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

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D6: Guide on STE(A)M education policies and educators' needs

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Abstract:	This document presents an analysis and a list of STE(A)M education policies and the needs of educators in order to implement them.
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Table of contents

List of tables

Abstract

D6 Guide on STE(A)M education policies and educators' needs presents STE(A)M education policies identified and by the community members and the needs of the educators in order to implement them.

The guide is developed as part of the STEAMonEdu project funded through the Erasmus+ programme of European Union, which aims at increasing the adoption and impact of STE(A)M education by investing in the community of stakeholders and the professional development of educators.

In this context, an EU and country level policy analysis supports the project in reaching its targets, but also supports further research as well as any stakeholder interested in the implementation of STEAM in education across Europe. The guide covers both policies at the EU level and those at national and regional level in five countries: Germany, Greece, Italy, Romania and Spain.

D6 includes the following main parts:

1. A presentation of the **methodology** used by the project partners in order to collect and analyse STE(A)M education policies. This part includes specific common definitions that supported the research, as well as the framework used to analyse the collected policies and the overall policy context.
2. An **overview of the policy contexts** in EU and the five EU member states regarding the implementation of STE(A)M in education. Besides analysing the collected policies, this document aims at providing a broader picture of the past and current efforts or endeavours to promote STE(A)M, as well as a look into what future holds. Challenges and bottlenecks are also explored and summarised.
3. A **list of STE(A)M education policies** collected by the STEAMonEdu community available at https://steamonedu.eu/platform/policies. Project partners have reached out to their wider networks in order to collect the most relevant policies that promote STE(A)M. This guide presents 15 policies that are bringing significant impact on the education systems, by reforming the curriculum or by ensuring a broader reach of STE(A)M in schools.
4. A summary of findings related to the **efficiency and impact of the collected policies**. Even though there's very little information about the evaluation of the policy impact in the field of STE(A)M in education, it is worth mentioning what it's available, and to stress the importance of measuring the efficiency and impact of ongoing and current policies.
5. A short **analysis of STE(A)M educators needs** that provides a very useful insight in what policies should be focusing on.
6. A list of **conclusions and recommendations** for policy makers and for education stakeholders, by going through the policy context, the existing landscape of policies and at the needs of STE(A)M educators.

1 Methodology to select and analyse policies

This section summarises and presents the methodological framework used by the project partners to identify, select and analyse STE(A)M in education policies.

The process to identify and collect policies has been supported by desk research as well as data collection through online surveys. The project partners aimed at identifying and collecting the most relevant policies according to the definitions agreed within the consortium and mentioned below, in section 1.1.

The partners have been responsible for collecting and analysing policies, as follows:

1. ALL DIGITAL – EU level
2. SDI – Germany
3. CTI and RDEWG – Greece
4. SGI – Italy
5. EOS – Romania
6. COLECTIC – Spain (with a focus on Catalunya)

1.1 Collecting the policies

While the desk research has been undertaken by the project partners, the online surveys have been opened to external stakeholders, through the wider STEAMonEdu community, with the scope to identify and collect as many relevant policies as possible. All policies are available on the STEAMonEdu online platform, at https://steamonedu.eu/platform/policies. The summary of each policy is available in English, however the full content of the policy is only available in the national language in which it was originally published.

Table 1 – Policy structure on the STEAMonEdu platform

Type of Information	Mandatory/ optional	Comments
General Info		
Title	**Mandatory**	
Language	**Mandatory**	
Purpose (100 words)	**Mandatory**	A concise statement of the rationale for the policy. Summary (one paragraph) clearly stating the important policy content.
Issuing date	**Mandatory**	When was this policy issued?
Key Terms	**Mandatory**	The values have to be individually searchable. Multiple keywords may be given. Already used keywords to appear when typinng.
Originating country/region	**Mandatory**	In addition to countries "EU" should be mentioned first in the list in order to be able to upload EU policies.

Policy approval authority	**Mandatory**	The highest administrative or academic officer or group authorizing the policy.
Initiator / author	Optional	This refers to the policy maker, i.e. the person(s) that initated the policy, if available.
Applicability and audience		
Audience	**Mandatory**	Exactly who the policy applies to.
Aplicability area	**Mandatory**	
Educational Framework	**Mandatory**	This refers to the framework for which this policy has been designed
Details		
Reason for policy	**Mandatory**	The information in this section answers the question as to why the policy exists (legal or regulatory reasons, description of conflict or problem the policy will resolve, overall benefits)
Description of the policy	**Mandatory**	Most important section of the policy. It will provide specific direction for the intended audience. Period and sources may be given.
Implementation procedures and plan	**Mandatory**	Reference to detailed procedures that are recommended in order to carry out the intent of the policy.
Structures for implementation	**Mandatory**	Who should implement the procedures
Monitoring and evaluation	Optional	Methodology for monitoring and evaluation
Definitions	Optional	List unique terms that, by being defined, would add to the reader's understanding of the basic policy
Cognizant office / helpdesk	Optional	The office and specific individual position title (with contact details) that should be contacted for interpretations, resolution of problems, and special situations.
Related policies / references	Optional	Information about related policies or procedures, guidelines, forms, etc. Give complete references and ensure that documents cited are readily available

1.2 Analysing the policies

For this guide, STEAM education is defined as an approach to teaching in which students demonstrate innovative and critical thinking and creative problem-solving at the intersection of these disciplines. STEAM education uses arts integration as an instructional approach and for experiential and inquiry-based learning — and provides multiple access points for students to engage in the creative process and meet objectives in all subject areas.

In the context of this project, the following STE(A)M policies have been collected and analysed:

- EU policies
- National (governmental) policies
- Regional policies
- Institution level policies (e.g. schools)

The following types of documents may constitute STE(A)M policies:

- Legislations
- Strategies
- Regulations
- Action (operational) plans
- Policy actions
- Policy communications / recommendations

The analysis of the collected policies has been carried out by using a series of criteria / policy questions that are presented in the matrix template below. This activity has been performed by the responsible project partners. In this effort, some policy makers have been consulted to bring clarity and accuracy to the policies, and to the implementation progress.

Table 2 – Policy analysis matrix template

#	Policy analysis question	Checklist			Choice explanation
		Yes	*No*	*Partially*	
1	Is the problem well framed?	☐	☐	☐	
2	Is it based on evidence and research findings?	☐	☐	☐	
3	Does it offer realistic recommendations and solutions?	☐	☐	☐	

4	Does it include targets and/or performance indicators that can be tracked?	☐	☐	☐	
5	Did the policy produce the intended outcomes and impacts? (only for implemented policies)	☐	☐	☐	
6	Does it have the potential to be adapted and reused in other contexts?	☐	☐	☐	

Based on the analysis, 15 most relevant policies have been selected to be included in this guide, in section 3: *STE(A)M education policies collected by the STEAMonEdu community.*

Beyond analyzing the policies, the STEAMonEdu consortium performed an analysis of the policy context in each project country and at the EU level, by researching a number of existing publications as well as by gathering information from the wider project community. The findings are presented in the following section of the guide, section 2: *STEAM education policy overview in EU and the partners' countries*.

2 STE(A)M education policy overview in EU and the partners' countries

The STEAMonEdu project partners have completed a survey in which they were asked to provide a STE(A)M education policy context overview in their countries, respectively at the EU level. Here are their findings:

2.1 EU

The current European scenario has recognised the importance of an integrated and multidisciplinary education, creating new skills and competences in the labour market. 21st century skills encompass creative and critical thinking, problem-solving, and a technical and scientific approach among the most relevant and transversally envisaged competences. Expertise and knowledge of STEM 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 STEM Education as a means to foster scientifically oriented careers, initiating from a very early age.

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".

Moreover, a series of consultations between major EU policy makers led to the publication of official recommendations (COUNCIL RECOMMENDATION of 22 May 2018 on key competences for lifelong learning) and communications (Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions) that encourage progress on adoption and implementation of STEAM education, by calling for better research, knowledge sharing and awareness raising.

Among the notable initiatives to advocate towards a STEAM Education framework, a series of funding schemes have been set by the European Commission in order to provide support for STEAM Education in Europe.

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.

The programme enables societal actors such as citizens, policy-makers, enterprises, researchers to develop collaborative actions in full alignment to the increasingly demanding needs and expectations of European society. This has generated Responsible Research and Innovation, an overarching and innovative approach towards research and innovation.

Nevertheless, the challenge to achieve a full integration of the STEAM disciplines remains, despite the attempt of developing and consolidating a structured and effective educational framework. Not all STEAM disciplines are equally represented and accessible to young target groups.

2.2 Germany

The Standing Conference of the Ministers of Education and Cultural Affairs of the Länder in the Federal Republic of Germany has focused its work on the further development and introduction of nationwide educational standards in the area of mathematical, scientific and technical teaching.

It has succeeded in describing demanding and feasible educational goals in the form of competencies. Schools must develop teaching concepts and out-of-school learning and experience opportunities. The individual Länder have recorded the activities to strengthen mathematical, scientific and technical education in a catalogue of measures.

There is a well-established STEM policy which was initiated more than 14 years ago. Meanwhile STEM education is supported even for very young children and starts already in the kindergarten. Implementation in educational curricular of individual competences in connection with media use or in connection with STEM subjects has already taken place.

Some STEAM actions and initiatives are already visible for kindergarten and pre-school, but for primary, secondary and high school STEAM is not anchored in German educational system. In contrast, a considerable number of non-formal educators and initiatives offer a wide range of STE(A)M educational opportunities.

The Federal Ministry of Education and Research published the STEM Action Plan in 2019 and defined four fields of action: STEM education for children and young people, STEM professionals, opportunities for girls and women in STEM, and STEM in society.

It would also be possible to access the structure of the previously established STEM networks, which have already created local bodies for STEM education and training and support educational institutions such as kindergartens and schools in exploring and discovering the world of mathematics, IT, science and technology with children and young people.

2.3 Greece

There are no official state policies to promote the implementation of STE(A)M Education in Greek public schools. The policies are exhausted in the urge for implementation of STE(A)M Education in texts of the Institute of Educational Policy (IEP). IEP is a scientific agency that provides support to the Minister of Education, Research and Religious Affairs on issues, among others, regarding primary and secondary education. IEP deals with scientific research and study and provides ongoing scientific and technical support on relevant educational policy planning and implementation.

2.4 Italy

The responsibility for the development of educational policies at a national level in Italy lies with the MIUR - Ministry for Education, University and Research. Currently, the reference

document is the PNSD - National Digital Development Plan, which is part of the "La Buona Scuola" initiative (law 19.07.2015). It is a strategic plan that defines the general lines of action for the digital transformation of the school. STEAM education is located within the "Digital, Entrepreneurship and Work" area of expertise. The STEAM approach is mainly presented as a way to preparing for STEAM careers in the world of work with emphasis on its effectiveness in the development of soft skills. Its concrete promotion is entrusted almost exclusively to Action # 20 "Girls in Tech & Science", aimed at stimulating girls' enrolment in STEM study courses. The delta in the inscriptions is the suggested measurable indicator.

The declination of the MIUR strategic lines on educational policies is entrusted to the individual schools, which enjoy wide decision-making autonomy as established by law 59/1997. In Italy there are 8,160 schools, divided into over 40,000 locations. On average, each institution has 900 students and 120 employees. Each institution must define its own educational policies in the form of a PTOF (Three-Year Plan of the Educational Offer). It is in these plans that concrete references can be found to policies based on the STEAM approach.

Unfortunately, from this context derives a great fragmentation of policies and a difficulty in identifying strategic lines of national scope, in the absence of a development by MIUR of the scant indications provided in the 2015 plan. There is a growing interest in the STEAM approach in the local PTOFs in the last three years, but at the same time very often the initiatives are attributable more to isolated experimental practices or projects than to actual development lines. The hope is that within a few years the current fragmentation and periodicity will create the humus for the development of a grassroot movement for the widespread adoption of the STEAM approach.

2.5 Romania

During the past decade efforts have been made to reframe the national core curriculum, from an outcomes-based curriculum, to a competence-based curriculum, in connection to the 8 key competences defined for lifelong learning promoted by the European Council. Romania's participation in international testing programmes, such as PISA and TIMSS, has also been a defining factor in the way curricular policies have been shaped during the last decade. This has had a significant impact on how STEAM education is understood, but there is little information available on how practices have changed in order to incorporate this shift in understanding.

Both by public and private bodies have promoted a series of system level programmes supporting teaching practices of STEAM subjects. There is a need for greater cooperation between these bodies, as their initiatives have been mostly developed independent of each other.

Currently, there is no overarching frame for the promotion of STEAM education, with no national level strategy. The Romanian education system needs new approaches towards STE(A)M education, that could raise interest in these subjects, as policies are limited in their scope and support for educational practices.

2.6 Spain

In Spain, the educational competences of the formal levels of education are divided between the state government (Ministry of Education and Professional Training) and the regional governments (Councils or Departments of Education). In this way, the Ministry of Education and Vocational Training establishes the common contents and assessable learning standards of core subjects and sets the minimum number of hours for core subjects. The Departments for Education of the Autonomous Communities complement the contents of core subjects, and they establish the contents of specific subjects and the subjects that are freely structured by the Autonomous Communities. Accordingly, the regional government makes methodological recommendations to educational institutions within their remit. Thus, everything that is related to formal education in the field of STE(A)M is the responsibility of regional governments.

Let's focus on Catalunya, where Colectic, the STEAMonEdu partner, is implementing this project. The Government of Catalonia, some universities and some jointly private initiatives are promoting STE(A)M education through different initiatives at Catalunya. Supporting teachers and learners, creating and developing activities and generating new communities are the main strategies developed.

In 2009, the government established that the Catalan Department of Education should favour initiatives for the development of pedagogical and curricular innovation projects that aim to stimulate the capacity, learning, personal skills and potential of educators, the school success of all students, the improvement of educational activity, and the development of educational projects of the educational centers. It also stated that these projects may refer to one or more centers and involve, where appropriate, links with universities, economic sector or other organizations. The two decrees – Decree 119/2015 of 23 June on the organization of primary education and Decree 187/2015 of 25 August on the organization of compulsory secondary education – determined the competences in the scientific, technological and mathematical fields and their evaluation.

In 2016, in relation to the STEM disciplines (Science, Technology, Engineering and Maths), the Parliament of Catalonia urged the educational authorities to take the necessary actions to ensure that all students achieve, during primary education, the necessary basic skills to be, in addition to consumers, creators of technological solutions in the digital society, taking into account the digital competence that students must develop at this stage Therefore, the mandate implies that programming and educational robotics activities should be developed at school from of the first courses of compulsory education.

At the same moment (2016), the Secretariat for Digital Policies, in collaboration with the Department of Education took an initiative: the creation and promotion of the Bitbot programme to stimulate and promote the private initiative in order to achieve one goal: to have more STE(A)M activities in the after-schools programmes.

Subsequently, by Government Agreement on 2017, the STEMcat interdepartmental working group was created, with the aim of drawing up and monitoring a plan to promote scientific and technological vocations in engineering and mathematics with students in Catalonia.

3 STE(A)M education policies collected by the STEAMonEdu community

A total of 19 STE(A)M education policies have been collected and analysed by the project partners through the STEAMonEdu community, 15 of which are being presented below.

3.1 EU

The most relevant policies related to STEAM Education are listed below, although the majority still address STEM instead of STEAM disciplines.

1. **Digital Education Action Plan (2021-2027)** - *Resetting education and training for the digital age*

The Digital Education Action Plan (2021-2027) expressly refers to STEM disciplines by envisaging a more consistent participation of women in STEM 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 STEM 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*".

2. **European Skills Agenda for sustainable competitiveness, social fairness and resilience**

Within the actions contributing for Skills for jobs in a green and digital economy, STEM disciplines are explicitly addressed among the 12 actions included in the Skills Agenda. More specifically, an evident need of "*Increasing STEM graduates and fostering entrepreneurial and transversal skills*" has been identified. This will contribute to supporting the Commission in improving the relevance of skills within Member States enhancing sustainable competitiveness, ensuring social fairness and building on resilience. Especially following the critical scenario caused by the public health crisis, it is of uttermost importance for citizens in the EU to strengthen their existing skills and adapt to the changed labour market.

3. **COUNCIL RECOMMENDATION of 22 May 2018 on key competences for lifelong learning** (2018/C 189/01)

The Council Recommendation of 22 May 2018, having regard to the Treaty on the Functioning of the European Union and to the proposal from the European Commission refers explicitly to the fact that nowadays, competence requirements have changed with the result that technologies currently cover a crucial role in society and entrepreneurial, social and civic competences have become essential for citizens to adapt to change.

The Recommendation also makes reference to the aforementioned surveys compiled by the Organisation for Economic Cooperation and Development (OECD) Programme for International Student Assessment (PISA) or the OECD Programme for the International Assessment of Adult Competencies (PIAAC), which have highlighted across Europe the

absence of basic skills among teenagers and adults, especially in disciplines such as reading, mathematic or science.

There is an explicit reference to STEM Education whilst clarifying the background context for the Recommendation, by stating that "*In order to motivate more young people to engage in science, technology, engineering and mathematics (STEM) related careers, initiatives across Europe started to link science education more closely with the arts and other subjects, using inquiry-based pedagogy, and engaging with a wide range of societal actors and industries. While the definition of those competences has not changed much over the years, the support of competence develop-ment in STEM becomes increasingly relevant and should be reflected in this Recommendation".*

It also encourages Member States to support the development of key competences with particular attention to a series of aspects among which "*fostering the acquisition of competences in sciences, technology, engineering and mathematics (STEM), taking into account their link to the arts, creativity and innovation and motivating more young people, especially girls and young women, to engage in STEM careers;"*

In relation to the delivery of key competences, in the perspective of fostering a variety of learning approaches and environments, "*Learning methodologies such as inquiry-based, project-based, blended, arts- and games-based learning can increase learning motivation and engagement. Equally, experimental learning, work-based learning and scientific methods in science, technology, engineering and mathematics (STEM) can foster development of a range of competences".*

Moreover, the Reference Framework establishes eight key competences among which but not limited to Mathematical competence and competence in science, technology and engineering.

It is essential to note that a Recommendation does not entail an obligation towards Member States in the subsequent adoption of a specific practice. The Commission aims to provide guidance and a clear indication of the actions to undertake in order to ensure full alignment with the EU strategies and key priorities, but it is not mandatory to fulfil such expectations.

4. **Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions** - *School development and excellent teaching for a great start in life* (COM(2017)248final).

The Communication refers to STEM Education explicitly, whilst addressing the challenge of *Developing better and more inclusive schools.* The Commission commits to act in order to complement actions taken by Member States, by offering "*Support improvements in school level education in science, technologies, engineering and maths (STEM) by promoting best practice in developing links and cooperation of higher education, research, businesses with schools at EU level and effectively addressing gender gaps and stereotypes in STEM, using Erasmus+*".

5. **Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions** - *Renewed EU Agenda for Higher Education* (COM(2017)247final).

In the Communication, among the challenges that Europe's higher education systems faces, the Commission lists "*A mismatch between the skills Europe needs and the skills it has: many parts of the EU are experiencing shortages in certain high-skill professions, both in terms of qualifications and the quality of the associated skills. At the same time, too many students graduate with poor basic skills (literacy, numeracy, digital) and without the range of transversal skills (problem-solving, communication, etc.) they need for resilience in a changing world*."

The Communication further explores ways of tackling skills mismatches and promoting excellence in skills development with direct reference to STEAM Education. More specifically, the Communication states: "*Addressing Europe's high-level skills needs requires action. First, more people need to be attracted to the fields of study that prepare students for jobs where shortages exist or are emerging. In many EU Member States there is unmet demand for graduates in science, technology, engineering, (arts) and math's (STE(A)M) fields, medical professions and teaching. Second, all students in advanced learning, irrespective of discipline, need to acquire advanced transversal skills and key competences that will allow them to thrive. High-level digital competences, numeracy, autonomy, critical thinking and a capacity for problem-solving are increasingly crucial attributes"*.

This is continued further, with a commitment on behalf of the Commission to address such issues with particular specific actions, and with reference to STEAM Education it aims to "*Launch an up-scaled EU STE(A)M coalition bringing together different education sectors, business and public sector employers to promote the uptake of relevant STE(A)M subjects and modernise STE(A)M and other curricula, including through more multi-disciplinary programmes and cooperation between relevant faculties and HEIs".*

6. **Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions** - *Rethinking Education: Investing in skills for better socio-economic outcomes* - COM/2012/0669 final

The Communication still refers to STEM against STEAM education, but highlighting the growing demand of specific profiles and STEM related skills. More specifically, the Commission states that "*the demand for a qualified workforce in technology and research intensive sectors is and will remain at a high level, with an impact on the demand for science, technology, engineering and mathematics (STEM) related skills. Greater efforts must now be made to highlight STEM as a priority area of education, and increase engagement at all levels. Although broad challenges are well known, such as the need to make it more attractive to females, it is also now important to increase understanding of the career pathways followed by STEM graduates*".

7. **Erasmus+ Programme Guide**, version 2, based on REGULATION (EU) No 1288/2013 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 11 December 2013 establishing 'Erasmus+': the Union programme for education, training, youth and sport and repealing Decisions No 1719/2006/EC, No 1720/2006/EC and No 1298/2008/EC (Text with EEA relevance).

The policy aims to provide guidelines for the implementation of the Erasmus+ Programme and in particular, to enhance the attractiveness of STEM by reforming STEM curricula with a STEAM approach. The policy also comprises actions to increase the level of interest towards STEM Education via the development and implementation of national STEM strategies."

Among the key priorities addressed by the Programme, there is a clear reference to *Increasing the levels of achievement and interest in science, technology, engineering, and mathematics (STEM).* The priority focuses on *"Promoting the development of national STEM strategies; developing partnerships between schools, businesses, higher education institutions, research institutions, and wider society; promoting effective and innovative pedagogies and assessment; promoting the STE(A)M approach to education through interdisciplinary teaching of STEM in cultural, environmental, economic, design and other contexts, with the involvement of all academic discipline".*

Likewise, while addressing the priority of *Tackling skills gaps and mismatches* there is a specific reference to STEM and STEAM: *"developing, testing and implementing flexible and modular course design (part-time, online or blended) and appropriate forms of assessment; d) increasing attractiveness and reforming curricula for STEM with a STEAM approach including real-world applications, inquiry-based and ICT-enriched learning, collaborative practices, including university-business cooperation".*

3.2 Germany

1. **STEM Action Plan**

Was published in 2019 by the Federal Ministry of Education and Research and it defined four fields of action: STEM education for children and young people, STEM professionals, opportunities for girls and women in STEM, and STEM in society.

On the one hand the plan aimed to establish networking clusters in different regions of Germany. On the other hand, a networking hub / centre was initiated. Those activities were funded from the government with 55 million Euro.

3.3 Greece

1. **Proposal for the inclusion of STE(A)M education in:**
    a. the institution of 'Educational Groups' at the Model and Experimental Schools
    b. into the subject matter "Flexible Zone of Cross-thematic and Creative Activities" of the primary school

The Institute of Educational Policy (IEP) has proposed in 2015 to design curricula based on STEM Education as it better serves learning through holistic problem solving and it bridges the gap between science and its applications.

Specific reference, also, to the implementation of STE(A)M Education is on a proposal of IEP (2020) for the pilot introduction in Primary and Secondary Education of the action entitled "Skills Workshops". "Skills Workshops" is the trial introduction of new thematic cycles in the Kindergarten and the Elementary and High School curriculum in order to enhance the cultivation of mild skills, life skills and technology and science skills in students.

STEAMonEdu project partners proposed the inclusion of STE(A)M practices in the subject matter of the "Flexible Zone" at the Elementary Schools. This discipline aims to develop the initiative of students and teachers and to foster their critical and creative thinking through methodologies of holistic and interdisciplinary knowledge approach and the implementation of activities and work plans.

The inclusion of STE(A)M practices to 'Educational Groups' at the Experimental Schools was also recommended. ''Educational Groups' are groups of pupils that operate optional after the mandatory morning program in Experimental schools in order to develop pupil's knowledge and skills, cultivating interests and inclinations and the introduction in the school curriculum new subjects and teaching practices. Respectively STE(A)M practices can be implemented in the day-long program of all the schools.

3.4 Italy

1. National Digital School Plan

The enhancement of STE(A)M education is one of the elements on which the National Digital School Plan launched by the Italian Government (PNSD, Law 107/2015) is based. It is a guidance document of the Ministry of Education, University and Research that aims to innovate the Italian education system through digitization, highlighting the opportunities it offers in terms of training, skills, and employment. The Plan is organized in 4 fundamental steps (tools, skills, accompaniment, and training) to be achieved through a series of objectives and actions divided into specific areas.

The *Digital, Entrepreneurship and Work* area aims to promote and bridge the digital divide in terms of skills and employment, promote careers in STE(A)M (Science, Technology, Engineering, Arts & Maths) and enhance the relationship between school and work.

The STEAM Lab project is part of the PNSD and provides classrooms dedicated to the experimentation of competitive paths in STEAM for students of all levels.

2. Elements in briefs

Elements in brief is an example of 3-year educational plan that every Italian school has to develop and update every year by law in order to adapt the general national guidelines to

their local communities' real educational needs. Schools benefit of a large autonomy in deciding their own local educational policies.

It is the first vertical design action of the Istituto Comprensivo Manzoni-Poli (primary and secondary school) that aims to create a mutual path for the building of a competent, hospitable and world-open community.

The competence concept is defined as a blend of knowledge, skills and attitudes which means *disposition/mentality to act or react to ideas, people, situations*.

That concept, indeed, represents a full awareness of the need to activate training actions capable of develop connections and overlaps among the different sectors and through the recognition of an intrinsic potential that leads each competence to reach other fields of cultural and relational experience. STEAM education is considered a strategic asset to be developed by specific projects, tailored for kids of primary schools and the first cycle of secondary school.

3.5 Romania

STEAM education is a concept that became a reference point Romania quite recently, but which is believed to be a essential element in preparing the young generations for the future.

The shift from an outcomes-based curriculum, to a competences-based curriculum started almost a decade ago, through the Act on Education (1/2011). This was reflected in the way that STEAM curricula were subsequently developed. This included the creation of a graduate's profile and minimal standards, with maths, sciences and cultural awareness as some of the focus points of the educational process.

In 2015 when the curricular framework for the lower secondary cycle was developed the process included a public consultation on different types of frameworks. It was meant to give stakeholders an opportunity to argue for a curriculum that would be skewed either towards STEM or humanities and it reflected a desire to link education with labour market needs. When it was implemented, the curricular framework was a mixture of the two types of subjects, that still favoured STEM in terms of number of hours allotted.

Another available path to bringing STEAM to the classroom is the trans/interdisciplinary curriculum. This has not become a reality, as there are outstanding issues on how teachers would be payed when delivering joint sessions. A series of such curricula are in development at the National Centre for Policies and Evaluation in Education, including some with a focus on STEAM.

International testing programmes, especially PISA and TIMSS, have had a significant impact in the design of curricula and evaluations. This is evident in the presentation notes of the science curricula which explicitly mention convergence with these testing programmes as a goal.

1. CRED

For the past two years, a large-scale project, called CRED, has trained primary and lower secondary teachers to accommodate the changes in the curriculum. This was done in parallel with the creation of a large body of open educational resources, which should become available within the next year.

CRED project "Relevant Curriculum, Open education for all" aims to achieve the following:

- Curricular empowerment / training of 55,000 primary and secondary school teachers for a methodological approach focused on key competencies, in accordance with the new curriculum and adapting learning activities to the specific needs of each student, including those at risk of dropping out of school;
- Facilitating student-centered teaching and learning process, more specifically, to facilitate learning in order to enable and support each student to progress in learning activities, regardless of possible learning difficulties, regardless of ethnicity, disability, etc.;
- Design and development of teaching and learning process focused on skills training in the context of the new reference framework of the National Curriculum developed through the project;
- Integrated approach (in the sense of making connections with real life);
- Assuming new roles by teachers, facilitating learning in non-formal and informal educational contexts;
- Using alternative methods of formative assessment;
- Respect for diversity;
- Capitalization of the hours available to teacher (25%) to the advantage of each student's progress;
- CDS design capitalizing on the needs, resources, and local cultural, social, economic context;
- Review of curricular documents targeting the "Second Chance" Program.

2. Action plan for education in Romania 2019 -2030

More recently, in 2019, in order to support the integration of STE(A)M approach in the Romanian educational system, the Ministry of Education developed an "Action plan for education in Romania 2019 – 2030". Ideally, this should bring a new approach to mathematical skills, creative thinking skills, computational thinking and coding, engineering and technological innovation modernization of the student assessment system, as well as a calibration of the assessment of learning outcomes according to individual pathways and clearly defined standards. The results of implementing the "Action plan for education in Romania 2019 – 2030" will be:

- Elaboration of a new STE(A)M curriculum, based on a trans-disciplinary approach
- Creation of OERs (Open Educational Resources) to support the implementation of the STE(A)M curriculum

- Implementation of an updated competences framework for educators from the STE(A)M field
- Phasing the implementation of the new curriculum at all school levels
- Ongoing monitoring, impact evaluation, and adjustment of resources and indicators for reaching maximum impact.

3.6 Catalunya, Spain

STE(A)M: universities and private initiatives

Some Universities have also created similar initiatives. For example, *Aquí STEAM* (Here STEAM) is an initiative of the Universitat Politècnica de Catalunya (UPC) specifically aimed at girls between 9 and 14 years old in Catalonia to attract female talent to study technology and engineering**.** The programme aims to break the stereotypes and gender roles established in society and to make visible new female references in an attractive and close way for girls.

Another great example is the new STEAM en acción (STEAM in Action) that will be developed by La Fundació Aigües de Manresa – Junta de la Sèquia, the Universitat Politècnica de Catalunya (UPC) and financed by the bank BBVA. It is a transversal educational proposal that aims to educate students from day-to-day experiences. In addition to one exhibition, "Mathematics and life", multidisciplinary and interactive activities have been designed, aimed at an audience ranging from 3 to 18 years old, all of them thought and developed by UPC members.

Fundació Catalana per a la Recerca i la Innovació (Catalan Foundation for Research and Innovation,a private entity funded with public sources) develop the Open STEAM teaching innovation workshops, offering support and updating to teachers for the introduction of the scientific method in primary, secondary and high school classrooms. Its content provides a practical approach to encourage teacher training in scientific experimentation activities, aimed at these educational levels.

At a national level, Inspira STEAM is a pioneer project for the promotion of the scientific-technological vocation among girls, based on awareness-raising and orientation actions taught by professional women from the world of research, science and technology. This is the first time that the group mentoring technique has been used in a project to promote STE(A)M (Science, Technology, Engineering, Arts and Maths) among elementary school students. It is held by the Universidad de Deusto, with the cooperation of Innobasque in Euskadi, Edenway and the Universitat Rovira i Virgili in Catalonia, CIONET in Madrid, UCA and Universidad de Jaén in Andalusia, Universidad de Vigo and the Universidade da Coruña in Galicia, the Universidad de Oviedo in Asturias, the UCAM in Murcia and with the cooperation of companies as BBK, Roche, Barcelona Activa, Silk, HP Foundation among other companies. Tons of talent and a supra-territorial vision to make this initiative possible.

1. **SteamCAT plan**

A big step was taken a little bit later: with the aim of promoting the scientific, technological, engineering and mathematical vocations through creativity, design and art in students in Catalonia, the STEAMcat pedagogical innovation programme was created in 2018 (see the official government document). The programme is part of the support for innovation and research, which is one of the lines of action in relation to the specific objectives mentioned,

and which must also contribute to the overall improvement of the other actions of the STEMcat Plan.

At first, 40 educational centers were selected (20 Infant and Primary Education centers and 20 Compulsory Secondary Education centers) to be part of the STEAMcat pedagogical innovation programme from the 2018-2019 academic year. Nowadays, 51 educational centers are part of the community. This network of STEAMcat educational centers emphasize the relevance of equity and promotion of the scientific-technological vocations among women and in disadvantaged social contexts.

The STEAMcat programme aims to boost the development of teachers' professional skills and the application of methodologies that promote in students an improvement in the understanding of the world, based on scientific, technological, mathematical and engineering contents, from creativity, the arts and the humanist vision that critical thinking entails.

2. Bitbot program

The Secretariat of Digital Policies, in collaboration with the Department of Education, promotes the Bitbot program to promote the extracurricular offer of activities in the field of programming and educational robotics in Catalonia (STEAM actions). It was created in 2016, as a unique initiative that aims to increase interest and vocations in the field of ICT and improve the digital competence of young people.

The Bitbot program includes the catalogue of educational programming and robotics activities in Catalonia, the holding of talks in schools and organizations, and a training service for monitors who want to conduct and develop educational and leisure activities in the fields of programming and educational robotics. In 2019 the Bitbot program was integrated into the STEAMcat plan, the general plan of the government of Catalonia created to integrate all STEAM promotion policies.

4 Analysis of the efficiency and impact of STEAM educational policies

Project partners attempted to find and include information a national and EU level regarding the efficiency of STE(A)M education policies. Their findings are presented below.

4.1 EU

It appears that there is a positive trend in the development and integration of STEAM Education in Member States' frameworks. The Recommendations do not entail an obligation, but they exert a considerable amount of political pressure, highlighting the Commission's trends, key priorities and course of action also in a strategic perspective. The inclusion of STEAM Education and practices in the latest Digital Education Action Plan (2020-2027) proves a strong commitment and the clear need for a multidisciplinary approach to education, with a major prevalence of STEM competences for the creation of future professional profiles, more in line with current societal needs.

Nevertheless, this is the time to drive a very focused action able to leverage in the adequate policy making environments and advocate with relevant stakeholders towards a further integration of STEAM Education and practices.

4.2 Germany

The STEM report is published by the association "Institute of German Economy Cologne" every six month. It promotes the "MINT-Lücke" (STEM gap) to show how many labour forces are missed to cover all jobs in the STEM sector. Due to the figures it presents, political and economic stakeholder can refer to the developments on reducing the STEM gap and plan further activities. It allows to initiate more national activities, however currently there is no consideration of the STEAM approach.

4.3 Greece

The official state policy for the implementation of STE(A)M practices in education is limited to advice and exhortations. IEP exhortations have not brought significant results. STE(A)M educational programs are applied in Greek educational system by initiatives of the teachers themselves, mainly IT teachers, with the entry of educational robotics activities in schools and their participation in competitions, Erasmus programs and eTwinning.

4.4 Italy

There is a lack of data to be able to carry out a quantitative assessment. On a qualitative level, we note the appearance of references to the STE(A)M approach in a few dozen PTOFs for the three-year period 2018/20. It is a sign that the indications of the PNSD have stimulated interest in the topic in the most innovative schools. However, the percentage compared to the 8,160 schools remains negligible at the moment.

4.5 Romania

There is little information on the effectiveness of current policies and practices. Romania has a higher than average percentage of girls participating in higher education programmes in STEM. However, this does not seem to be the result of policy, but rather historical trends.

Some indication of the effectiveness of teaching practices can be measured from international testing programmes in which Romania has taken part. This should be considered in the context of the curriculum that was in use. None of the previous testing cycles include results that reflect the latest changes in the curriculum and practices.

The CRED project might be in a position to carry out some evaluation of the effectiveness of the training sessions that targeted 55000 teachers.

Next year, with the first national end of cycle exams for lower secondary schools we will be in a better position to evaluate possible changes in student performance.

4.6 Catalunya, Spain

There is not data available about efficiency and impact of this policies, so it's difficult to assess both impact and efficiency. But we should consider several factors, as positive ones:

- The existing initiatives are still ongoing, and the number of participants (centers, training providers and individuals) is increasing
- new initiatives are appearing
- the current initiatives involve the government, the universities, private companies acting as sponsors, non-profit, training providers - it seems that the educational community is really involved, but it's not the only one.

5 Short analysis of STEAM educators needs

Within their research work at regional or national level, the STEAMonEdu partners also performed an analysis of the STEAM educators' needs. Their findings are presented below:

5.1 ALL DIGITAL, EU

- Need for further action to implement an interdisciplinary educational approach based on applied research and scientific method and projects, through increased investments at national and EU level;
- Increased opportunity for STEAM educators to deliver training programmes in joint collaboration, within a coherent and structured multidisciplinary approach;
- Increased access to training programmes for the creation of new professional profiles encompassing a strong STEAM focus, providing learners with complex problem solving abilities, critical thinking, people management skills, creativity and cognitive flexibility;
- Enhanced support at local and regional level to fill existing gaps and mismatches between STEM-related training systems and jobs through detailed review of educational framework. Increased mobilisation of funds to enhance STEAM education in action plans and public-private partnerships implemented at local and regional level;
- Internationalisation of STEAM courses and training programmes for a more effective integration in university courses and enhancing opportunities for traineeships, project collaborative work in an international context, encouraging inter-professional synergies;
- Nurture engagement and participation by providing an extensive and high-quality STEAM education experience for learners, encouraging an open and receptive disposition towards STEAM disciplines and an integrated approach to STEAM education, boosting citizen empowerment. It is essential to engage learners through career counselling, advice on accreditation opportunities and new profiles required in the labour market;
- Provide evidence-based results to encourage STEAM education practices and career choices;
- Support STEM education practice by ensuring curriculum review against STEAM qualifications.

5.2 RDEWG, Greece

- Knowledge why they use a STE(A)M practices approach and what a STE(A)M practice involves.
- Ability and confidence in teaching multiple STE(A)M disciplines
- Knowledge of evidence-based instructional practices, methods and pedagogical strategies to integrated STE(A)M education into their daily school timetable
- Knowledge of ICT to apply it productively in everyday school work
- Financial and administrative support as well as logistics and high-speed internet

5.3 CTI, Greece

Interest in STE(A)M education models is literally exploding across the school-based landscape, supporting curriculum reorganization through STE(A)M initiatives. These initiatives include a shift from teaching students to remember and execute isolated facts and skills, to learning students to experiment as scientists, engineers and mathematicians. However, these kind of educational reform movements require remodeling of the educational process. Based on the

innovations that the STE(A)M approach promotes, several challenges must be supported; educator preparation is one of them (Spyropoulou & Kameas, 2019). Additionally, since the role of educators (trainers, teachers and tutors) is of strategic importance, especially when it comes to acquiring technical and behavioral skills (Borges, Coelho Junior, Faiad, & Rocha, 2014), there is a greater need for well-qualified STE(A)M educators who understand what is needed and how to teach relevant and high-quality STE(A)M courses.

In addition, STE(A)M educators may have different academic background; as a result, the prior content knowledge may different. Thus, the curricula of the Professional Development Programs for STEM educators may differ based on the specific needs of the group of educators. Towards this, a creation of a competence profile for STEM educators may facilitate the design and development of such training programs (Spyropoulou & Kameas, 2020b, 2020c).

Studies have shown that educators lack confidence in delivering science materials and encounter difficulty in gaining students' interest to study science subjects; there is also evidence for a similar association between confidence, anxiety, and efficacy with teacher effectiveness (Nadelson et al., 2013). Thus, there is also the question of the use of STE(A)M approach in educational practice and the appropriate preparation of educators not only for the required technical knowledge and skills, but also for the design of appropriate educational activities that take advantage and feel confident with the STE(A)M integrated approach (Spyropoulou & Kameas, 2019).

The preparation of educators is one of the main challenges of STE(A)M education (Nadelson et al., 2013), as it requires a great deal of learning on the part of educators that will be difficult to achieve without support and guidance (Borko, 2004). In addition, implementation of STEM Education initiatives involves the inherent challenge of supporting a strong conceptual and foundational understanding of key concepts within multiple disciplines (Shernoff, Sinha, Bressler, & Ginsburg, 2017). In a case study (Dare, Ellis, & Roehrig, 2018) where nine educators implemented STEM courses, the findings suggested that they needed continued support as they navigate through multiple disciplines into their classrooms, especially when the STEM topics focus on engineering. In the study presented in (Dan & Gary, 2018), eight primary school teachers were interviewed and presented different needs in attaining professional development including the lack of knowledge about how to apply STEM knowledge into practical teaching, differentiation of needs and skills, and their values, and the lack of support and guidance. The study presented in (Nadelson et al., 2013) showed that for educators, the years of teaching experience did not bring higher knowledge and comfort with teaching STEM or a greater feeling of effectiveness for teaching STEM, therefore their professional development may be needed on multiple topics at different stages in their careers.

In (Spyropoulou & Kameas, 2020c, 2020a) work, the role of educator in STE(A)M Education was investigated and the educators' views regarding the challenges, the difficulties and the professional development needs of STE(A)M Educators was examined. The participants were 59 Greek educators, who have implemented STE(A)M-related courses.

The results showed that the educators face various challenges in implementing STE(A)M educational programmes. Thirteen main challenges were identified: (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.

An important topic, which emerged from the qualitative analysis of the questions related both with challenges and difficulties, is the perspective of parents about STEM education. Parents' perceptions about traditional education, combined with "fear of what's new" and several misunderstandings concerning STEM education appear to affect educators' effectiveness. This outcome in conjunction with the high valued difficulties about the deficits in supporting the role of the educator in the educational context and the decreased interest from educational community, reflect the need for a more holistic and systematic support of the role of educator and the need for school reform in order to support STE(A)M education (Spyropoulou & Kameas, 2019) .

The educators' responses regarding the ways with which they try to face the mentioned difficulties reveal that they need to have flexibility and creative skills in order to adapt their lessons based on the specific needs and the available resources. Evidently the majority of the participants believe that they need non-formal education, e.g. lifelong learning seminars in order to be more effective in implementing STEM-related courses. However, more educators stressed that they prefer to deal with the difficulties regarding their lack of experience and/or knowledge skills primarily through research and personal study instead of attending training programs. This may be due to the lack of targeted training programs based on specific and different needs of educators, who want to implement STEM-related programs. Some educators also mentioned collaboration and interaction with colleagues as a way of informal education.

Some differences with respect to participants' gender and academic background revealed the preferred ways with which they try to face difficulties and challenges. However, their preferences in training topics seem to have differences mostly in the different academic background, indicating that educators with different academic background may have different needs for professional development. On the other hand, it was observed that technical training (such as development of STEM applications) is a common need for the majority of the participants. Regarding the importance of different dimensions and characteristics of the role of STE(A)M educator, the findings reveal some differences between educators with different academic background, especially in the teaching and learning dimension.

5.4 HELLIWOOD, Germany

- Infrastructure and teacher qualification for implementing digital learning offers are too less developed in many regions/schools. There is a discrepancy and lots of challenges educational policies between national and regional level.
- STEM is well established for many years – there are many awards to promote STEM education for secondary schools, e.g. MINT friendly schools. But there is no connection to Art.
- There are no formal concepts for STEAM-education until now. The consistency and uniformity for STEAM-education is not available.
- Break up gender stereotypes. Still STEM-classes/schools count more boys than girls.
- Ability to work in a team - educators need to become aware of the opportunities to exchange with colleagues from other disciplines and the benefits of interdisciplinarity.
- The assessment and evaluation frameworks of student's work/ learning are too rigid. Thus, alternative ways of learning are hardly possible. Reasons for that are strict schedules, assessment limitations, fear of losing control.

5.5 SGI, Italy

The main needs of educators in the school environment to be implemented in the context of educational policies are essentially two: training and overcoming the disciplinary organization.

Even the very definition of STEM / STEAM is still the subject of discussion and the perception of the topic and its contents by educators is often confused. Widespread training and information on the subject is a critical need.

However, the real blocking element of the diffusion of the STE(A)M approach is that it contrasts with the traditional school structure, which reflects an analytical conceptual model substantially incompatible with the systemic and holistic nature of the STE(A)M approach. "Factors such as assessment (not formative), parental expectations for traditional teaching methods, predefined timing of instruction, structure of school textbooks, organization of curricula or programs, and finally training of the teaching staff linked to a highly disciplinary approach keep the school bound to a traditional structure. " (from "STEM AND STEAM: DEFINITIONS, CURRICULUMS, ROLE OF THE ECONOMY, GAP OF GENDER" by Marco Bardelli)

5.6 EOS, Romania

The most pressing needs of the educators when it comes to STE(A)M educational policies, are the following:

- Better access to equipment for school laboratories which makes difficult to sustain innovative and experimental school classes – to integrate STE(A)m elements
- More support for educational partners to get involved in the educational process, for example in the form of grants.
- Less bureaucracy related to extra-curricular activities
- Continuous access to training opportunities
- Access to updated support materials
- The creation of mechanisms for sharing experiences and expertise

5.7 COLECTIC, Spain (Catalunya)

- Acquire technical and pedagogical skills and competences.
- Understand how the STEAM competences can be assess and evaluated.
- Learn how to overcome the gender gap, and the individual and special needs of the trainees.
- To share their good practices, and to build a community, a network outside their own centres.
- School managers and directors must be supporting the trainers and educators in the adoption of the STE(A)m educational practices. STE(A)m require coordination between trainers/teachers.
- School or after-school spaces need to be more flexible in order to facilitate workshops, working groups
- More and diverse technologies are needed
- More dissemination of the successful experiences is needed

6 Conclusions

This guide presents a synthetic description of the context and an overview of the main EU and national level policy initiatives aimed at addressing both STEM and STEAM challenges. The information included in this publication has been collected by the members of the STEAMonEdu community and curated by project partners.

1. **Quantity and quality of STE(A)M policies.** The research performed within the project identified only 20 policies both 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, and this translates into education systems that are not fully reformed in order to respond to the current societal challenges and opportunities.

2. **STEAM vs STEM**. STEAM 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. At EU level, the new Digital Education Action Plan introduces the concept of STEAM only to encourage women to consider technical studies. Despite an official communication between the EU Parliament and the European Commission, and a funding programme to promote integration of STEAM, the challenge to achieve a full integration of the STEAM disciplines remains.

3. **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 able to meet the growing demands of businesses and allowing professionals to excel and perform outstandingly in a highly technical and evolving fast-paced environment. Most of the EU countries have integrated STEM in education by now at various levels, but impact is still low due to the lack of proper policy support.

4. **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. In all five countries where the research has been performed, very little information has been found regarding policy efficiency. Ultimately, there is currently no official and transversally accepted framework which enables comparisons across different EU member states. The OECD's PISA programme offers insight on the separate disciplines, but does not offer a full assessment of STEAM opportunities and practices.

5. **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. This only proves that there is an urgent need for coordinated support from the policy side both at EU and at the national level.

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