portfolio encompasses a) a stage of defining the domain and the possible evidences that can be collected, b) a selection phase of evidence that will be included, c) a presentation phase and d) a self-reflection phase. It can be either material or digital, and it can be based on a predefined template or free-form.

4.2.3 Reflections on appropriate teaching methods for STE(A)M education

Methods related to arts – role-play and portfolio – were ranked as being less effective, while problem and project-based learning have received a much more positive evaluation across the board. However, it should be noted that the research that has produced these results was focused on teachers that were concerned with only one discipline. How does this hold up in STE(A)M education, which is, at its core, a collaborative teaching effort?

Problem and project-based learning are likely to be suitable approaches to STE(A)M education, as they promote collaboration and student agency. They seem to fit a variety of disciplines and can be used to deal with complex and ambiguous topics. In the end, it will

[16] Adapted from: Role play template - two roles, by James Dalziel
https://www.lamscommunity.org/lamscentral/sequence?seq%5Fid=924470

probably come down to how the participating educators manage to coordinate their efforts and align the activities with the learning outcomes.

Other methods, such as the jigsaw or reciprocal teaching, are more situational and have more specific focuses. It is easy to see how the jigsaw method can be used to promote social engagement and social justice, but it will require a particular context and learning goal in order to be used in STE(A)M education.

Arts-inspired methods will probably be more relevant in the context of STE(A)M education, than was the case when their merits were judged on their contribution to teaching specific disciplines, but they might need to be complemented with other methods that also support STEM related goals.

In terms of organizing an activity Wong and Huen (2017) have proposed a high-level model of integrated STEM education with an attached lesson plan that includes five steps: a) knowledge and skills, b) situated learning, c) planning, d) implementation and e) consolidate and question. The STEAMonEdu Project has developed a series of 30 learning activity templates using the tools provided by LAMS.

5 Body of Knowledge (BoK)

5.1 Introduction

Bodies of knowledge are tools, of varying degree of length and complexity, that attempt to map a specific domain. They range in shape and format from simple lists of topics relevant to a domain or activity, with no added description and minimal hierarchical ordering (National Certification Council for Activity Professionals, 2020), to large compendia attempting to provide detailed and exhaustive maps of an area. Some well-known examples are *A guide to the project management body of knowledge* (Project Management Institute, 2008) and The Cyber Security Body of Knowledge (Rashid et al., 2019).

The aim of this body of knowledge is to provide a tool that would enable educators and policy makers to quickly map out areas pertaining to STE(A)M education, whether it's competence development or accessing resources, and chart a path towards their goals. It should not be interpreted as standard – professional, quality assurance or any other kind – but as a tool for reflection.

For conceptual consistency, in developing the body of knowledge, we have relied on other outputs of the Project, but this does not mean that there aren't other ways of mapping the domain.

For example, the *Competence framework for STEAM educators* (Spyropoulu & Kameas, 2020) envisages five positions (teacher-trainer-tutor, learning designer and creator, orchestrator and manager, community member, professional) that an educator can assume. Other sources only refer to three (author-creator, manager, coach), which could be seen as overlapping to a significant extent we the ones we have used, but not entirely.

5.2 Organisation and regulation

5.2.1 Policies

The STEAM movement started in the USA, but it has since become a global phenomenon, with policy makers looking for ways to promote it.

5.2.1.1 Local and regional policies

Local and regional policies[17] are represented by STE(A)M-related initiatives, strategies, action plans and public-private partnerships implemented at local and regional level that can play an important role in bridging the gap in development between the various regions. The most common STE(A)M policies encountered at local and regional level are the educational policies developed in schools and universities by STE(A)M educators with the aim to create a holistic method of learning through STE(A)M so that children can develop their skills and focus on their development to choose the occupation that suits them best. In many cases, improving competences linked to STE(A)M-related jobs does not require the use of expensive traditional educational infrastructure, and there are also many opportunities, especially in vocational

[17] https://www.borbolycsaba.ro/en/wp-content/uploads/2019/08/COR-2018-06435-00-01-PA-TRA-EN.pdf

education and adult training, for organizing specialized, short-term training courses, sometimes only a few months in duration. Local and regional authorities may have a positive impact in this regard, given that the presence of a competent STE(A)M workforce is a decisive factor in determining the competitiveness of a community or region.

5.2.1.2 National policies

At EU level the quantity and the quality of STE(A)M national policies are still very low, and this translates into education systems that are not fully reformed in order to respond to the current societal challenges and opportunities. STE(A)M is largely unknown as a concept, and, as a consequence, it is not addressed by policy makers at national level, as the large majority of policy initiatives are related to STEM only. Most of the national STE(A)M policies are still ongoing or do not include a monitoring and evaluation framework, thus it is very difficult to assess the efficiency and impact of these policies.

National STE(A)M policies developed and approved by policy makers refer mainly to Action plans, Relevant STE(A)M curriculums and STE(A)M educational policies for different STE(A)M subjects.

STE(A)M education is not confined only to formal settings. On the contrary non-formal education providers, such as NGOs, students' unions, public and private training centres play an essential role in supporting and developing STEAM programmes and training opportunities.

5.2.1.3 EU level policies

At EU level consultations between policy makers led to the publication of official recommendations (Council Recommendation of 22 May 2018 on Key competences for lifelong learning)[18] and communications that encourage progress on adoption and implementation of STEAM education, by calling for better research, knowledge sharing and awareness raising. The updated Digital Education Action Plan (2021-2027) published by the European Commission expressly refers to STEAM disciplines by envisaging a more consistent participation of women in STEAM education practices, in order to foster gender equality and women's enhanced access to education and the labour market. More explicitly, the Commission aims to "*encourage women's participation in STEAM with the European Institute of Innovation and Technology (EIT) and support the EU STEM Coalition to develop higher education curricula which attracts women to engineering and ITC based on the 'STEAM' approach*". The "Science with and for Society" Programme has been established by the Commission as a vehicle to address the relevant European societal challenges tackled by Horizon 2020, by developing actions focused on building capacities and conceiving innovative methods to connect science to society. The ambition is to make science more appealing to young target groups, fostering innovation and broadening the field of educational research work.

[18] https://steamonedu.eu/wp-content/uploads/2021/01/WP3_D6_Guide-on-STEAM-education-policies-and-educators-needs_FINAL.pdf

5.2.2 Stakeholders

5.2.2.1 Educators

STE(A)M educator expression started to be used almost 10 years ago when the STE(A)M movement started to grow, and STE(A)M educational activities started to be implemented. In a broader sense STE(A)M educators represents all the teachers, trainers that implement STE(A)M related activities during their teaching classes. In a particular way, STE(A)M educators represents those teachers/trainers that develop strategies, skills, tools, and techniques in order to effectively teach science, technology, engineering, arts and math to students. The ability to encourage students to use different skills to solve problems and collaborate is essential for all STE(A)M educators.

A STE(A)M educator is the one that performs the following activities within his teaching work[19]:

- Facilitate and improve the school's science and technology programs
- Provide leadership in the development and implementation of the curricula for technology, engineering, and science programs
- Ensure that topics taught in the classroom meet state and national standards and requirements
- Maintain current knowledge of developments in the STE(A)M model and science and technology overall
- Collaborate with other schools in the county to support STE(A)M programs and initiatives
- Plan and execute programs to actively engage students, parents, and the community
- Plan and conduct science lab lessons for students at an age-appropriate level, with safety measures in place
- Plan and oversee technology curricula
- Provide leadership for professional development for other STE(A)M educators and paraprofessionals in the school to promote learning and teaching best practices
- Supervise and ensure the safety of students in the class
- Exhibit strong written and verbal communication skills
- Develop course syllabus or curricula overview on an as-needed basis
- Use a variety of technological applications and online resources
- Enhance productivity and learning opportunities through technology.

5.2.2.2 School managers

STE(A)M school managers in the context of STE(A)M education are very important because they are the ones that can encourage the adoption and implementation of STE(A)M based programmes and STE(A)M related resources at the level of each school. STE(A)M school managers have a positive attitude towards the STE(A)M activities, in many cases they organise trainings for the teachers within the school, encourage the exchange of good practices related to STE(A)M, find different online training resources related to STE(A)M, find STE(A)M

[19] https://resilienteducator.com/teaching-careers/stem-steam-teacher/

communities, all this with the aim to develop skills and competencies of their colleagues, in order to be able to adapt the curriculum they teach to STE(A)M education.

Schools are starting STE(A)M-based learning programmes to equip students with the skills and knowledge needed to thrive in the 21st century.[20] STE(A)M learning will not only produce tomorrow's designers and engineers; it will develop innovative mindsets and the ability to problem-solve, ensuring that students become creators of technology, not just passive consumers. In this context, school managers that promote the use of STE(A)M in their schools bring an immeasurable value in their school, in the life of their students and in the life of the local community.

5.2.2.3 CPD providers

CPD stands for Continuing Professional Development[21] and is the term used to describe the learning activities professionals engage in to develop and enhance their abilities. CPD enables learning to become conscious and proactive, rather than passive and reactive. CPD is the holistic commitment of professionals towards the enhancement of personal skills and proficiency throughout their careers.

In the STEAMonEdu context, CPD combines different methodologies to learning, such as training workshops, conferences and events, e-learning programs, best practice techniques and ideas sharing, all focused for an individual to improve and have effective professional development in the STE(A)M field.

Engaging in Continuing Professional Development ensures that both academic and practical qualifications do not become out-dated or obsolete, allowing individuals to continually ‘up skill’ or ‘re-skill’ regardless of occupation, age or educational level.

5.2.2.4 Parents

Parents[22] have a very important role as the child’s main teacher, because parents as teachers are able to motivate children, are able to encourage the formation of new skills at home and provide valuable information for others who work with children. The understanding of parents in understanding STE(A)M is good, with this learning parents can learn from the things that are around them.

The role of parents in this STEAM approach is to assist children in exploring and building their own knowledge. When learning is done face-to-face, this assistance is carried out by the teacher in classroom learning. On the other hand, when this learning is done online, the task lies with the parents. Parental involvement cannot be separated from the world of early childhood education, especially in online learning as it is today.

[20] https://elearning.tki.org.nz/Teaching/Future-focused-learning/STEM-STEAM
[21] https://cpduk.co.uk/explained
[22] https://www.atlantis-press.com/proceedings/incesh-21/125962135

Parents have a very important role as the child's primary teacher, according to Bailey, et al., in [12] because parents as teachers are able to motivate children, are able to encourage the formation of new skills at home and provide valuable information.

5.2.2.5 Local community

STE(A)M local community can be represented in the context of STEAMonEdu project by the school community. The school, itself, is a community of its members-teachers, administrators, staff, students, and families of students. But this collaboration can reach to the outside, to the community-at-large, to include parents and local businesses.

Partnerships between schools and local community offer a clear benefit: they enhance learning opportunities by providing students with resources, experiences, and environments they would not otherwise have.

Different research indicates that family and community involvement in schools is associated with improvements in students' academic achievement, higher attendance rates, and improved quality of school programs, as well as improved student behaviour and school discipline. This approach is also available for STE(A)M field. On the other hand, local community it is also related to community of teachers from the local level, teachers who can come from several schools from the community and who can exchange experience related to STE(A)M learning activities.

5.2.2.6 Non-formal education providers

Non - formal education providers[23] are to be considered as main partners in open schooling for better learning outcomes and catering for diverse student needs. Local non-formal education providers are key stakeholders in open schooling. Non-formal education often already has a complementary role in the learning path of many students, and it makes them a natural ally. Non-formal education providers often have tools or methodologies missing from school and provide a more open learning environment. As they are embedded in the local community, they can also support the development of open schooling partnerships, especially in the STE(A)M field where the partnership between all local actors is very important.

According to the Council of Europe, non-formal education[24] refers to planned, structured programmes and processes of personal and social education for young people designed to improve a range of skills and competences, outside the formal educational curriculum.

5.2.2.7 Universities

Pedagogical departments and other departments belonging to universities and that are dealing with teachers' professional development are enriching their training programmes by adding STE(A)M education.

[23] https://www.phereclos.eu/wp-content/uploads/2021/02/PHERECLOS-policy-brief-4.pdf
[24] https://www.coe.int/en/web/compass

5.2.2.8 Students

In the context of STEAMonEdu project, STE(A)M educates students[25] in the fields of science, technology, engineering, art and mathematics with an interdisciplinary approach, leading students to adapt to constantly changing professional knowledge and rapidly changing social life. STE(A)M education philosophy can be summarized as: based on mathematics, engineering and art interpret science and technology. STE(A)M Education supports students to understand the world in a multi-disciplined way, transforming the world in the form of comprehensive innovation, and cultivating their ability to solve problems.

5.2.2.9 Regional policy makers

Regional policy makers refer to regional education policy makers in the context of STE(A)M education. Regional policy makers in the STE(A)M field are those experts that have particular knowledge in STE(A)M areas and tend to play an important role in developing the policy making process in this expertise area at regional level. Regional policy makers can work very close with STE(A)M teachers/educators in order to develop STE(A)M-related initiatives, strategies, action plans and educational policies, with the aim to bridge the educational development gap that can occur between regions. Regional policy makers develop regional policies and forward these policies to national policy makers and specialized governmental bodies (e.g ministry of education) that can approve and adopt these policies.

5.2.2.10 National policy makers

National policy makers are people who are involved in making policies and policy decisions at national level. Policy makers play a very significant role in the centralised education system as every component in the system gets implemented on the basis of their decisions. In the STE(A)M context, national policy makers are the leaders that bring a change in education, people who develop the STE(A)M educational policies for a school, state or country for which they are responsible.

National policy makers develop and approve policies that refer to Action plans, Relevant STE(A)M curriculums and STE(A)M educational policies for different STE(A)M subjects.

5.2.2.11 EU policy makers

EU policy makers are European experts which are responsible to make and to adopt policies at European level, in all areas of expertise, including STE(A)M education.

The current European scenario has recognized the importance of an integrated and multidisciplinary education, creating new skills and competences in the labour market. Expertise and knowledge of STE(A)M disciplines has thus become determinant to achieve an overarching education able to contribute to the education of a new category of professionals. The attention is high on STE(A)M Education as a means to foster scientifically oriented careers, initiating from a very early age. In this context, EU policy makers, through EU institutions, create official recommendations and communications that encourage progress on adoption and implementation of STEAM education, by calling for better research, knowledge sharing and awareness raising.

[25] https://steamedu.com/developing-steam-education-to-improve-students-innovative-ability/

5.3 STE(A)M elements

5.3.1 Science

Science[26] and the subjects contained within this umbrella term, such as chemistry, physics, and biology, are extremely important for educational development because we are all surrounded by scientific concepts every day, while scientific evidence is used to make important decisions in a huge range of fields.

It is crucial for students to learn the scientific method because it teaches them to solve problems and make decisions based on evidence and logical thought patterns. This can be especially important for logical learners, but the core skills involved in the scientific method are useful for students with all learning styles or preferences.

Aside from learning how to think scientifically, it is also useful for students to gain an understanding of how science links with the other STE(A)M components. While technology and engineering are both hugely reliant on scientific knowledge and discovery, the process of hypothesizing, testing, and drawing conclusions from the evidence are applicable elsewhere.

The following areas/topics are part of the Science discipline when we refer to STE(A)M educational practices and activities:

- Astronomy
- Biology
- Chemistry
- Earth Sciences
- Geology
- Physics

5.3.2 Technology

Technology in STE(A)M education[27] is of particular importance as a basic understanding of technology is now required for almost any kind of work. In today's world, the field of technology is vital because it is all around us, assisting our everyday lives, driving entire industries, and keeping us connected. Technology can be used to assist with science, engineering, the arts, and mathematics, while it can also be taught as a distinct subject of its own – known as technology education.

A major focus of many technology programs is bridging the gap that exists between widespread usage of technology and less common knowledge about how technology actually works and how to create or fix it. The STE(A)M field of technology can also be said to include Information Technology (IT) and computer-based disciplines too.

With the overall importance of technology and technology-based lessons established, it is also important to understand how technology works in a STE(A)M context. As stated, one of the

[26] https://www.viewsonic.com/library/education/steam-education-preparing-all-students-for-the-future/
[27] https://www.viewsonic.com/library/education/the-importance-of-technology-in-steam-education/

big focuses of STE(A)M education is on integration, and it could be argued that technology is the easiest of the five STE(A)M fields to integrate with the others.

The links between science and technology are numerous and, according to Georgette Yakman, “science provides the framework by which all technology is developed and structured to function.” Similarly, electrical engineering and mechanical engineering are obvious examples of areas where engineering crosses over with technology and where the two concepts can be taught in unison.

The arts are a broad field, but areas like computer-aided design and photography are good examples of cross-over with technology. In addition, technology can assist with mathematics in a number of ways, from the use of calculators or computer spreadsheets to perform arithmetic through to the use of software to make graphs and charts.

Technology-based subjects are a key part of a good academic curriculum, helping to equip students with transferable skills, and technology is also relatively easy to integrate with the other main STE(A)M education fields – science, engineering, the arts, and mathematics.

Despite this, technology is arguably the most abstract of the STE(A)M fields because technology education is less clearly defined than many other academic subjects, and this continues to present a challenge to educators.

Technology discipline integrates the following STE(A)M areas/topics:

- Algorithm design
- Artificial Intelligence
- Big Data
- Cloud Computing
- Computer architecture and organization
- Computer security
- Cyber security
- Database system
- ICT
- Informatics
- Information technology management
- IT Security
- Networks
- Operating Systems

5.3.3 Engineering

Engineering[28] can be broadly described as the application of scientific principles in order to create objects, machines, structures, products, and more. It is most commonly divided into four main fields: civil engineering (buildings, bridges, infrastructure, etc.), electrical engineering (electronic devices, electrical circuits, control systems, etc.), mechanical engineering (robotics, vehicles, engines, etc.), and chemical engineering (chemical

[28] https://www.viewsonic.com/library/education/steam-education-preparing-all-students-for-the-future/

manufacturing, oil refinery, etc.) However, aerospace engineering is sometimes included as a distinct fifth branch.

In truth, the importance of teaching engineering concepts and principles within academic institutions cannot be overstated because the world needs engineers of all kinds to create the objects and infrastructure we rely on.

In addition to engineering being dependent on scientific principles, there is a major cross-over with mathematics and especially geometry. However, engineering also links with the other STE(A)M fields in various ways. The arts, for example, are based on creativity, and there is a very clear artistic element to designing and engineering a bridge or a building. Similarly, the actual engineering process relies on technology, including computers and other machines.

The following STE(A)M areas/topics are integrated by Engineering discipline:

- Biomedical engineering
- Chemical engineering
- Civil engineering
- Electrical engineering
- General engineering
- Mechanical engineering
- Nuclear engineering
- Software engineering
- Systems engineering

5.3.4 Arts

As stated, the STE(A)M education initiative has grown out of the previously existing concept of STEM education. The difference between the two ideas can be summarized as the added presence of the letter 'A' for the arts; in reality, this is quite a significant difference and not one that should be under-estimated in terms of its importance.

After all, 'the arts' in this context refers to not only visual or aesthetic arts but also social studies, language arts, fine arts, musical arts, and physical arts – and all of the subjects that fall within those sub-categories[29].

The arts are an extremely broad field[30] that encompasses a wide range of subjects, many of which have not traditionally been viewed as particularly "academic". The arts were divided into sub-categories as: fine arts, language arts, physical arts, manual arts, and liberal arts.

Prior to the concept of STE(A)M, many of these subjects were not considered critical to the end goal of developing students into highly skilled citizens, with abilities and qualifications that are in demand in the workforce. However, this view has since changed. The language arts, for instance, have cross-over with every other STE(A)M field because they focus on effective communication, while liberal arts are also considered important academic subjects.

[29] https://www.academia.edu/8113795/STEAM_Education_an_overview_of_creating_a_model_of_integrative_education
[30] https://www.viewsonic.com/library/education/steam-education-preparing-all-students-for-the-future/

Historically, fine arts and physical arts have struggled to be viewed as important vocational subjects, but this view has also changed. Today, there is a greater appreciation for the importance of developing creative and expressive skills. Clearly, there are many potential career options for people with drawing, painting, and performing skills.

Arts discipline integrates a range of STE(A)M areas/topics, as stated bellow:

- Dance
- Economics
- Entrepreneurship
- Fashion designing
- Fine arts
- Geography
- Graphic designing
- History
- Language arts
- Legal studies
- Multimedia
- Music
- Philosophy
- Physical education
- Political science
- Psychology
- Sociology

5.3.5 Mathematics

Finally, the last piece of the STE(A)M puzzle is mathematics[31], and, in many ways, it also helps to bind the other elements together. After all, mathematics is needed to solve problems in fields like science, technology, and engineering, while it can also provide the necessary structure to the arts. Of course, numeracy is also an essential life skill more generally.

One of the challenges with mathematics as an academic subject is that although it is widely seen as being a core part of the curriculum, many students find it difficult to enjoy. Therefore, many STE(A)M education initiatives aim to boost engagement in this area and encourage more students to continue to study the subject at a college or university level.

A major benefit that mathematics offers over many subjects is its universal nature, regardless of language, which opens up career possibilities all over the world. Within the workforce, advanced mathematics skills are in high demand in a range of fields, from scientific research and data analysis roles, through to engineering and medicine.

The following STE(A)M areas/topics are integrated by Mathematic discipline:

- Algebra
- Calculus and analysis

[31] https://www.viewsonic.com/library/education/steam-education-preparing-all-students-for-the-future/

- Combinatorics
- Computation
- Dynamical system and differential equations
- Game theory
- Geometry and topology
- Information theory and signal process
- Logic
- Mathematical physics
- Number theory
- Operations research
- Probability and statistics

5.4 STE(A)M Perspectives / roles of educators[32]

5.4.1 Educator as teacher-trainer-tutor

Which refers to implementing the educational procedure. Competences under this heading are distributed across six areas: a) pedagogy, b) content knowledge, c) instruction, d) use of content and tools, e) feedback and assessment, f) learner empowerment.

5.4.2 Educator as Learning designer and creator

Which refers to designing and producing outputs. Competences under this heading are distributed across three areas: course / curriculum / activity design, content and tools design and development, learner development.

5.4.3 Educator as Orchestrator and manager

Which refers to coordinating procedures and outputs. Competences under this heading are distributed across two areas: a) educational procedure management, b) resource management.

5.4.4 Educator as Community member

Which refers to interacting with the environment. Competences under this heading are distributed across two areas: a) community building, b) application of policies.

5.4.5 Educator as Professional

Which refers to developing and applying competences. Competences under this heading are distributed across two areas: a) transferable skills, b) digital skills, c) professional development.

5.5 STE(A)M Learning Design Principles

A large variety of learning design principles have been proposed for STEM and STE(A)M education (e.g. Butler et al., 2020; Castek et al., 2020; Kim, 2021), to help guide the creation of effective learning activities and programmes. We have selected four of them that also function as check-list for quality STE(A)M activities.

[32] Spyropoulou, N., & Kameas, A.,(2020), STE(A)M educator competence framework and profile https://steamonedu.eu/wp-content/uploads/2021/06/D8.1-STEAM-educator-competence-framework-and-profile.pdf

5.5.1 Equal treatment of STE(A)M elements

STE(A)M education is not possible as an endeavour of a single educator, but rather a team of educators (Huser et al., 2020). This raises issues in regard to how the five elements of STE(A)M come together to create a meaningful educational experience. Historically, the position of the arts among the other STE(A)M elements has been an issue of contention, with widely differing definitions to what constitute arts in this setting. It is of utmost importance that arts are treated on an equal footing with the other elements, with their own educational outcomes (Perignat & Katz-Buonincontro, 2019), rather than as an appendage to STEM education.

5.5.2 Appropriate disciplinary and pedagogical approaches

STE(A)M education transcends a mono-disciplinary approach, in favour of disciplinary approaches that enable all participating knowledge domains to be fully accessed. There are multiple disciplinary approaches that are conducive to the implementation of STE(A)M education activities, that have been successfully employed in order to achieve this goal: cross-disciplinarity, inter-disciplinarity, trans-disciplinarity, multi-disciplinarity, arts-integration.

From an instructional point of view, the appropriateness of different pedagogical methods varies significantly in relationship to STE(A)M educational activities. Collaborative, hands-on approaches – like problem-based and project-based ones – seem to better suited to this type of educational activities, rather than the ones focusing on individual work – like the portfolio-method.

5.5.3 Use of real-world contexts

Meaningful education needs to be connected to real life problems and contexts, in order to avoid the possible pitfalls that are associated with knowledge that is disconnected from the reality that it describes. This is a principle that applies beyond STE(A)M education, but is especially relevant for it, because of its emphasis on making and problem-solving.

5.5.4 Equity

Educational spaces have built in axiological and ideological structures, that might not offer the proper environment for STE(A)M education. A proactive approach is needed to make sure that participants have equitable access (Castek et al., 2020) that recognizes individual and collective identities. While all educators need to enact mechanisms that promote equity in their work, it is recommended that a system level approach is also taken (e.g. Texas Education Agency, 2020).

5.6 Instructional design and assessment

In a broader sense, the instructional design process consists of determining the needs of the learners, defining the end goals and objectives of instruction, designing and planning assessment tasks, and designing teaching and learning activities to ensure the quality of instruction.

Simply put, instructional design is the creation of **instructional materials**. Though, this field goes beyond simply creating teaching materials, it carefully considers how students learn and what materials and methods will most effectively help individuals achieve their academic goals.

Basic Components of Instructional Design[33]:

While there are a number of instructional design models and processes, many of their components are similar. They include analysis, design, development, and evaluation.

Analysis

A needs analysis typically includes understanding the needs and learners including why a training or learning solution is required. It may be the case that training is not the solution, and some other type of performance improvement or non-training solution will be recommended. In this stage, the goals of the training will start to be developed, including learning objectives, and determine how the training will be delivered.

Design & Development

Design and development includes the actual design and development of the instructional materials or determining the delivery methods to be used. It often includes drafting curriculum and lesson plans, developing any instructional materials including presentations, e-learning and anything else to be used in the training.

Evaluation

Evaluation looks at how it can be determined if the training or learning solution used was successful.

In the context of STE(A)M education and of the STEAMonEdu project, the instructional design and assessment refers to STE(A)M meta-methodology developed[34], which includes: STE(A)M learning design principles and curricular approaches, analysis of teaching method suitability.

A meta-methodology is defined as a "*form of meta-level research where the subject matter is other research methods*" (Edwards, 2014). In order to develop the STEAMonEdu meta-methodology, project partners reviewed and explored all the existing methodologies, while trying to understand possible developments connected to technological and pedagogical changes. The analysis goes from principles, to curricular approaches and on to specific methods, with some final considerations on how a learning activity can be organized.

Meta-methodology was developed based on a literature review, the experience of the LAMS community[35], as well as the review of STE(A)M education practices and policies collected by the STEAMonEdu partnership.

Learning design principles and curricular approaches

In terms of learning design principles, we turned to STEM to see how the science and maths are seen as being best approached. Butler et al. (2020) proposed a list of six such principles:

[33] https://www.td.org/talent-development-glossary-terms/what-is-instructional-design
[34] https://steamonedu.eu/wp-content/uploads/2021/09/D7.1-STEAM-education-framework.pdf
[35] https://www.lamscommunity.org

problem solving design and approaches[36], disciplinary and interdisciplinary knowledge, engineering design and practices, appropriate use and application of technology, use of real-world contexts, appropriate pedagogical practices. Similar suggestions were promoted by the CHOICE Project, which, when designing STE(A)M workshops, advocates for "*active participation of the learners, promote rather a non-formal frame of learning, collaborative approach and focus on the development of transversal skill and competencies applicable in a real-world context*" (La Monica Grus, 2020).

Margot & Kettler (2019) suggest some pedagogical practices to support STEM integration, such as:

- using hands-on, practical applications of content in order to solve their challenges,
- introducing students to STEM professions,
- using a project-based approach,
- helping students apply content knowledge to solve problems,
- utilising the engineering design process in the classroom to make real connection to the world.

Others suggest **inquiry-based teaching method (**Thibbaut et al., 2018) or **project-based teaching method** (Kennedy & Odell, 2014; Pitt, 2009; Ritz & Fan, 2015).

An important discussion focuses on the extent to which the individual components of STE(A)M need to be integrated. In their review of STE(A)M education Perignat and Katz-Buonincontro (2019) found five types of disciplinary integration:

- transdisciplinary: several fields of knowledge come together in a way that disregards boundaries.
- interdisciplinary: several fields of knowledge come together, but each retains its boundaries.
- multi-disciplinary: collaboration between several disciplines that do not merge together.
- cross-disciplinary: the practice of observing one disciple through the eyes of another.
- arts-integration.

A UNESCO document (Ng, 2019) references an integrative approach, called neo-disciplinary[37], which "*disregards traditional subject boundaries altogether 'to create new categories of skills and knowledge networks'*". When digging deeper for the initial proposal regarding such an approach not many details can be found, but what can be gleaned from it, make it an interesting avenue to pursue, that could fit STE(A)M education.

[36] „a problem-solving attitude refers to both the learning process and the individual's ability to handle obstacles and change. It includes the desire to apply prior learning and life experiences and the curiosity to look for opportunities to learn and develop in a variety of life contexts." (European Commission, 2019, p. 11).
[37] https://delaforce.info/?tag=stem

Analysis of teaching method suitability

The analysis made within STEAMonEdu project is based on three sources of information: a) a series of articles ranking the suitability of teaching methods in several subjects; b) examples of STE(A)M education practices collected through the STEAMonEdu project; c) the practices of the LAMS community in developing learning activity templates.

The ranking and the examples collected by the STEAMonEdu project were used in order to select the descriptions of several teaching methods' that were available on the LAMS community website.

More information's about ranking of teaching method suitability, raking of instructional methods by teachers, description of selected teaching methods and reflections on appropriate teaching methods for STE(A)M education, can be consulted on the STE(A)M education framework document which includes a chapter about meta-methodology and description of instructional design and assessment.

5.7 Resources

5.7.1 Educational resources

5.7.1.1 Learning activity templates

In the context of STEAMonEdu project, learning activity templates represent a set of learning activity templates developed with the scope to guide educators and to serve as blueprints for the creation of new STE(A)M lessons / projects that can be implemented in the classroom (and outside of it). In order to create learning activity templates, STEAMonEdu consortium used LAMS[38] (a web application for designing, managing and delivering online learning using collaborative learning activities) to create and manage the learning activity templates. The project consortium identified LAMS as being a perfect match for supporting the development of STE(A)M learning activity templates and for using these in order to empower educators.

The process of developing learning activity templates has been done by using a methodology that includes five steps, from research on STE(A)M education good practices and LAMS templates, to analysis of best lesson methods for STE(A)M lessons and the creation of templates based on the findings of research and analysis.

STEAMOnEdu partners have developed 7 STE(A)M specific learning activity templates that are hosted on a LAMS platform belonging to RDEWG project partner: https://pekesde.lams.sg/.[39] These are built on eLearning strategies such as INQYIRED-based learning, PROBLEM-based learning and PROJECT-based learning. STEAMOnEdu partners have proactively participated in this task, by creating each, at least one learning activity template. The templates will support the community of STEAMOnEdu educators to adapt new educational strategies and methods in order to create new effective STE(A)M lessons for their classes.

[38] https://www.lamsinternational.com/

[39] Learning Activity Management System

More details about learning activity templates developed under STEAMonEdu project can be consulted in the document STE(A)M learning activity templates, one of the project deliverable.

5.7.1.2 Educational activity

A STE(A)M educational activity is a lesson that covers one of the core STE(A)M subjects: **Science, Technology, Engineering, Art, and Math**. It's a common acronym in the education world to reference these important subjects and skills — in and out of school.

STE(A)M educational activities are used by STE(A)M educators in the classroom, with the aim to:

- Design and implement educational programs that integrate the scientific fields of STE(A)M and promote STE(A)M educational approach;
- Design and implement STE(A)M educational activities based on real life situations;
- Know, understand, select and design STE(A)M related educational activities based on learners' needs, characteristics, prior knowledge and educational objectives of the course;
- Create and modify suitable educational content to support and enhance STE(A)M teaching and learning;
- Create and develop a variety of resources (audiovisual material, etc.) to effectively design educational activities that require the integration of concepts and skills from different disciplines;
- Use technology in order to design and develop STE(A)M applications for STE(A)M educational activities;
- Facilitate learners' STE(A)M competences.

5.7.1.3 Learning object

A learning object[40] is "a collection of content items, practice items, and assessment items that are combined based on a single learning objective". The concept encompassed by 'Learning Objects' is known by numerous other terms, including: content objects, chunks, educational objects, information objects, intelligent objects, knowledge bits, knowledge objects, learning components, media objects, reusable curriculum components, nuggets, reusable information objects, reusable learning objects, testable reusable units of cognition, training components, and units of learning.

The core idea of the use of learning objects is characterized by the following: discoverability, reusability, and interoperability. To support discoverability, learning objects are described by Learning Object Metadata, formalized as IEEE Standard for Learning Object Metadata[41].

For this standard, a learning object is defined as any entity, digital or non-digital, that is used for learning, education, or training; a metadata instance for a learning object describes relevant characteristics of the learning object to which it applies. Such characteristics can be regrouped in general, life cycle, meta-metadata, educational, technical, educational, rights, relation, annotation, and classification categories. The conceptual data schema defined in this standard specifies the data elements of which a metadata instance for a learning object is

[40] https://en.wikipedia.org/wiki/Learning_object
[41] https://standards.ieee.org/standard/1484_12_1-2020.html

composed and allows for linguistic diversity of both learning objects and the metadata instances that describe them.

One of the key issues in using learning objects[42] is their identification by search engines or content management systems. This is usually facilitated by assigning descriptive learning object metadata. Just as a book in a library has a record in the card catalog, learning objects must also be tagged with metadata. The most important pieces of metadata typically associated with a learning object include:

1. **objective**: The educational objective the learning object is instructing
2. **prerequisites**: The list of skills (typically represented as objectives) which the learner must know before viewing the learning object
3. **topic**: Typically represented in a taxonomy, the topic the learning object is instructing
4. **interactivity**: The Interaction Model of the learning object.
5. **technology requirements**: The required system requirements to view the learning object.

IEEE Standard for Learning Object Metadata was used within STEAMonEdu project in order to create meta-data profiles for the educational platform developed and also for the development of the OER specification document.

The design and development of the metadata profiles of the different platform content types (that include learning objects and integrate properly the relevant with the project educational aspects and terms) was one of the most important tasks of the project. Several educational resources of different kinds were developed during the project lifetime for different purposes, such as scenarios, projects, activity templates, lesson plans, etc. ". Therefore, a range of content types and learning objects were created within the project.

The basic decisions in the design of the metadata profiles of educational practices and policies as well as the metadata terms that have been used for them represented the basis of all the relevant content types that were designed. DCMI/LRMI (Dublin core)[43] metadata terms have been used for profiling the initial educational learning objects (classes), i.e., educational practices, policies and repository entries.

More details about how learning objects were developed and used within STE(A)MonEdu project can be consulted in the deliverable STE(A)M educational objects meta-data profile.

5.7.2 Other resources

5.7.2.1 Hardware

In a generic way, hardware resources are the **assignable, addressable bus paths that allow peripheral devices and system processors to communicate with each other**. Hardware resources typically include I/O port addresses, interrupt vectors, and blocks of bus-relative memory addresses.

[42] ECEL2006-5th European Conference on elearning: ECEL2006. Academic Conferences Limited. ISBN 978-1-905305-30-8
[43] https://www.dublincore.org/

In the context of STE(A)M education, hardware resources needed to teach STE(A)M lessons in the classroom are very diverse, depending on the specifics of the lesson and STE(A)M discipline addressed. Bellow you can find a list with a few hardware resources used by STE(A)M educators in their STE(A)M lessons[44]:

- PCs/laptops
- Projector
- Tablets/smartphones/ iPads
- USB cables
- Interactive whiteboard
- Microphone
- Audio speakers
- Markers, Papers
- Washable paint, brushes, chalk for marking the ground, milestones
- LEGO® MINDSTORMS® Education EV3 Robotics kit (Physics/Chemistry/Technology - science area/topic)
- BBC micro: bits micro-controllers
- 3D Printers
- Bee Bot Robot kit (Robotics science area – a floor robot that is specially designed to be used by preschoolers as well as by elementary school students)
- Boomwhachers
- Bee Bot track/mat kit
- mBot robotic kits
- Engino
- UDOO kits

In addition, in the article "The Promise of the Maker Movement for Education", Martin (2015) [45]presents a classification of useful digital tools for education in general:

Digital Physical Tools, also called rapid prototyping tools or digital manufacturing tools, to shape materials or objects and that can support student projects can be:

- Computer numerical control router: creating small parts from metal, wood or plastic, for use in projects or for prototyping.
- Laser cutter: cutting stock into shapes used in a project.
- Digital embroidery machines: decorating cloth, sewing circuit designs into cloth with conductive thread.
- Vinyl or paper cutter: creating stencils and stickers, templates for circuit board designs.

Digital Logic Tools: low-cost, hobbyist-friendly microcontrollers, mini-computers or similar electronics devices. They're small devices that can be programmed and that can process input from a variety of input devices (sensors, switches, data coming from internet) and that can control various output devices (motors, LEDs, screens, speakers) and save the data on memory

[44] https://steamonedu.eu/platform/practices

[45] Martin, L. (2015). The Promise of the Maker Movement for Education. Journal of Pre-College Engineering Education Research (J-PEER), 5(1), Article 4. https://doi.org/10.7771/2157-9288.1099

cards, for example. Arduino, Raspberry Pi are some the most common used. Big communities support the learning process to use them through manuals, tutorials, videos, forums, web spaces where they share the code.

For more examples related to hardware used in STE(A)M lessons, the educational practices uploaded by community members of the STEAMonEdu platform - https://steamonedu.eu/platform/practices, can be consulted. The practices uploaded on the platform addresses lessons from all STE(A)M subjects and present all the hardware resources needed for each STE(A)M discipline/STE(A)M area/topic.

5.7.2.2 Software

Software resources refer to a collection of instructions[46] that tell a computer how to work (1,2). This is in contrast to hardware, from which the system is built and actually performs the work.

At the lowest programming level, executable code consists of machine language instructions supported by an individual processor—typically a central processing unit (CPU) or a graphics processing unit (GPU). Machine language consists of groups of binary values signifying processor instructions that change the state of the computer from its preceding state. For example, an instruction may change the value stored in a particular storage location in the computer—an effect that is not directly observable to the user. An instruction may also invoke one of many inputs or output operations, for example displaying some text on a computer screen; causing state changes which should be visible to the user. The processor executes the instructions in the order they are provided unless it is instructed to "jump" to a different instruction or is interrupted by the operating system. As of 2015, most personal computers, smartphone devices and servers have processors with multiple execution units or multiple processors performing computation together, and computing has become a much more concurrent activity than in the past.

The majority of software is written in high-level programming languages. They are easier and more efficient for programmers because they are closer to natural languages than machine languages.[3] High-level languages are translated into machine language using a compiler or an interpreter or a combination of the two. Software may also be written in a low-level assembly language, which has a strong correspondence to the computer's machine language instructions and is translated into machine language using an assembler.

Based on the goal, computer software can be divided into:

- **Application software** uses the computer system to perform special functions beyond the basic operation of the computer itself. There are many different types of application software because the range of tasks that can be performed with a modern computer is so large—see list of software.

[46] https://en.wikipedia.org/wiki/Software

- **System software** manages hardware behavior, as to provide basic functionalities that are required by users, or for other software to run properly, if at all. System software is also designed for providing a platform for running application software,[13] and it includes the following:
  - **Operating systems** are essential collections of software that manage resources and provide common services for other software that runs "on top" of them. Supervisory programs, boot loaders, shells and window systems are core parts of operating systems. In practice, an operating system comes bundled with additional software (including application software) so that a user can potentially do some work with a computer that only has one operating system.
  - **Device drivers** operate or control a particular type of device that is attached to a computer. Each device needs at least one corresponding device driver; because a computer typically has at minimum at least one input device and at least one output device, a computer typically needs more than one device driver.
  - **Utilities** are computer programs designed to assist users in the maintenance and care of their computers.
- **Malicious software**, or **malware**, is software that is developed to harm or disrupt computers. Malware is closely associated with computer-related crimes, though some malicious programs may have been designed as practical jokes.

Main software resources used to run STE(A)M educational activities in the classroom, are[47]:

General resources (which are required for a various range of STE(A)M categories of activities):

- Internet connection
- Office 365-Accounts for schools
- Microsoft office (Word, Excel, Power Point)/Google docs/Libre Office Suite
- Dropbox
- Doodle
- Other online tools as: WebQuest, Kahoot, Genially, Postermywall, YouTube, Paleta, moviemaker, Prezi, Vimeo

Software resources that can be used for **Physics science area/topic,** for example**:**

- Ev3Dev
- Ev3Python
- Audacity
- Mentimeter
- Edpuzzle

Software resources for **STE(A)M Coding lessons, for example**:

- Tinkerkcad - 3D Design
- Fusion 360
- Arduino IDE
- Scratch
- Microsoft Make Code for micro: bit

[47] https://steamonedu.eu/platform/practices

- Hour of code activities
- CODINC
- Minecraft Education Edition
- MIT App Inventor - Massachusetts Institute of Technology

Software resources for **STE(A)M Robotics lessons, for example**:

- Meet Edison
- Lego WeDo 2
- LEGO Mindstorm EV3 Home Edition (Software)

For more examples of software resources that can be used in STE(A)M educational activities, can also be consulted the section with educational practices of the STEAMonEdu platform: https://steamonedu.eu/platform/practices.

STEAMonEdu community members specified a range of software resources that can be used with students during STE(A)M lessons in the classroom, resources that cover all STE(A)M disciplines, STE(A)M areas/topics.

5.8 Professional development

5.8.1 Validation of STE(A)M competences

A teaching competency is **a set of professional skills that enables practical teaching situations to be appropriately resolved**[48]. Competence includes knowledge, skills, attitudes and experiences, which has to be target category of profession of educator. **Ability to perform or carry out defined tasks in a particular context**, at a high level of excellence.

Teacher must possess the knowledge and skill needed to attain the goals and must be able to use that skill appropriately if the goals are to be achieved. There are various competencies like pedagogical, personal, social, and professional competencies of teacher to improve student's performance.

In the context of STE(A)M education**, Lifelong learning (LLL)** and **Continuous professional development (CPD)** come together. Continuous professional development is a constantly changing landscape, that is underpinned by certain factors, such as the conceptualization of the place of STE(A)M education within lifelong learning, the stakeholders that bringing it to life, or the competence frameworks used to.

Lifelong learning has created the necessary environment in which STE(A)M education can thrive. Among other things, this is because it allowed the development of collaborative pedagogies, and it unified the paradigm that applies both to educational professionals and learners.

[48] The STE(A)MonEdu MOOC course, W6.2.1.a - Professional development in STE(A)M education why and how? Mihai Iacob, Fundatia EOS Romania - https://mooc.cti.gr/steamonedu.html

The formal element that brings together lifelong learning and continuous professional develop is a qualifications' framework. Within the European Union they are developed at national level, with clear correspondences to the European Qualifications Framework.

Another tool that helps navigate qualifications at European Union level is the ESCO – European Skills, Competences, Qualifications and Occupations Framework. The STEAMonEdu project is attempting to link STE(A)M educator's competence to this framework so that they might be more readily certified across the Union.

Training opportunities arise when a network of actors comes together, each of them with their own agendas, needs and resources. Learners will be interested in being able to access educational activities that open further possibilities. Educators need a clear image of how any training is connected to the curriculum they follow. The local community wants its resources to be used efficiently and its needs to be met.

Transferable skills as communication, collaboration, openness for change and critical thinking are also very important for STE(A)M educators. (Thomas Schmidt, CEO of Helliwood media & education).[49]

In our days, the qualification of educators is based on a holistic approach as it relies on the complex requirements of a constantly changing society. One reason is the rapid change of digitization but also the requirements which come from a globalized world.

The determination of specific competences supports the orientation for qualifying educators and for promoting key areas. The competence models had demonstrated that different transferable skills are relevant for the qualification of STE(A)M educators and their students. But the relevance and announcement of such skills depend on the originator and area in which they are demanded.

Other important transferable skills for STE(A)M educators are leadership skills, teamwork skills, presentation and communication skills, ethic skills, information management skills, entrepreneurship skills.

In the STEAMonEdu project, validation of educators STE(A)M competences was done through the MOOC course developed, entitled "Design, orchestration and implementation of STE(A)M education".

STEAMonEdu MOOC course supports the professional development of educators and managers/directors at all levels of education and guides them in becoming the STE(A)M education tutors, designers and orchestrators.

The participants to STEAMonEdu MOOC gained knowledge and developed competences in the following areas:

- Modern approaches of STE(A)M education

[49] The STE(A)MonEdu MOOC, W6.4.2.b Transferable skills examples, Helliwood media & education (Germany) - https://mooc.cti.gr/steamonedu.html

- Design and implementation of STE(A)M educational activities
- Content creation for STE(A)M education
- STE(A)M educational procedure and resource management
- Community building, participation and interaction.

More details about validation of STE(A)M competences can be consulted in the training materials for weeks 6.2 and 6.4 of the STEAMonEdu MOOC course.

6 STE(A)M-ready OER Specification

The scope of this document is to enable educators to quickly identify the suitability of OERs for teaching specific STE(A)M subjects using specific techniques. The STE(A)M-ready OER Specification document was developed based on the metadata created within D2 - STE(A)M educational objects meta-data profile, one of the STEAMonEdu deliverables that provided a basis of the metadata profiles used for STE(A)M educational objects as well as an ontology of STE(A)M education terms concepts and items that will be used to index STE(A)M education resources.

6.1 Introduction

6.1.1 What are Open Educational Resources (OER)?

UNESCO, 2002, defined the Open Educational Resources as “Teaching, learning and research materials in any medium – digital or otherwise – that reside in the public domain or have been released under an open license that permits no-cost access, use, adaptation and redistribution by others with no or limited restrictions.”

This is something relevant to our purpose, as far as, when we create STE(A)M activities, we may be interested in sharing them with the educational community not only for them to know and value, but also for other educators and teachers to use. That is why we have introduced this "open" concept here. These OER can be referenced in the repositories. In fact, we can find a lot of them there.

6.1.2 UNESCO Recommendation on OER (2019)

The Recommendation on OER - adopted unanimously by the UNESCO General Conference at its 40th session in November 2019 - supports the creation, use and adaptation of inclusive and quality OER, and facilitates international cooperation in this field.
It is the only existing international standard-setting instrument on OER.
The Recommendation outlines five Areas of Action, namely:

- Building the capacity of stakeholders to create, access, re-use, adapt and redistribute OER;
- Developing supportive policy for OER;
- Encouraging inclusive and equitable quality OER;
- Nurturing the creation of sustainability models for OER; and
- Promoting and reinforcing international cooperation in OER.

At an international level, the adoption of the Recommendation constitutes a decisive step towards building more open and inclusive knowledge societies and towards the achievement of the UN 2030 Agenda.

6.2 STE(A)M OER SPECIFICATIONS - EXAMPLES FROM PROJECT PARTNERS

6.2.1 STE(A)M OER specification Romania

General information:

- STE(A)M OER name: Lecțiile patrimoniului. Scenarii educaționale pentru gimnaziu
- Abstract: The aim of the guide is to offer templates which lower secondary teachers can adapt for teaching science, math and humanities using heritage as a starting point.
- Language: Romanian
- STE(A)M discipline: Science, Arts, Mathematics
- Area/Topic: Geometry, Mathematics, History, Communication, Arts
- Key terms: STE(A)M education, built heritage
- License: CC BY-NC-SA
- Author of the OER:

Lead authors:

Mihai Iacob – Centrul pentru Educație și Formare Sintagma

Angelica Mihăilescu – Asociația MetruCub – resurse pentru cultură

Authors:

Despina Hașegan
Silvana Râpeanu
Iulia Iordan
Raluca Bem-Neamu
Claudia Pamfil
Vera Marin
Valentina Bilcea

- Author's occupation: Researcher

Audience and Educational Framework

- Audience: educators
- Age range: 11-15
- Audience competence: Beginner
- Educational/training framework: Lower secondary education
- Educational/EQF level: 1

Educational details

- Educational subject: Arts, Communication, History, Mathematics, Geometry, Natural sciences
- Description of the OER:
- Duration: 5 - 90 hours
- Difficulty: Medium
- Educational use: Interdisciplinary project, group work
- Learning Outcomes:

Each of the 15 scenarios is accompanied by descriptors of learning outcomes, that are related to key competences and the training profile of the lower secondary graduate in the Romanian public schools.

- Orientation/Focus: acquire new knowledge, develop new skills, develop new attitudes
- Delivery mode: Face to face learning
- Hardware/Software/Other Resources: The scenarios require a variety of resources, depending on the approach taken. Typically, resources include work sheets, flipchart sheets, folders, measurement instruments, maps, photos, post-its.

Implementation

- Country were the OER was implemented: Romania
- Framework/organization that was applied to: Liceul „D. Bolintineanu” Bucharest
- Audience size: 25
- Description, evaluation and lessons learned during the OER implementation:

The resource is a guide for educators, with practical details on how to implement educational activities that use built heritage as a focal point. Because the educational activities were set in public area of central Bucharest, the educators were given practical information on how to handle the additional constraints. Each scenario includes suggestions on how to evaluate the acquisitions of students and how they might be linked to key competences and the graduate's profile. Additional support was needed to enable the educators to overcome the administrative burdens related to organizing field trips.

Educational material/resources (file URL) accompanying the OER (if available)

- Educational material/resources name: Lecțiile patrimoniului. Scenarii educaționale pentru gimnaziu
- License: CC BY-NC-SA
- Educational resource type: educational scenarios
- Language of the material/resource: Romanian
- URL:https://culturaineducatie.ro/wpcontent/uploads/2016/11/sce_Lp_ghid_F6_digital.pdf

6.2.2 STE(A)M OER specification Greece

General information:

- STE(A)M OER name: Introduction to the DigCompEdu framework
- Abstract: The aim of this presentation is to introduce learners to the main concepts of DigCompEdu framework.
- Language: English
- STE(A)M discipline: Technology
- Area/Topic: Technology
- Key terms: DigCompEdu, competence framework, competence
- License: CC BY-NC-SA
- Author of the OER: Natalia Spyropoulou
- Author's occupation: Researcher

Audience and Educational Framework

- Audience: Educators, Researchers, Practitioners
- Age range: 18+
- Audience competence: Beginner
- Educational/training framework: Elementary/primary school; Middle/junior high school; Higher Education
- Educational/EQF level: 5

Educational details

- Educational subject: Technology
- Description of the OER: The aim of this video presentation is to introduce learners to the main concepts of DigCompEdu framework.
- Duration: 11:48
- Difficulty: Easy
- Educational use: presentation
- Learning Outcomes:
    1. identify what the DigCompEdu framework is and its scope
    2. clarify the structure and the contents of the DigCompEdu framework

- Orientation/Focus: acquire new knowledge
- Delivery mode: online learning
- Hardware/Software/Other Resources: : computer

Implementation

- Country were the OER was implemented: Worldwide
- Framework/organization that was applied to: STEAMonEdu Massive Open Online Course
- Audience size: 1000+
- Description, evaluation and lessons learned during the OER implementation

Educational material/resources (file URL) accompanying the OER (if available)

- Educational material/resources name: W6.3.3.a: Introduction to the STE(A)MComp Edu framework
- License: CC BY-NC-SA
- Educational resource type: video
- Language of the material/resource: English
- URL: https://mooc.cti.gr/2021/mod/lesson/view.php?id=6044&pageid=7024

6.2.3 STE(A)M OER specification - Italy

General information:

- STE(A)M OER name: MOOC *“CrowdDreaming: Youth co-create digital culture”*
- Abstract:

The aim of this project is to raise teachers' awareness about digital cultural heritage and prepare them for providing support to young people in developing digital cultural heritage projects.

- Language: English-Italian-Greek-Croatian-Latvian
- STE(A)M discipline: All subjets
- Area/Topic:

The course enhances the value of the cultural heritage as mean to promote the European identity, common values, cultural dialogue and understanding, promoting the value of Digital Cultural Heritage as a mean for social inclusion and it promotes the use of innovative and content-based learning education in the field of culture

- Key terms: education, digital education, STE(A)M education, cultural heritage, digital heritage
- License:
- Author of the OER:
  1. All Digital (Telecentre-Europe AISBL)
  2. Stati Generali dell'Innovazione (SGI)
  3. Centar tehničke kulture Rijeka (CTC)
  4. Latvijas Informācijas un komunikācijas tehnoloģijas asociācija (LIKTA)
  5. Hellenic Open University (HOU)

- Audience: teachers, heritage workers
- Age range: 25 - 70
- Audience competence: Beginner
- Educational/training framework: high school - University
- Educational/EQF level:

Educational details

- Educational subject: all the subjects
- Description of the OER:

The program includes 6 themes:

1. The Art of Crowd dreaming method
2. Project development
3. Digital Tools for Digital Content Creation
4. Digital Storytelling
5. Digital Cultural Heritage
6. Media literacy

- Duration: 35 hours (26h training + 9h coaching circles)
- Difficulty: Easy
- Educational use: interdisciplinary
- Learning Outcomes:
  1. Enhance the value of the cultural heritage as mean to promote the European identity, common values, cultural dialogue and understanding

2. Include disadvantaged audience in the fruition of digital cultural assets, promoting the value of Digital Cultural Heritage as a mean for social inclusion
3. Promote the use of innovative and content-based learning education in the field of culture
4. Facilitate the acquisition of digital competences for both teachers and students
5. Increase public awareness (among schools, education systems, civil society organisations, communities, policy-makers) on the value of Cultural heritage as a mean for European values education and social inclusion

- Orientation/Focus: acquire new knowledge, develop new skills
- Delivery mode: Online Course
- Hardware/Software/Other Resources: No

Implementation

- Country were the OER was implemented: Italy, Greece, Latvia, Croatia
- Framework/organization that was applied to:
- Audience size: 25+
- Description, evaluation and lessons learned during the OER implementation

Educational material/resources (file URL) accompanying the OER (if available)

- Educational material/resources name:
- License:
- Educational resource type:
- Language of the material/resource:
- URL: https://crowddreaming.eu/results/

6.2.4 STE(A)M OER specification Germany

General information:

- STE(A)M OER name: Programmieren für die Zukunft – Eine Wetterstation mit dem Calliope mini
- Abstract:

The manual for a weather station with the Calliope mini contains detailed didactic, pedagogical, argumentative and technical support for teachers to create their own weather station independently and easily on site. The Calliope mini, a minicomputer with the help of which children can be introduced to programming step by step, is at the centre.

- Language: German
- STE(A)M discipline: Natural science, Technology, Informatics, Arts
- Area/Topic:

The manual supports teacher’s experience in conducting learning activities related to natural phenomena in combination with technological steps.

- Key terms: education, digital education, STE(A)M education

- License: CC by-SA 4.0
- Author of the OER:

Helliwood media & education im fjs e.V.

- Audience: teachers, educators
- Age range: from 20
- Audience competence: Beginner
- Educational/training framework: school, non-formal education
- Educational/EQF level:

Educational details

- Educational subject: weather, precipitation, light, temperature, wind
- Description of the OER:

The handbook provides a detailed introduction to implement a learning activity with Calliope within a class. Within four examples the educator understands how to code a Calliope for measuring weather phenomena like temperature, light etc.

- Duration: 4 x 60 Minutes
- Difficulty: Easy
- Educational use: interdisciplinary
- Learning Outcomes:
- Orientation/Focus: develop new skills
- Delivery mode: Book
- Hardware/Software/Other Resources: calliope set

Implementation

- Country were the OER was implemented: Germany
- Framework/organization that was applied to: German Initiative Code Your Life
- Audience size:
- Description, evaluation and lessons learned during the OER implementation

Educational material/resources (file URL) accompanying the OER (if available)

- Educational material/resources name: Programmieren für die Zukunft – Eine Wetterstation mit dem Calliope mini
- License: CC by-SA 4.0
- Educational resource type: pdf
- Language of the material/resource: German
- URL: https://www.code-your-life.org/Praxis/Calliope_mini/mediabase/pdf/2780.pdf

6.2.5 STE(A)M OER specification Spain

General information:

- STE(A)M OER name: 2021 - Innovació educativa, impressió 3D i cultura maker a la clase (2021 - Educational innovation, 3D printing and culture maker in the classroom)

- Abstract: This training course aims to train teachers in schools in profiles that integrate design and digital manufacturing technologies into STE(A)M activities, especially those related with having student and educational communities answering to the COVID-19 pandemic challenges. Educators obtain the necessary skills and competences in design and using digital technology, to be able to bring these technologies to the classroom and share with their students and other teachers what they have learnt. In short, this training allows primary and secondary school teachers to involve their educational community in being part of the movement of teachers and educators that has produced EPIS and articles for individual protection for health personnel.

(More info: The situation caused by the Covid-19 pandemic has caused a great deal of movement in the maker community around the world, including Catalonia. Colectic, the authors of this training, has offered this online training to different professionals with the need to identify useful digital tools and resources to manage educational projects, social and educational; and has also provided computer equipment to people with special social needs. In short: using the available technologies, 3D printing technology and citizen collaboration networks framed in the maker culture, FLOSS and the commons, Colectic has positioned itself as one of the leading organizations in Catalonia in the face of the crisis derived from the COVID-19 pandemic.

This crisis is not over and now more than ever initiatives are needed that show some of the good practices carried out, that have the capacity to incorporate more agents of change and that transfer the know-how acquired to be able to give life to new ones. Initiatives and strategies that may be needed in the future, incorporating the educational community to reach more groups, more entities and more people. Students, at all levels of education, can also be incorporated into these strategies, inspired by the Learning-Service models that, from Colectic, we are promoting in collaboration with different educational and social entities.)

- Language: Catalan
- STE(A)M discipline: Technology, Engineering, Arts, Mathematics are involved
- Area/Topic: e.g – health, eco-system
- Key terms: e.g - STE(A)M education, 3D printing, problem solving, learning by doing, PBL.
- License: e.g - CC BY-NC-SA
- Author of the OER: Luis Miguel Castillo, trainer, Colectic SCCL
- Author’s occupation: e.g – non formal trainer

Audience and Educational Framework

- Audience: e.g -Educators
- Age range: e.g – 18-99
- Audience competence: e.g - Beginner
- Educational/training framework: e.g - Elementary/primary school; Middle/junior high school
- Educational/EQF level: N/A

Educational details

- Educational subject: e.g - 3D printing for health protection.
- Description of the OER: Capacity building training for teachers and educators on the topic "Educational innovation, 3D printing and maker culture in the classroom. Learning by Making in the Classroom: How to Use 3D Printing against Covid-19"
- Duration: full duration of the OER implementation: e.g – 16 hours
- Difficulty: e.g - Medium
- Educational use: e.g Interdisciplinary project, group work, project-based learning, problem-based learning, Learning-Service.
- Learning Outcomes: e.g - Acquisition of practical skills that will help students build their own generators
    3. Understand how to apply 3D printing to the specific needs of the class and adapt to the curriculum.
    4. Promote a methodology based on learning with the active participation of students and inspired by the model of Learning-Service to the community.
    5. Introduction and use of design for the manufacture of objects
    6. Technical skills on the use of 3D printing machinery.
    7. Troubleshooting 3D printing
- Orientation/Focus: e.g - develop new skills and competences on how to apply STE(A)M education projects and 3D printing technologies
- Delivery mode: e.g - Face to face learning
- Hardware/Software/Other Resources: e.g – 3D printers, computers and laptops

Implementation

- Country were the OER was implemented: e.g – Spain
- Framework/organization that was applied to: public library at Barcelona city.
- Audience size: e.g – 15
- Description, evaluation and lessons learned during the OER implementation

The 15-hour training program is divided into 6 training sessions of 2.5 hours each.
Participants have completed a prior questionnaire (analysis of prior knowledge) and a subsequent satisfaction questionnaire.
At the end of the training, the participants have expressed their satisfaction with the training action, have a better perception of the usefulness of this technology in the classroom, have expanded their knowledge in relation to 3D printing technology, understand how it can be applied to a STE(A)M educational project and within the framework of the COVID-19 community response. On the other hand, they also comment that they will have difficulties to have this type of technology in the educational classroom.

Educational material/resources (file URL) accompanying the OER (if available)

- Educational material/resources name: - Innovació educativa, impressió 3D i cultura maker a la clase (2021 - Educational innovation, 3D printing and culture maker in the classroom)
- License: CC BY-NC-SA

- Educational resource type: digital content (handouts, digital presentation, videos)
- Language of the material/resource: Catalan
- URL: https://campus.colectic.coop/course/view.php?id=69

7 Educator's professional development

The educators' professional development has emerged as a recognised area of research, due to its importance for the learning process and its influence on student achievement (Borko, 2004). Training programmes should consider teachers' own professional aspirations and their representation of educational practices.

Hopefully, in the not too distant future, STE(A)M educator's competences will find their way into initial professional training, not just in their transversal aspects, but as a goal in themselves. In the meanwhile, continuous professional development (CPD) is the vehicle through which educators can acquire and improve these competences. It has been noted that CPD should also include methods for modelling and fostering creativity in the classroom (Perignat & Katz-Buonincontro, 2019) and STE(A)M education serves this purpose well.

On a practical level, MOOCs are a tool that is currently being used to deliver training for STE(A)M teachers across the world, just like the STEAMonEdu Project does, but it is not the only one taking this approach[50]. One of the main reasons behind this movement is that it helps overcome the deficit of expertise that might be encountered in anyone setting, while keeping the costs reasonable.

The chapter is divided into two parts: the first one deals with the ever-changing landscape of continuous professional develop, with emphasis on acquiring competences for STE(A)M education. The second part reflects on educators' agency, when it comes to creating opportunities for continuous professional develop.

7.1 STE(A)M education and continuous professional development

Continuous professional development is a constantly changing landscape, that is underpinned by certain factors, such as the conceptualization of the place of STE(A)M education within lifelong learning, the stakeholders that bringing it to life, or the competence frameworks used.

Lifelong learning has created the necessary environment in which STE(A)M education can thrive. Among other things, it allowed the development of collaborative pedagogies, it unified the paradigm that applies both to educational professionals and learners and it allowed the development of competence frameworks (e.g. Council of the European Union, 2018).

The formal element that brings together lifelong learning and continuous professional develop is represented by qualifications frameworks. Within the European Union they are developed at national level – the National Qualifications Frameworks (NQFs) – with all countries having mapped a clear correspondence to the European Qualifications Framework (EQF).

A tool that helps navigate qualifications at European Union level is the ESCO - European Skills, Competences, Qualifications and Occupations Framework. The STEAMonEdu project is attempting to link STE(A)M educator's competence to this framework so that they might be more readily certified across the Union.

[50] For example, the Choice Project takes a similar approach to training content delivery (https://www.euchoice.eu/)

Competence frameworks are versatile tools, that map the requirements for a certain area, like a profession or a learning domain. The Joint Research Centre of the European Union and UNICEF (2019) are just two examples of institutions that are preoccupied with developing such tools. In educational setting, commonly used frameworks target digital competences (DigComp) and their application in educational professions (DigCompEdu), social competences, entrepreneurial competences (EntreComp) and transferable skills. These instruments act as mediators that shape the development of training offers.

Training opportunities arise when a network of actors comes together, each of them with their own agendas, needs and resources. For example, educators need a clear image of how any training is connected to the curriculum they follow, the local community wants its resources to be used efficiently and its needs to be met and policy makers will want measurable results that inform their actions.

7.2 Educator's agency in continuous professional development

STE(A)M education needs to have a critical and empowering approach to continuous professional development. This means that it needs to question its own contribution to education and empower the educators to make their own decision regarding to opportunity to participate.

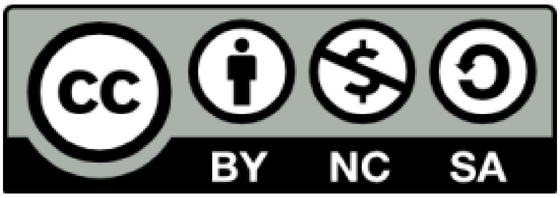
Learning involves a change on the learner's side, but when should this occur? Not all changes in the social and technological environment need to be immediately reflected in educational practices. Is STE(A)M education something worth incorporating in your practices? It should be up to each educator to decide.

It is very important that educators feel reasonably in control of their own professional development and that they incorporate new content in a meaningful way. Psychology uses the concept of *locus of control* (Rotter, 1966) to define a general tendency to attribute internal or external control over events. An internal locus of control – that attributes success to abilities and effort – is preferable to an external locus of control – that attributes success to how difficult the task was or how lucky you were.

Trainings are a place of exchange between participants, especially when the trainers and the trainees are education professionals. You become an agent just by accessing the page of a course, because you validate the fact that it is discoverable and that it is in some way attractive, but educators can exert this role in much more active and diverse ways. Each interaction during a course will bring another level of agency, with participants informing the organizers, the trainers and their peers of how you feel about the experience and how it can be better articulated.

Educators can also have an active approach towards the content of a training and try a) to transform it and adapt it to their own context, while considering the licensing restrictions that may apply and b) create new content, based on their own experiences and expertise. To this end, OERs provide a framework for using and reusing training materials and Creative Commons[51] the licensing arrangement that makes visible the rights and limitations they entail.

Training materials for the STEAMonEdu MOOC are licenced (see pictogram below) in a way that can be adapted for a new training course, while mentioning the names of the original authors and sharing the end products under the same license. Also, persons or institutions doing the adaptation will not be able to charge a fee for the materials.



(Image source: Creative Commons)

Each educators experience is a valuable resource that can be converted into training materials for their colleagues. Writing a blogpost, offering a short testimonial about a STE(A)M related experience, creating a video or a visual story are some of the ways of conveying one's experience, that has an underlying formative aspect attached to it. The STEAMonEdu platform[52] has a section where educators from across many countries have presented this type of content.

A more complex endeavour is to create a new training experience for other educators. Some of the modules of the STEAMonEdu MOOC set out the basic elements of course design, the use of OERs and examples of tools that can be used in STE(A)M education.

[51] https://creativecommons.org/about/cclicenses/
[52] https://steamonedu.eu/platform/

References

1. Aronson, E., Blaney, N., Sikes, J., Stephan, G., & Snapp, M. (1978). The JIGSAW classroom. Beverly Hills, CA: Sage Publications.
2. Bamford, A. (2006) The Wow Factor: Global research compendium on the impact of the arts in education. Munster: Waxmann Verlag Gmbh.
3. Boboli, C., (RO/EPP) (2019), Strengthening STE(A)M education in the EU – Policy recommendations.
4. Borko, H. (2004) Professional Development and Teacher Learning: Mapping the Terrain. In Educational Resources, vol. 33, no. 8, pp. 3–15, Nov.
5. Butler., D., McLoughlin E., O'Leary, M., Kaya, S., Brown, M. & Costello, E. (2020). Towards the ATS STEM Conceptual Framework. ATS STEM Report #5. Dublin: Dublin City University.
6. Castek, J., Woodard, R., & Schira Hagerman, M. (2020). Principles for Equity-centered Design of STEAM Learning-through-Making. University of Arizona. Retrieved from: https://circlcenter.org/events/synthesis-design-workshops.
7. Chapman, S.B. & Kirkland, S. (2013). Make Your Brain Smarter: Increase Your Brain's Creativity, Energy, and Focus. New York: Free Press.
8. Centeno, C. (2020). DigComp at Work Implementation Guide. Okeeffe, W. (ed.). Publications Office of the European Union, Luxembourg.
9. Cisco Systems, Reusable information object strategy (PDF), archived from the original on 2013-05-30.
10. Colectic & ALL DIGITAL (2020). Policy Influence Kit. Internal document of the STEAMonEdu Project (https://steamonedu.eu).
11. Council of the European Union (2018). Council Recommendation of 22 May 2018 on Key competences for lifelong learning.
12. Council of Europe, Compass – Manual for Human Rights Education with Young People, 2nd edition updated in 2020.
13. Dian, K., Atlantic press, Advances in Social Science, Education and Humanities Research, volume 581 (2021), Parents' Roles in STEAM Learning in Early Childhood.
14. Diego-Mantecón, Jose Manuel & Blanco, Teresa & Ortiz-Laso, Zaira & Lavicza, Zsolt. (2020). STEAM projects with KIKS format for developing key competences. Comunicar
15. ECEL2006-5th European Conference on elearning: ECEL2006. Academic Conferences Limited. ISBN 978-1-905305-30-8.
16. Educating for an Open Society Foundation (Ed.) (2020). Guide on STE(A)M education policies and educators' needs. Internal document of the STEAMonEdu Project (https://steamonedu.eu).
17. Edwards M.G. (2014) Meta-methodology. In: Michalos A.C. (eds) Encyclopedia of Quality of Life and Well-Being Research. Springer, Dordrecht.

18. European Commission (2019). Key competences for lifelong learning. European reference framework. Luxembourg: Publications Office of the European Union.

19. Finegold, D., & Notabartolo, A. S. (2010). 21st century competencies and their impact: An interdisciplinary literature review. Transforming the US Workforce Development System. In Finegold D, Gatta M, Salzman H, Schurman SJ, eds. Champaign, IL: Labor and Employment Relations Association, 19-56.

20. Gerard, R.W. (1967), "Shaping the mind: Computers in education", In N. A. Sciences, Applied Science and Technological Progress

21. Huser, J. et al. (2020). STEAM and the Role of the Arts in STEM. New York: State Education Agency Directors of Arts Education.

22. IBM, "What is Software Development". IBM. IBM. Retrieved 4 October 2021

23. Johnson, D., "What is Software". Business Insider. Business Insider. Retrieved 4 October 2021.

24. Keane, L., & Keane, M. (2016). STEAM by design. Design and Technology Education, 21(1), 61-82.

25. Kennedy, T. J., & Odell, M. R. L. (2014). Engaging Students in STEM Education. Science Education International, 25(3), 246– 258.

26. Huser, J. et al. (2020). STEAM and the Role of the Arts in STEM. New York: State Education Agency Directors of Arts Education.

27. La Monica Grus, C. (2020) D3.2 Working Guidelines. Non-formal education for promoting co-production of educational resources. Available at: https://d836acf4-f09b-4b78-9de2-b13f46b0b860.filesusr.com/ugd/6c0a6f_ea0b73b82ad54abd8e109f2eef447140.pdf.

28. Li, Y., Wang, K., Xiao, Y. & Froyd, J. E. (2020). Research and trends in STEM education: a systematic review of journal publications. International Journal of STEM Education 7, 11.

29. Iacob, M., & Proietti, E. (2020) Digital competence. European research, policy and frameworks. In Capogna, S., Cianfriglia, L. & Cocozza, A. (Eds.). Digital culture for educational organizations. Guidelines for Teachers and Education Agencies, Eurilink University Press: Rome.

30. Iacob, M., Fundatia EOS Romania in collaboration with STEAMonEdu project partners (2021), STE(A)M education framework. Internal document of the STEAMonEdu Project (https://steamonedu.eu).

31. Inoa, R., Weltsek, G. & Tabone, C. (2014). A study on the relationship between theatre arts and student literacy and mathematics achievement. Journal for Learning through the Arts: A Research Journal on Arts Integration in Schools and Communities, 10(1), 1-21.

32. Kim, S. (2021). Design Principles for Learning Environment based on STEAM Education. International Journal of Advanced Culture Technology, 9(3), 55–61. https://doi.org/10.17703/IJACT.2021.9.3.55.

33. Knoll, M. (1995). The Project Method: Its Origin and International Influence. In Lenhart, V. & Röhrs, H. (Eds.) Progressive Education across the Continents. A Handbook, New York: Lang.

34. Marshall, J. (2014). Transdisciplinarity and art integration: Toward a new understanding of art-based learning across the curriculum. Studies in Art Education, 55(2), 104-127.

35. Martin, L. (2015). The Promise of the Maker Movement for Education. Journal of Pre-College Engineering Education Research (J-PEER), 5(1), Article 4. https://doi.org/10.7771/2157-9288.1099.

36. National Certification Council for Activity Professionals. (2020). Certification Standards.

37. Ng, S. B. (2019). Exploring STEM Competences for the 21st Century. Current and Critical Issues in Curriculum, Learning and Assessment. UNESCO.

38. Palincsar, A.S. (1986). Reciprocal teaching. In Teaching reading as thinking. Oak Brook, IL: North Central Regional Educational Laboratory.

39. Papadouris, P. (2021) W1.1.1.b Conceptual clarifications of STE(A)M Education, aims and objectives [Lecture notes].

40. Perignat, E., & Katz-Buonincontro, J. (2019). STEAM in practice and research: An integrative literature review. Thinking Skills and Creativity, 31, 31–43.

41. PHERECLOS, Policy brief paper 4, Non-formal Education Providers in Open Schooling.

42. Pitt, J. (2009). Blurring the boundaries–STEM education and education for sustainable development. Design and Technology Education: An International Journal, 14(1).

43. Popescu, C., Bunescu, L., Papadakis, S., (2021), STE(A)M learning activity templates. Internal document of the STEAMonEdu Project (https://steamonedu.eu).

44. Project Management Institute (Ed.). (2008). A guide to the project management body of knowledge (PMBOK guide) (4th ed). Project Management Institute, Inc.

45. Rashid, A., Chivers, H., Danezis, G., Lupu, E., & Martin, A. (Eds.). (2019). The Cyber Security Body of Knowledge.

46. Rahmawati, Y., Ramadhani, S. F., & Afrizal (2020). Developing Students' Critical Thinking: A STEAM Project for Chemistry Learning. Universal Journal of Educational Research, 8(1), 72–82. https://doi.org/10.13189/ujer.2020.080108

47. Ritz, J. M., & Fan, S.-C. (2015). STEM and technology education: International state-of-the-art. International Journal of Technology and Design Education, 25(4), 429–451.

48. Rotter, J. (1966). Generalized expectancies for internal versus external control of reinforcement. Psychological monographs, 80 1, 1-28.

49. Sala, A., Punie, Y., Garkov, V. & Cabrera Giraldez, M. (2020) LifeComp: The European Framework for Personal, Social and Learning to Learn Key Competence, Publications Office of the European Union: Luxembourg.

50. Sotiroiu, M., Robberstaad, J., Ben-Horin, O. & Stergiopoulos, P. (2021) O1 The GSO4School. Framework and master plan. Available at:

http://gso4school.eu/wpcontent/uploads/2021/O1_D1_1/D1_1_GSO4SCHOOL%20Framework%20and%20Master%20Plan_FINAL.pdf.

51. Spyropoulou, N. D., & Kameas, A. D (2019). STEM Education: Future and Current Challenges for the Preparation of STEM Educators, in International Conference New Perspectives in Science Education. Italy: Filodiritto Editore.
52. Spyropoulou, N. D., & Kameas, A. D. (2020a). A holistic framework of STE(A)M educator's competences. In ICERI2020 Proceedings, pp. 4445-4450.
53. Spyropoulou, N., & Kameas, A. (2020b). Investigating the role of STE(A)M Educators: a case study in Greece. In 11th International Conference on Information, Intelligence, Systems and Applications, IISA, 1-6.
54. Spyropoulou, N. D. & Kameas, A. D. (2020c) Methodology for the development of a Competence Framework for STE(A)M Educators, in European Distance and E-Learning Network (EDEN) Conference.
55. Spyropoulou, N. D., & Kameas, A. D. (2020d). STEM Educator challenges and professional development needs: The educators' views. In IEEE Global Engineering Education Conference 2020 (pp. 554–562). IEEE Computer Society.
56. Spyropoulou, N., Iossifides (Iosifidis), A., Zaharakis, I., and Kameas, A., STEAM educational objects meta-data profile. Internal document of the STEAMonEdu Project (https://steamonedu.eu)
57. Stacey, O., De Lazzari, G., Grayson, H., Griffin, H., Jones, E., Taylor, A., & Thomas, D. (2018). A Review of the Existing Literature on Globalization of Science Curricula. In O. Stacey, G. De Lazzari, H. Grayson, H. Griffin, E. Jones, A. Taylor, & D. Thomas (Eds.), The Globalization of Science Curricula (pp. 5–21). Springer International Publishing.
58. STEAMonEdu MOOC course (2021): STE(A)M education for educators: Design, orchestration and implementation of STE(A)M education.
59. Texas Education Agency (2020) Texas STEM Framework. Available at: https://tea.texas.gov/sites/default/files/Texas_STEM_Framework_v20200728.pdf
60. Thibaut, L., Knipprath, H., Dehaene, W., & Depaepe, F. (2018). The influence of teachers' attitudes and school context on instructional practices in integrated STEM education. Teaching and Teacher Education, 71, 190-205.
61. UNICEF (2019). Global Framework on Transferable Skills.
62. University of Mississippi. "System Software". Archived from the original on 30 May 2001.
63. Winer, Goldstein & Vincent-Lancrin (2013). Arts for art's sake? The impact of arts in education. Educational Research and Innovation, OECD Publishing.
64. Wong, G. K., & Huen, J. H. (2017). A conceptual model of integrated STEM education in K-12. In 2017 IEEE 6th International Conference on Teaching, Assessment, and Learning for Engineering (TALE) (pp. 296-302). IEEE.

65. Smyrnaiou, Z., Georgakopoulou, E., Sotiriou, M., & Sotiriou, S. (2017). The Learning Science Through Theatre initiative in the context of Responsible Research and Innovation. In Proceedings of the 10th International Multi-Conference on Society, Cybernetics and Informatics: IMSCI 2017, 15(5), 9.

66. Zendler, A. (2018). English Teachers Assess Instructional Methods Supporting Knowledge Processes. International Journal of English Language Education, 6(1), 68.

67. Yakman, G., Interview - Developing STEAM Education to Improve Students' Innovative Ability.

68. Zendler, A., Seitz, C. & Klaudt, D. (2018) Instructional Methods in STEM Education: A Cross-contextual Study, EURASIA Journal of Mathematics, Science and Technology Education, 14(7), 2969-2986.