EUROPEAN COMMISSION
Education, Audiovisual and Culture Executive Agency

Erasmus+: Support for Policy Reform and Online Linguistic Support
Competence development of STE(A)M educators through online tools and communities
STEMonEDU — No 612911

D7: STE(A)M education framework

Work package: 3
Type: Report
Dissemination level: Public
Version: 1.0
Delivery date: 11/08/2021

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

Contributors Achiles Kameas, Athanasios Iossifides, Cornelia Popescu, 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

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Abstract

The STE(A)M education 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 STEAM education programmes. It

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, parents and the community, other educational service providers. 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. 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 future developments connected to technological and pedagogical changes.

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 five presents some of the elements that 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 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:

- 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.

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	Policies	- MOOC Module 5 - Policy influence toolkit - Guide on STE(A)M education policy - STEAMonEdu platform
		Parents and the community	- Not covered by the STEAMonEdu Project
		Other providers of educational services	- MOOC Module 6
3	Understanding competences	Educator's competences	- STE(A)M educator's competence framework - STE(A)M Educator's profile - MOOC Modules 2-4 - 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
		Curricular approaches	
		Teaching methods	
5	Specifications for OERs		- Examples of OERs - Learning activity templates - MOOC design guidelines
6	Professional development and communities of practice		- MOOC Module 6
7	STEAM body of knowledge		- STE(A)M ontology

As evident from the table, the project aims to touch a very wide array of issues pertaining to STE(A)M education, from the standpoint of the educator. Still, some areas remain unexplored, such as students' competences or engagement with parents and the local community.

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 of science and arts related competences.

1.1 How it started

STEAM - 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. The concept 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. It 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[1].

Before diving deeper into its meanings, let's see 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 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*".

[1] This opens up a debate about intentionality. While we agree 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.

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.

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[2] 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.

It is the treatment of arts that holds the key to understanding and practicing STE(A)M education. 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.

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. Throughout this document we will use this spelling, unless quoting other studies which have used the "STEAM" spelling.

STE(A)M education did not assume 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

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

ranged from the reduction of arts to creative thinking, to a fully integrated approach, where arts come with their own means of knowledge production and educational outcomes.

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.

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: the purpose, the definitions of STEAM, the definition of arts within STEAM, creativity as an outcome, arts education and 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: engaging minority and female students in STEM subjects, increasing interest in STEM fields, and developing skills necessary for STEM careers. 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	*"there seems to be a range of definitions for the "Arts" in the STEAM acronym. 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.

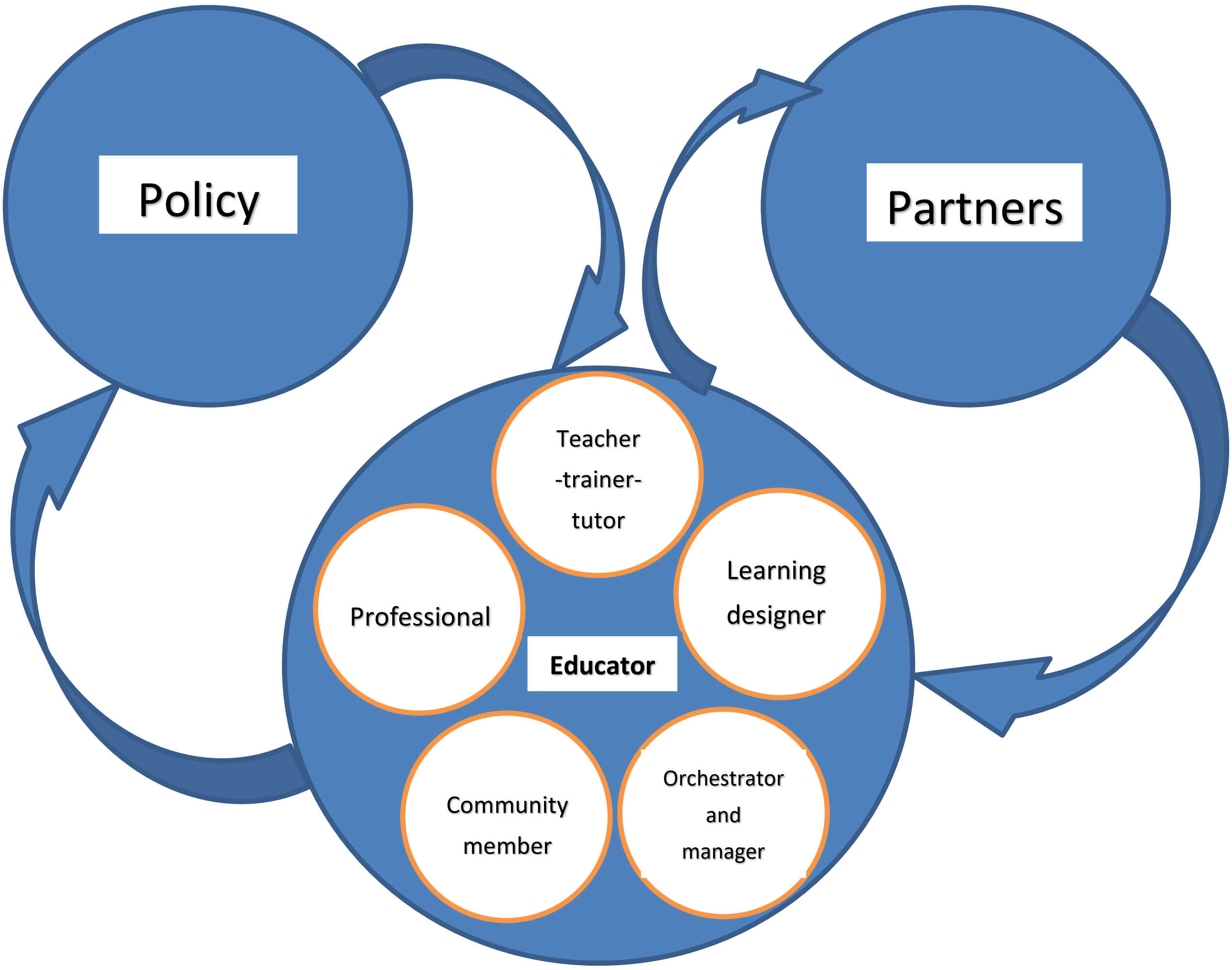
As noted by Huser et al. (2020, p. 4), STE(A)M is not merely equivalent to arts integration. STE(A)M is seen as a practice that recognizes the real-world role of the arts. Throughout its outputs and activities, the STEAMonEdu Project has taken an integrated approach to STE(A)M education, with arts as an integral part of the instructional process[3].

[3] **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 systems, find themselves in a complicated entanglement of regulations and stakeholders - each with their own needs 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 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 are 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 beneficiaries 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**" 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 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**" refers to coordinating procedures and outputs. Competences under this heading are distributed across two areas: a) educational procedure management, b) resource management.
- "**Community member**" refers to interacting with the environment. Competences under this heading are distributed across two areas: a) community building, b) application of policies.
- "**Professional**" 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 system

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 the voice of parents and the community should 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 [4] 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.

[4] **Available at: 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[5], the grant programme "Fondul Științescu"[6], or the "Lecțiile patrimoniului" Project[7] which used built heritage to teach a variety of STE(A)M subjects.

At European level, a recent collaboration[8] 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.

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.

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

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 treated 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.

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 2.2 Content management 2.3 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

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 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.

3.2 Students' competences

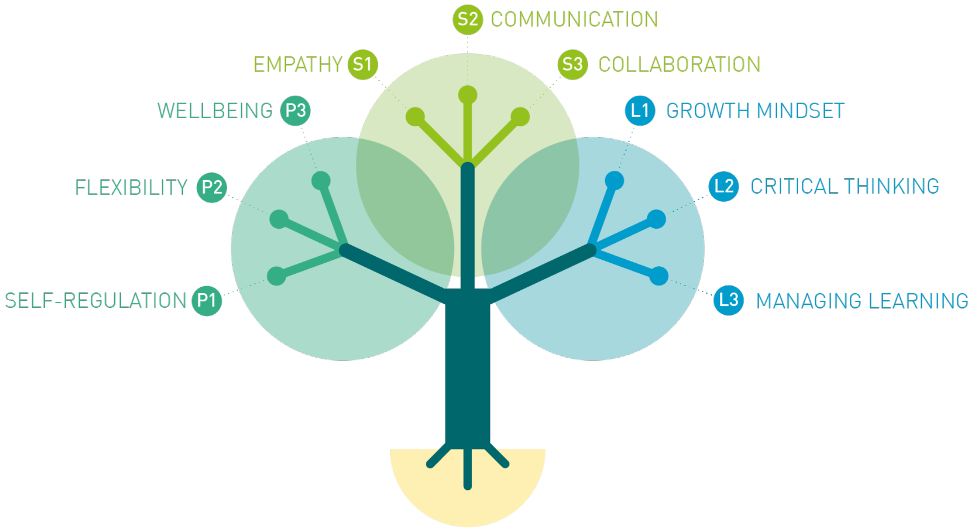
In our review, we have not found any references to specifically developed frameworks of students' STE(A)M competences, but there are many frameworks that are being used as a benchmark and guide when developing STE(A)M projects, such as: key competences, national standards, 21st century competences, digital 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 divided intro 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[9], 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 future developments connected to technological and pedagogical changes. Not all references are centred on STE(A)M education, as the available literature is still limited. Some of the selected literature is based on STEM education, if it could be considered a good enough proxy. 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[10], 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,

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

[10] „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).

- 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 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 boundries.
- 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[11] 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 of the knowledge processes build, process, apply, transfer, assess and integrate. The definitions they used for these processes were:

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

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

No.	Computer science teachers	Maths teachers	English language teachers
16	concept mapping	portfolio method	leittext method
17	leittext method	leittext method	experiment
18	web quest	web quest	programmed instruction
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[12]: 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

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

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[13]: 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 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[14]: 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.

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

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

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 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 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[15]. One of the main reasons behind this movement is that it helps overcome the deficit of expertise that might be encountered in any one 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.

5.1 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).

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

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.

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.

5.2 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.

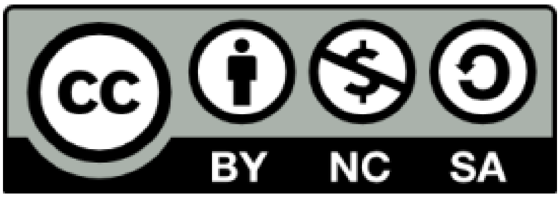
Learning involves a change on the learner's side, but when should this occur? Not all changes in the social and technological environment need to be immediately reflected in educational practices. Is STE(A)M education something worth incorporating in your practices? It should be up to each educator to 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[16] 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.



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[17] 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.

[16] https://creativecommons.org/about/cclicenses/
[17] https://steamonedu.eu/platform/

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