WP3 Analysis of STEAM policy gaps and needs

Deliverable 3.1 Policy Context for STEAM

Deliverable 3.1

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Abbreviation	Description
AI	Artificial Intelligence
ENG	Engineering - Ingegneria Informatica
ICT	Information and Communication Technologies
LC	The Lisbon Council
OECD	Organization for Economic Co-operation and Development
PoliMI	Politecnico of Milan
STEM	Science, Technology, Engineering and Mathematics
STEAM, STE(A)M	Science, Technology, Engineering, Arts, and Mathematics
UNESCO	United Nations Educational, Scientific and Cultural Organization
UoE	University of Exeter

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Abstract

Deliverable 3.1 of the Road-STEAMer project, serving as the inaugural policy report for WP3, is dedicated to policy analysis and the current landscape of STE(A)M (Science, Technology, Engineering, Arts, and Mathematics) policies in Europe. It specifically examines policy initiatives and targeted strategies implemented by various European countries to promote innovation and interdisciplinary education.

Presently, Europe faces a shortage of skilled workers, particularly in Science, Technology, Engineering, and Mathematics (STEM) sectors, a challenge that is echoed globally. In addition to the overarching scarcity of STEM professionals, there persists a significant underrepresentation of women and marginalised communities in these occupational domains. These issues transcend those directly affected, as STEAM education offers potential advantages for all individuals, regardless of their occupation, by equipping them with the skills needed to navigate an increasingly complex and digitised world more effectively.

The current policy report seeks to accomplish a dual objective:

- At the macro-policy level, the primary goal is to compile EU initiatives in STE(A)M education. Mapping the EU policy landscape serves as the initial step towards analysing policy gaps (deliverable 3.2).

- Simultaneously, at the macro-policy level specific to individual nations, an examination of the evolving policies implemented by EU member states over time is conducted.

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1. Introduction

1.1 About Road-STEAMer

The primary objective of the project is to formulate a STEAM roadmap for science education within Horizon Europe. This roadmap constitutes a strategic plan aimed at guiding the European Union's principal funding program for research and innovation in promoting heightened interest in STEM fields. The approach involves integrating artistic methodologies, emphasising creative thinking and applied arts (the "A" in 'STEAM'). The consortium endeavours to deliver this roadmap for Europe by:

- Fostering collaboration and co-creation with stakeholder communities in science education, research, innovation, and creativity. This entails intensive exchange, dialogue, and mutual learning to generate enhanced knowledge and shared understandings of relevant opportunities, challenges, and needs.

- Adopting a bottom-up approach that prioritises educational practice and the agency of practitioners over high-level conceptualizations of STEAM and generic top-down plans for its incorporation into science education.

- Concentrating on strategies to harness the power of STEAM approaches, exemplified through noteworthy cases and best practices. The goal is to facilitate a connection between open science and open schooling, catalysing an increased impact on science education as a pivotal tool for addressing the current scientific and societal challenges faced by Europe.

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1.2 About this deliverable

D3.1 represents the first of three reports in WP3 'Analysis of STEAM policy gaps and needs', the objectives of which include studying local and international policies and legislation related to STEAM education, published literature and white papers/surveys on the subject. The primary goal of this initial deliverable is to communicate the information acquired from EU and national policies. The data is sourced from open and accessible repositories, EU websites, policymakers' websites, and the collective expertise of the project consortium. The objective is to present this information in a manner that facilitates the easy identification of gaps and enables the suggestion of additional measures.

D3.1 is organised into the following sections:

1. **Introduction**: This section provides an overview of the research questions and policy concepts guiding the analysis. It outlines the key inquiries and fundamental policy principles under investigation during the analysis process.
2. **Methodology**: The next section outlines the methodology employed, as well as the processes of data collection and analysis utilised in examining STEAM (Science, Technology, Engineering, Arts, and Mathematics) policies. It offers a comprehensive overview of the approach taken and the tools utilised to portray the existing landscape of STEAM policies.
3. **STE(A)M education policy analysis**: The third section pertains to the analysis of data and the presentation of findings.
4. **Beyond policies:Bottom-up initiatives on STEAM:** The fourth section focuses on the selective grassroots initiatives on STEAM education.
5. **Discussion and Conclusion**: In the concluding section, there is a discussion of the findings and a description of the anticipated next steps in the research or policy implementation process.
6. Additionally, D3.1 includes an **appendix** containing the policy texts used.

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2. Policy-making and STEAM. Concepts and questions for inquiry

2.1 Road-STEAMer policy agenda

Examining the intersection of policy-making and STEAM involves delving into specific concepts and formulating essential questions for investigation. The study of STEAM education is a multifaceted process with various perspectives to explore. This encompasses policy formulation, official and semi-official strategic initiatives, societal implications, inclusivity issues, representation of diverse groups in higher STEAM education, as well as challenges related to labour skills shortages and digital transition.

Within the realm of education, numerous topics warrant investigation, extending to curriculum formulation, execution of activities, and attainment of an interdisciplinary approach. Exploring the role of art and humanities and their integration with more conventional areas such as mathematics and engineering is crucial. Additionally, examining the dichotomy between vocational and general education, as highlighted by Al Quraan and A Forawi (2019, 85), adds another layer of complexity to the inquiry.

Within the framework of Horizon Europe program, the pressing contemporary issues that European Union countries currently confront, emphasising the necessity for enhanced policy-making in the STEAM field, were recognized as follows :

- Europe is grappling with a pressing **skills crisis,** characterised by challenges in employment and a shortage of qualified STEAM professionals. The education system's struggle to impart necessary skills hampers readiness for digital and green transitions. Additionally, underrepresentation of women and marginalised groups in STEAM exacerbates the issue. Recognising the importance of STEAM knowledge for all citizens underscores the need for high-quality, accessible science education. Innovative approaches, including out-of-school science activities and integrating arts into STEM, not only enhance engagement but also cultivate essential soft skills.

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Emphasising interdisciplinary approaches in STEAM education is crucial for addressing complex challenges like the climate crisis. Moreover, promoting a broader societal understanding of the value of arts contributes to fostering a versatile and adaptable society in the face of future uncertainties.

- Europe is also experiencing a **deficit in scientists** specialising in STEAM and ICTs, as highlighted by the Employment and Social Developments in Europe report 2023 and the European Commission Joint Research Centre. Labour shortages, particularly in STEAM and ICT sectors, are exacerbated by mismatches in the tertiary graduate labour market, where well-educated individuals struggle to find suitable employment. Quality of education issues, including a gap in graduates' skills meeting employer expectations and the oversight of crucial "soft skills" in STEAM education, are identified challenges. Policy initiatives like Action 7 of the European Skills Agenda aim to address these gaps by emphasising STEM graduates and ensuring digital skills for individuals aged 16-74. The evolving technological landscape underscores the importance of digital skills for trust, resilience, and active participation in the Digital Decade. Despite 85% of Europeans using the internet, only 58% possess basic digital skills. The demand for ICT specialists is projected to reach 20 million by 2030, while concerns about AI highlight the need for a holistic approach, aligning with the core principles of STEAM education. Labour market participation disparities exist along gender, socio-economic, ethnic, and disability lines, with gender-imbalanced sectors like STEAM facing stark shortages. Encouraging STEAM graduates among women and marginalised groups not only addresses shortages but also brings diverse perspectives and solutions, fostering a more inclusive workforce.

These areas of focus were initially linked to a specific conceptual understanding of STEAM education and subsequently tied to the fundamental principles underlying policy analysis. In the context of the Road-STEAMer project, the term STEAM, intended as the integration of artistic approaches into Science, Technology, Engineering, Arts, and Mathematics (STEM), lacks a universal definition. The research work conducted in the project's first year underscores the complexity and diversity of the field, with an emphasis on interdisciplinarity and creative thinking. In particular, the project's research framework (D4.1) identified six key

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criteria for successful STEAM practices: Collaboration, Disciplinary interrelationships, Thinking-making-doing, Creativity, Real-world connection, and Inclusion/Personalization/Empowerment, all grounded in the core principle of Equity. The latter rejects hierarchies and advocates for an active role for students.

In contrast, policy has traditionally been defined within narrow and specific perspectives. A concise and formal definition of public policy is provided by Thomas Dye in his early and widely acclaimed text on the subject. Dye's definition of policy as 'what government chooses to do or not to do' (Dye 1972) confines the concept of policymaking to government decisions and exclusions, portraying it as a strictly top-down process. However, this perspective overlooks two significant aspects: firstly, the acknowledgment that policies vary in types and degrees of binding, even at the governmental or EU level, and secondly, the existence of unofficial, bottom-up initiatives originating from the ecosystem that bring forth specific issues to the governmental policy agenda.

The objective of policy analysis outlined in document D3.1 is to gather and evaluate information concerning policies related to STEAM education at both the EU and national levels. This entails mapping the respective field, and highlighting the policy priorities that guide current educational policy. Within this context, the fundamental research inquiries include:

- Exploring how the mentioned challenges intersect with STEAM education and identifying the prerequisites for successful integration.
- Analysing the inclusion (if applicable) of arts and humanities in existing national and international policies.
- Evaluating the extent to which national governments have adopted EU recommendations and directives, and scrutinising their current policy strategies.

The primary focus is on top-down policy initiatives and policies designed by official instruments. However, we also recognize the importance of bottom-up and grassroots initiatives. It's essential to acknowledge that practitioners, educators, and community leaders play a significant role in decision-making. Their work often reflects real-life problems that require attention and solutions.

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2.2 Methodology

This section outlines the methodological framework utilised by the project partners to identify, select, and analyse policies related to STEAM education. The process of identifying and collecting these policies has primarily been facilitated through desk research, and data collection from the RoadSTEAMer network and consortium, were explored through thematic analysis.

In order to organise and analyse our data we collected the following information:

For EU policies:

Data collection for EU policies concentrated on identifying the type of policy, its objectives, key activities, and, where applicable, the associated time frame. To elaborate:

Policy Type: Six types of policy measures and texts were identified and specifically:

- Regulations: A "regulation" is a binding legislative act. It must be applied in its entirety across the EU.
- Directives: A "directive" is a legislative act that sets out a goal that EU countries must achieve. However, it is up to the individual countries to devise their own laws on how to reach these goals.
- Decisions: A "decision" is binding on those to whom it is addressed (e.g. an EU country or an individual company) and is directly applicable
- Recommendations: A "recommendation" is not binding.
- Opinions: An "opinion" is an instrument that allows the institutions to make a statement in a non-binding fashion, in other words without imposing any legal obligation on those to whom it is addressed
- Communications: Communications encompass various forms, such as policy evaluations, commentary, or explanations of action programs. They may also provide concise outlines of future policies or arrangements related to the specifics of existing policies.

Name/identifier: Refers to the policy text name

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Policy Purpose: Specific sections that refers to STEM or STEAM and what is the purpose
Key terms: The basic concepts of the policy text, coded
Key activities: How the policy purpose is connected with specific initiatives or recommendations.
Timeframe: If it is applicable
Related policy references: With which other texts it communicates

For National policies:

The data collection for national policies had a dual focus:

a. Recording national STE(A)M policies and legislation that establish the country's overarching framework.
b. Identifying bottom-up and grassroots movements that significantly impact the STE(A)M ecosystem.

Regarding the latter, the aim is to highlight noteworthy examples of social action rather than comprehensively mapping existing informal initiatives in EU countries (though not exhaustive). Each EU country has its tradition of formulating policy directions and proposals, and in this light, the results cannot be generalised.

This section pays particular attention to the integration of arts and humanities into traditional STEM fields, inspired by the RoadSTEAMer program's unique approach. The RoadSTEAMer consortium has prioritised and systematically studied the inclusion of arts and humanities as a distinct discipline within STEM, proposing a set of criteria for the effective adoption of STEAM approach on education[1] (D 2.2.). In the context of STE(A)M policy analysis, a focal point of research was whether the official policy documents explicitly referenced the term "STEAM" or adhered strictly to the more limited term "STEM." Adopting an interpretative approach to policy analysis involves seeking to comprehend the broader policy discourse concerning the role of the arts in interdisciplinary education.

National policies were initially categorised into three distinct groups, namely:

[1] You can check Road-STEAMer website: https://www.road-steamer.eu/

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- Countries with high priority in STE(A)M education
- Nations acknowledging the importance of STE(A)M education in their policies
- Countries may not prioritise STE(A)M education or may be in the process of developing such initiatives

The collected data on national policies were categorised as follows:

National Policies: Brief overview of STE(A)M national policies
Objectives: Official goals outlined in the policies
Crucial Platforms and Tools: Key programs or specific initiatives considered vital by each national government for successfully implementing their policies.
Target Audience: The specific demographic or group aimed at by the policy.
Policy Orientation: How the specific policy aligns with broader macro policies.

Data collection in the context of policy analysis typically involves four fundamental components: a) identifying the problem the policy aims to address, b) elucidating the underlying principles, values, or objectives, c) delineating the specific actions, platforms, and instruments necessary for policy implementation, and d) conducting assessment and evaluation. However, within the Road-STEAMer project, the fourth component presents challenges due to various factors, including limited accessibility to specific texts, a general dearth of evaluation data on STE(A)M policies and practices, and the ongoing nature of current policies.

Data gathering and collection policies were conducted utilising various resources, particularly publicly available policy texts published by the EU, research reports on EU and national policies, and national portals. Short interviews were also conducted to targeted stakeholders in Poland and Ukraine, using a short open-ended interview guide. Additionally, members of the Road-STEAMer consortium shared their valuable insights on policy-making in their respective countries.

In particular, and regarding the EU policy on STE(A)M education, a flow chart (Figure 1) was deployed in order to depict the evolution of objectives and priorities in policies over the past

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decade. As for national STEM policies, a short interview guide was developed for members of the Road-STEAMer consortium to utilise in gathering essential data from their network.

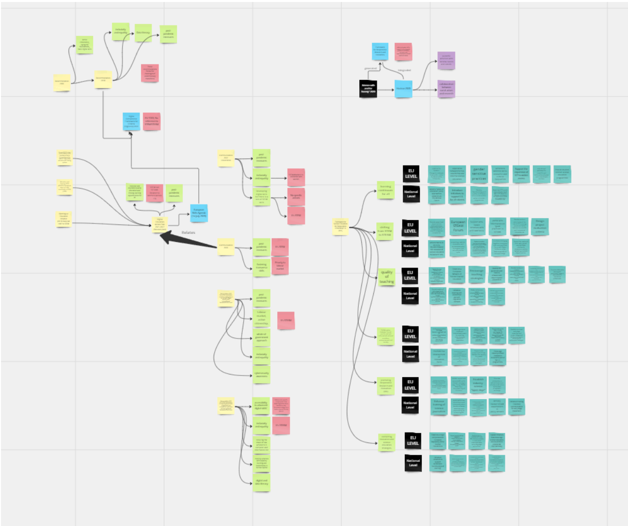

Figure 1. Flow chart on STE(A)M EU policy

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3. STE(A)M education policy analysis

3.1 Policy overview in EU

Certainly, the "Science Education for Responsible Citizenship" report[2], presented to the European Commission in 2015, emerges as a recent and influential policy document regarding STE(A)M. This report lays the groundwork for nurturing interest in science and STE(A)M, cultivating essential skills for individuals, and ultimately fostering a broader sense of societal responsibility and active citizenship. The "Framework for Science Education for Responsible Citizenship" delineates six key areas:

- Establishing a learning continuum for all.
- Transitioning from STEM to STEAM.
- Striving for quality teaching through pre-service preparation and in-service professional development.
- Establishing and maintaining collaborative networks among diverse stakeholders.
- Advocating for Responsible Research and Innovation (RRI).
- Aligning innovation and science education strategies at local, regional, national, European, and international levels, considering societal needs and global developments.

These six primary areas were organised with actions and recommendations at both the EU and national levels, with the objective of offering guidance for a systematic transformation of STE(A)M education throughout Europe. Interestingly, the incorporation of arts and humanities as an additional component, resulting in the extended acronym STEAM, signifies a notable expansion in the domain of science. This augmentation is situated within a context that advocates for positive views on science, highlighting principles of equity, accessibility, and the inclusion of marginalised groups.

[2] https://op.europa.eu/en/publication-detail/-/publication/a1d14fa0-8dbe-11e5-b8b7-01aa75ed71a1

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The subsequent policy document, released in 2018 as a Recommendation from the Council of the European Union on key competences for lifelong learning,[3] replaced the 2006 Recommendation. This transition signified a shift from the emphasis on cultivating basic digital skills to addressing contemporary societal and digital challenges, particularly focusing on aspects such as data literacy. The 2018 text reflected the significant societal transformations witnessed in recent years, underscoring the pervasive influence of technology and automation in everyday life and the workplace. The unmistakable impact of the COVID-19 pandemic and the emergent needs it introduced were apparent in the text.

Significantly, the incorporation of STE(A)M stood out as a defining aspect, portraying it as a driver of transformation. Acknowledging the amalgamation of computational expertise with creativity as vital instruments for advancement, achievement, and the promotion of a sustainable way of life, STE(A)M is recognized as a conduit for knowledge acquisition rather than just a component of a comprehensive and systematic educational framework. The integration of arts and creativity into STEM is associated with the overarching objective of inspiring youth, particularly women, to pursue STEM careers.

The 2020 Communication from the European Commission struck a different tone, calling for a revolutionary approach to upgrading EU skills to better align with the demands of the labour market and uphold the universal right to lifelong education[4]. On one hand, STEM is closely tied to specific societal needs, particularly the imperative to cultivate transversal and entrepreneurial skills through STEM studies (Action 3). Moreover, the alignment of STEM with specific educational objectives is emphasised in Action 7, which targets STEM graduates, especially those in secondary and higher education, with a focus on establishing networks that bridge the educational community, teachers, businesses, and professionals.

Furthermore, with the aim of enhancing excellence in science education, the Communication recommends actions such as fostering connections between different European countries through dedicated portals and leveraging platforms like the SCIENTIX[5]. These measures are envisioned to be undertaken collaboratively by partners across the European Union.

[3] https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32018H0604(01)
[4] https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52020DC0274
[5] https://www.scientix.eu/

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The 2020 Communication report also underscores the pivotal role of Universities (Action 5), highlighting two key instruments:
Firstly, the enhancement of universities through the further development of STEM/STEAM education, primarily through the **Erasmus+ Program 2021-2027.** Universities are recognized as fundamental entities for constructing a European Education Area (by 2025), supporting the implementation of European strategic cooperation in education and training, along with its underlying sectoral agendas. STEAM education is deemed particularly valuable in addressing gender disparities in the educational realm, especially in promoting interest in ICTs and engineering. However, the term STEM is generally preferred. According to available data on the Erasmus+ program 2021-2027, nearly 30% of programs and initiatives are designed with the primary objective of addressing gender issues.

Secondly, transnational collaborations facilitated by the **Horizon Europe Program.** Promoting open and extensive mobility and collaboration among universities and various stakeholders is deemed essential for enhancing the educational system across the European Education Area (EEA). The Horizon 2020 Program incorporated the Framework for Responsible Research and Innovation, originating from the "Science with and for Society"[6] initiative of 2020. The role of universities in digital transition, skill development, and STE(A)M education has become a specific focal point in the 2022 Communication[7], with a particular aim to address the underrepresentation of women in STEM and skill shortages.

The Digital Education Action Plan (2021-2027), pivotal in realising the European Educational Area by 2025, places significant emphasis on inclusivity and equal lifelong educational opportunities in STEM, influenced by the 2020 Communication report. Action 13, specifically dedicated to "Women's participation in STEM,"[8] addresses the persistently low participation of women in STEM curricula and professions. Official reports indicate that only one in three STEM graduates are women, with women particularly underrepresented in fields such as technology-oriented entrepreneurship. The key activities of this action, as outlined on the official EU portal, focus on raising public awareness through targeted events like ESTEM

6 https://op.europa.eu/en/publication-detail/-/publication/770d9270-cbc7-11ea-adf7-01aa75ed71a1
7 https://education.ec.europa.eu/sites/default/files/2022-01/communication-european-strategy-for-universities.pdf
8 https://education.ec.europa.eu/focus-topics/digital-education/action-plan/action-13?

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festivals, learning communities, and platforms like Girls Go Circular, along with a general call for interdisciplinary STEAM approaches. As observed in previous actions and policy texts, the incorporation of arts and humanities into STEAM is closely tied to inclusivity, particularly women's participation.

Two subsequent Recommendation texts from the Council of the European Union, aligned with the directive 2023/936 of the European Parliament and Council on a European Year of Skills, explicitly advocate for a transition to STEAM rather than STEM. This shift, forming part of an interdisciplinary approach inclusive of art, aims to bolster digital skills across all educational tiers, facilitate skill acquisition for adults, advance data literacy, ensure equitable access to knowledge, and foster the development of technological educational tools and practices. The move from a national whole-government approach to a European whole-government approach signifies a more comprehensive EU digital skills policy, with STEAM education positioned as its cornerstone[9].

3.2 EU policy in national context

From a policy perspective, the previously mentioned EU recommendations and proposals serve as calls to action at the national level. This section delves into how EU countries have formulated their domestic policies, examining the extent to which they prioritise STE(A)M educational practices. The analysis categorises EU countries based on the level of emphasis placed on STE(A)M education.

The criteria for determining the level of priority include:

- Priority tags assigned by previous research reports.
- Sustained commitment demonstrated by a country over time through ongoing policy implementation, reflecting responsiveness to societal and market needs as well as EU recommendations.
- The maturity level of a policy, evidenced by its identification of specific problems to be addressed and the inclusion of targeted action points for STE(A)M specific education.

[9] https://data.consilium.europa.eu/doc/document/ST-15740-2023-INIT/en/pdf

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Taking into consideration the findings of previous research on EU policies and STE(A)M, particularly the Kearney Report[10] (2016), this report aims to provide an updated version of the status of STEAM policies in EU countries. Cases such as Bulgaria and Finland now appear to have adopted standalone strategies on STE(A)M education as part of their broader national policies, demonstrating a long-term commitment to individual policy initiatives. Considering these developments, there appears to be a shift from "Countries with no standalone strategy," as mentioned in the Kearney Report, to countries prioritising STE(A)M education as a high priority, as suggested by this report.

The categories developed in this section follow a specific logic:

1. **EU countries prioritising STE(A)M education**

This category includes EU countries where:

- There is a consistent continuity in STEAM policymaking over time.
- There is a transition from short and mid-term policies to long-term strategies aligning with broader science, technology, and society objectives, as recommended by the EU.
- Specific action points are designed and executed within this framework.

2. **Nations recognizing the significance of STE(A)M education in their policies**

This category comprises countries that have:

- Implemented schemes for STE(A)M education, albeit recently or targeting specific areas like the labour market.

3. **Countries not prioritising STE(A)M education or in the process of developing initiatives**

In this final category, only a few countries are included, where:

- Data availability is limited.
- They have not yet developed a comprehensive toolbox for implementing STE(A)M education initiatives.

[10] http://www.eun.org/resources/detail?publicationID=783

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3.2.1 STE(A)M education as high priority

EU countries that have set STE(A)M as high priority are Belgium, France, Bulgaria, Finland, and Germany

Belgium has been actively pursuing a policy agenda focused on STE(A)M since 2012, with the introduction of the STEM Action Plan 2012-2020. This comprehensive strategy aimed to bring about structural changes in the educational system, placing a particular emphasis on increasing the participation of girls and students from disadvantaged backgrounds in STEM fields. The plan emphasises innovative and challenging STEM education, addressing labour market shortages and transitioning students from secondary to higher education and into the workforce. Structured around eight objectives, including providing attractive STEM education, attracting more girls to STEM, and enhancing society's appreciation of technical professions, the plan involves various stakeholders such as the education and business sectors. The STEM Platform, comprising experts from diverse fields, provides ongoing feedback to ensure the plan remains relevant and effective. Within this framework, the arts are highlighted as a discipline that can be integrated, albeit without specific guidelines.

Additionally, there was a notable focus on understanding the broader societal implications of STEM education. Monitoring and evaluation of these policies were integral parts of the strategic planning process, facilitated by tools such as the annual STEM course enrollment report (STEMMonitor). For instance, according to data published by the Department of Economy, Science & Innovation, there was a significant increase in the number of students entering STEM-related courses from the 2010-2011 school year to the 2019-2020 school year, with over 2,600 more pupils enrolling during this period[11].

Building on the success and lessons learned from the STEM Action Plan, Belgium launched the STEM Agenda 2030 in 2021[12]. This new initiative aims to raise awareness about STEM, address broader societal needs, and enhance STEM competencies. The target audience includes individuals with a vested interest in STEM, educators, and specifically, girls. STEM

[11] https://op.europa.eu/webpub/eac/education-and-training-monitor-2020/countries/belgium.html

[12] https://onderwijs.vlaanderen.be/nl/directies-en-administraties/onderwijsinhoud-en-leerlingenbegeleiding/secundair-onderwijs/stem-science-technology-engineering-mathematics/stem-actieplan/wat-is-de-stem-agenda-2030

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is recognized as a national priority that will impact various aspects of daily life, including education, employment, research, and societal development.

Bulgaria demonstrates a strong commitment to developing and supporting a national STE(A)M educational program. Significant strides were made in 2013-2014 with the adoption of several strategies. In 2022, a systematic approach was initiated, notably through the Resilience Plan and the initiatives of the Ministry of Education and Science (MoES) for the years 2024-2025 as part of the National Recovery and Sustainability Plan[13]. This comprehensive effort aims to systematically tackle the country's primary challenges, including economic growth, demographic shifts, and social inequalities[14].

Initially, the 2022 National Recovery and Resilience Plan prioritised the development of a national STEM environment as its first pillar, with a key component being the establishment of an online platform dedicated to adult learning. Subsequently, the MoES budget allocated resources for "STEM Centers and Innovation in Education," aiming to promote digital literacy and cultivate interest in STEM subjects. The objective is to establish innovative STEM centres aimed at enhancing students' motivation in STEM fields. These centres will offer the requisite technological infrastructure and employ educational methods conducive to project-based learning while developing new educational content. Notably, emphasis is placed on integrating STEM education with creativity and digital arts[15].

The Bulgarian Ministry of Education and Science is actively pursuing several key priorities to advance STEM education within the country. These priorities encompass a comprehensive approach aimed at enhancing STEM skills among various stakeholders, including students, parents, and educational authorities. Furthermore, there is a strong focus on improving the quality of STEM education by investing in professional development for teachers and implementing change management strategies to drive educational reforms. In parallel, initiatives are underway to modernise STEM infrastructure, such as labs, facilities, and

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[13] https://www.europarl.europa.eu/RegData/etudes/BRIE/2022/733662/EPRS_BRI(2022)733662_EN.pdf
[14] https://www.europarl.europa.eu/RegData/etudes/BRIE/2022/733662/EPRS_BRI(2022)733662_EN.pdf
[15] https://www.stemcoalition.eu/programmes/building-school-stem-environment-stem-programme-government-bulgaria

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libraries, through digitization efforts. Addressing inequality and promoting better integration are also key objectives, with the establishment of learning communities and the development of STEM knowledge maps and pathways through initiatives like STEM BUS Bulgaria. The ministry is committed to ensuring pragmatism, transparency, and visibility in STEM efforts, emphasising collaboration and information sharing through platforms like the Open Data STEM portal Bulgaria. Additionally, plans for integration with the anticipated EIT community hub in Bulgaria aim to further bolster STEM initiatives and networks for sustainable development.

In **Finland**, STE(A)M education is regarded as a crucial area of research and a key driver of social well-being. The national approach takes a comprehensive view, integrating various sectors of Finnish society, diverse stakeholders, and overarching objectives. From 2011 to 2016, STEM was integrated into a broader national development plan for education and science. The LUMA (STEM) Strategy for the Years 2014-2025[16] aligns STEM disciplines with circular economy, ecology, social responsibility, and social equality. Specifically, natural sciences and mathematics are recognized as crucial competencies for future needs across sectors, including technology, innovation, sustainable development, and citizenship. STEM expertise is essential for addressing challenges like climate change and advancing digitization, with a focus on research-based activities to ensure up-to-date learning and innovation.Challenges such as waning interest in STEM, a shortage of qualified teachers, declining student proficiency, and low female participation in STEM fields are addressed by the LUMA Strategy.

Thirty-one action points, corresponding to five strategic objectives, shape the National Action Plan:

- Ensuring a smooth everyday life and a functional society.
- Embedding STEM competence into the fabric of society.
- Upholding high-quality early childhood education, care, and teaching across different levels.
- Cultivating interest in STEM studies.

[16] https://julkaisut.valtioneuvosto.fi/handle/10024/164953

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- Enhancing communication about STEM competence and its opportunities.
- Notably, the strategy acknowledges arts and design as vehicles for fostering enthusiasm towards STEM, yet there is no dedicated action plan specifically targeting the integration of arts and humanities into STEM education.

Finland is another country that mentions art as a discipline that could encourage STEM education, but without systematically introducing specific proposals. Collaborations with museums are mentioned as support measures for promoting communication and interest.

Germany has established a longstanding and sustainable educational environment focused on STEM studies from an early age, as reflected in the STEM education chain (STEM Bildungskette) described by Li (2022). This framework involves teachers, students, and society working together within a supportive ecosystem, backed by governmental support. The Chancellor and the Governors of the Länder have deliberated on future policy directions for education reform and development in Germany. With a strong emphasis on MINT education (Mathematics, Informatics, Natural Sciences, and Technology), they issued the Dresden resolution titled “Progress through education — the German Qualification Scheme,” underlining the government's dedication to STEM education.

Germany's renowned professional teaching system underscores its commitment to training STEM personnel. The country has implemented various policy initiatives, including promoting excellence in science and teaching, establishing specialised training courses and schools, supporting outstanding students, and organising MINT competitions. Notably, Germany prioritises off-campus and on-campus experimental projects to foster talent, with initiatives like the DRL University Laboratory offering hands-on research opportunities for students aged 9-12.

Extra-curricular programs are also given priority to supplement school curricula and cultivate interest in STEM careers through university projects and experiential learning in companies. The 2019 STEM Action Plan provided support for various initiatives falling under the three pillars of the national STEM strategy (women, education, and society). Gender equality in STEM has been on the governmental agenda since 2008 with the National Pact for Women

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in STEM Occupation[17], "Go STEM," and the "Success with STEM – New Chances for Women" initiative in 2015. Both initiatives are part of Field of Action 3, "Chances for Girls and Women in STEM," in the Federal Ministry of Education and Research's STEM Action Plan. Other initiatives include nationwide STEM clusters, the STEM Networking Center (MINTvernetzt), and the "Code your Life" initiative, where boys and girls ages 8-14 can learn programming using various tools, including Minecraft, representing a more STEAM approach.

France has a tradition of implementing science-aware and science-focused policies and initiatives, primarily centred on collaboration between schools and industry, albeit not specifically targeting STEM fields. Through project-specific collaborations involving key stakeholders such as foundations, banks, and companies (Beernaert & Kirsch, 2013), ongoing efforts are made to foster interest in STEM and broaden the STEM community.

A notable example is the « Que faire dans le monde? Un métier!/ What to do later in life? A profession» program, which targets lower secondary schools. Additionally, the Action Sciences à l'école initiative, led by the Ministry of Education, supports science student projects and provides teachers with appropriate tools, targeting both lower and upper secondary levels.

Moreover, initiatives like "La main à la pâte" collaborate with the Ministry of National Education to support and train teachers, provide scientific and pedagogical resources in classrooms, and engage the scientific community to renew science education. This effort began in June 2000 with the adoption of a Plan for the Renovation of Science and Technology Education in Schools (PRESTE), gradually providing all schoolchildren with science education inspired by "La main à la pâte". The approach was later integrated into the new science and technology programs for primary schools. In addition, pilot colleges were established in 2016 as prototypes where pedagogical experimentation draws on contributions from the scientific and technical world to design the college of tomorrow. Located in priority education zones or rural areas for half of them, these establishments aim to promote an attractive and creative practice of sciences and technology in the classroom, fostering

[17] https://graduatewomen.org/wp-content/uploads/2014/01/2013-07-12-GERMANY-Pact-Background-Goals1.pdf

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synergies between researchers, engineers, and technicians working in laboratories and companies, on the one hand, and teachers, on the other. The objective: to work as a team to implement interdisciplinary projects.

Another relevant example is the "Paroles de Chercheurs" program initiated in 2020 and running again from 2023 to 2027. It implies interventions by researchers in secondary schools in the Paris region to inspire scientific vocations among young people.

However, a persistent obstacle for schools is the traditional assessment method and the rigid frameworks underpinning mandatory curriculum requirements. Educational professionals are grappling with integrating new teaching methods that align with these fixed objectives.

Established in 2012, the National Council for Scientific, Technical, and Industrial Culture serves as an advisory body to ministers responsible for Research and Culture. This council focuses on four cross-cutting themes (Gender equality, Climate change and sustainable development, Europe, History of science and technology) through five strategic orientations, aiming to promote scientific literacy and engagement.

The introduction of the new curriculum for lower secondary students in 2015, promoting interdisciplinary education through Enseignements Pratiques Interdisciplinaires (EPI), is noteworthy. This curriculum includes eight areas of interest, each addressing various aspects of STE(A)M, although not comprehensively. These areas cover topics such as body, health, well-being, and security; culture and artistic creation; ecological transition and sustainable development; information, communication, and citizenship; languages and cultures of antiquity; foreign languages and cultures; economic and professional world; and sciences, technology, and society.

Regarding Science and Society dialogue, a noteworthy aspect of the Law on Research Programming (LPR) of December 2020 is that it mandates at least 1% of the intervention budget of the National Research Agency (ANR) to be dedicated to sharing scientific culture.

The most recent Digital Education Strategy (2023-2027)[18] follows a similar approach, aligning with the aforementioned initiatives.

[18] https://www.education.gouv.fr/strategie-du-numerique-pour-l-education-2023-2027-344263

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3.2.2 Nations acknowledging the importance of STE(A)M education in their policies

EU Countries that have set STE(A)M as an important policy need are Austria, Romania, Denmark, Spain, Malta, Italy, Greece, Poland, Croatia, Lithuania, Estonia, the Netherlands and Latvia.

Austria has initiated the "Join in STEM: BMBWF[19] action plan for more STEM experts" (2023-2030) to address the growing demand for STEM professionals. The BMBWF Action Plan aims to bolster STEM education and participation through various strategies. Recognizing the crucial role of STEM skills in addressing contemporary challenges such as digitalization and climate change, Austria underscores the importance of inspiring and supporting young people, particularly women, to pursue STEM education successfully.

Key initiatives include:

- Enhancing regional networking through the "STEM Regions" umbrella brand to promote effective and sustainable STEM education for all.
- Establishing an online platform to showcase and connect STEM activities nationwide.
- Promoting STEM careers through role models, science ambassadors, and contemporary communication channels to challenge stereotypes and encourage diverse participation.
- Supporting STEM talents throughout their educational journey to prevent talent loss.
- Improving teacher training and curriculum to enhance STEM learning, including interdisciplinary approaches and social/ethical considerations.
- These actions are aimed at increasing the proportion of STEM graduates and women in technical subjects by 2030, thereby contributing to Austria's long-term STEM education and workforce development goals.

[19] Ministry of Education, Science and Research (Bundesministerium für Bildung, Wissenschaft und Forschung or BMBWF).

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In recent years, **Romania** has initiated an Action Plan for Education (2019-2030) aimed at achieving specific objectives. These objectives include the development of a new trans-disciplinary STEM curriculum across all educational levels, the creation of Open Educational Resources, the revision of the framework for STE(A)M educators, and the establishment of monitoring and assessment tools. Additionally, fostering synergies and collaborations between educational institutions and various societal stakeholders, financial entities, companies, and schools is a key priority.

In line with this objective, technology leader Garrett Motion Inc. has forged an ongoing partnership with educational institutions in Romania, such as the Bucharest University of Economic Studies (ASE). This partnership involves providing support and financial backing for STEM university programs (2020-2021), organising mentorship initiatives, and offering internships to students.

The revised curriculum adopts a STEAM (Science, Technology, Engineering, Arts, and Mathematics) approach, emphasising the fusion of creative thinking with computational, technological, and mathematical skills.

In 2018, **Denmark** launched the Danish Technology Pact[20], a national initiative aimed at enhancing STEM sciences. Supported by the Danish Government, its primary objective is to equip individuals of all ages with the requisite skills for an increasingly technical and digital future. This is deemed essential for sustaining Danish competitiveness and tackling societal challenges through technological and digital innovation.

The pact is built upon close collaborations among academia, research institutions, business organisations, private companies, non-profit entities, and private foundations. It links STEM education with employment opportunities and labour market demands. Notably, the importance of creativity (STEAM) is underscored as a means to innovate and develop new technological solutions.

A key aspect of the government's strategy involves increasing enrollment in higher education programs within the STEM fields, aimed at addressing the shortage of STEM professionals.

[20] https://eng.em.dk/news/2018/apr/the-danish-government-launches-the-technology-pact

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Furthermore, digitising higher education and nurturing digital skills among students are complementary national initiatives undertaken to bolster the workforce for a tech-driven future.

In **Spain**, STEM programs are regionally organised and heavily reliant on initiatives from educational institutions and teachers. The Spanish government has made efforts to integrate STEM in the new curricula as well as in teacher training courses to promote its development. The Ministry of Education and Vocational Training has identified the increase of STEAM vocations, particularly among girls, as a crucial challenge for the Spanish educational system. The Alliance STEAM for Female Talent is a recent initiative that aims to engage women and girls to choose STEM-related studies, narrow the gender gap and bring new perspectives to technological projects. Programs like "STEM Talent Girl" and "Poderosas", which are included in the Alliance, directly and indirectly contribute to the advancement of STEM competencies (Estévez-Mauriz & Baelo, 2021). Currently, only 28% of women pursue STEM university careers in Spain, which is below the OECD-EU average, highlighting the need for concerted efforts to empower females in STEM fields.

At the regional level, certain autonomous communities like Galicia and Catalonia have begun integrating STEM education guides into teacher training programs. The aim is to provide teachers with robust pedagogical training applied to STEM disciplines and to implement policies fostering a holistic approach to STEM skills development from an early age. In Catalonia, an innovation project for the digitisation of educational centres funded by Next Generation and promoted by the Department of Education of Catalonia has equipped public schools with educational robots and digital panels in order to promote STEAM skills. Additionally, experimental projects such as "TIC STEAM" and "Ingenia Secundaria" in Castilla y León are incorporating programming techniques and robotics into education, leveraging information and communication technologies.

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Malta has prioritised science education as a high priority, aligning with France's approach, through the National Education Strategy 2024-2030[21]. However, a significant distinction lies in Malta's adoption of a whole-governmental approach, focusing not only on supporting science education but also on the development of scientific literacy. Criteria such as Real World Connections, the establishment of a community of practice for student learning, and interdisciplinary problem-solving and decision-making, as highlighted in the RoadSTEAMer program, are not only evident in Malta's strategy but are also firmly embedded within the national policy vision.

Within this framework, the primary target audience, as stated, is learners across all educational levels, with efforts coordinated accordingly. While STEM education is acknowledged as a means to better align with labour market and industry needs, the strategy emphasises measures such as financial incentives for students pursuing STEM careers and targeted scholarships in focal areas.

In terms of official policies and national strategic planning, **Croatia** may not be considered among the countries that have prioritised STEM education. Despite an active policy in 2014 (Education, Science, and Technology), according to available data, there is currently no such policy in place. This early policy initiative prioritised equal opportunities in science and was linked with the country’s further development. This goal is also served through the Act on Higher Education and Scientific Activity (October 2022), which aims to transform education in Croatia through digitization and modernization of higher education and science, laying the groundwork for future transnational collaborations and participation in Horizon programs.However, although the official policy on STE(A)M is narrow and broadly defined, a grassroots initiative has transformed the STEM landscape in the country. The STEM revolution, spearheaded by the Croatian Makers Project and mathematician Nenad Bakić, is a bottom-up initiative that has had a significant impact. The Croatian Makers Project[22] was successfully crowdfunded and has equipped Croatian schools with robots, distributed 25,000

[21] https://education.gov.mt/wp-content/uploads/2023/12/NATIONAL-EDUCATION-BOOKLET-DEC-2023-2030.pdf
[22] https://croatianmakers.hr/en/home/

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coding devices to more than 1,000 institutions, organised public events, competitions, and free workshops for everyone.

In **Italy**, the asset of the primary and secondary school system has been revised with law n. 107/2015, informally known as “La buona scuola” (“The Good School”). This law, despite not mentioning explicitly neither STEAM nor STEM, offers a number of references to concepts relevant for STEAM approaches. Its stated objectives notably include the “strengthening of logic / mathematics and scientific skills” (art. 7 letter b), but also “strengthening of [...] musical and artistic culture and competences” with an explicit mention for fostering collaborations with museums and other institutions (art. 7 letter d), which is interesting from a STEAM perspective as well as in terms of open schooling. Visual arts even get a second mention under letter f of the same article, while one-off extra funding for artistic institutions is covered under article 53. Additionally, it is worth noting that art. 60 explicitly encourages practices such as living-lab didactical approaches and opening the school to collaborations with other actors such as local authorities, industry / world of business, not-for-profit entities, which can be linked to “open schooling”, one of the focus areas of Road-STEAMer. Another element of law 107/2015 is the focus given to a mandatory number of hours to be spent in work placements (known as “school-work alternation”, in Italian: *alternanza scuola-lavoro*) in the last three years of secondary school. However, it must be noted that there is some criticism in regards to practical implementation of school-work alternation, as internship placements are not always coherent with the students’ learning pathways[23]. Furthermore, the objectives of the law also refer to environmental sustainability (art. 7 letter e) and development of students’ digital skills (art. 7 letter h), linked to the launch of an ambitious National Plan for the Digital School (artt. 56-59). There is a mention for boosting learning-by-doing / living lab approaches (art 7 letter i), which link to the Road-STEAMer criteria of thinking-making-doing and real-world applications, whereas “enhancing individualised learning paths and student engagement” (art. 7 letter p) echoes the Road-STEAMer criterion of Inclusion / personalisation / empowerment. Going beyond the objectives, the law reinforces the schools’ autonomy, granting them more flexibility in developing their own curricula (whilst following

[23] See for instance Salerno C. et al, "Alternanza scuola lavoro": an observational study of the experience in Italy in upper secondary school in the years 2016-2018.] G Ital Med Lav Ergon. 2020 Sep;42(3) 178-186. PMID: 33119978. https://europepmc.org/article/med/33119978

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nationally agreed frameworks per each type of school), with the possibility for upper secondary schools to introduce "optional" disciplines (art. 26) in addition to core ones.

The above mentioned National Plan for the Digital School has been subsequently fleshed out by the Ministry of Education, Research and University.[24] While only referring explicitly to STEM, this plan hints at STEAM when referring to critical thinking, problem-solving and creativity as some of the 21st century skills to be developed. Furthermore, among the 35 action points listed, there is one to tackle the "confidence gap" that leads to a low number of girls in tech and science (action 20), and another one to increase the number of students who apply for and who graduate with a STEM degree (action 21). Moreover, there are several actions referring to digital competences training for newly hired teachers as well as upskilling of the existing workforce. Other actions focus on digital access (e.g. broadband, digital labs) and on setting minimum standards. A few years later, with ministerial decree (DM) 147/2021 the ministry of education and research has allocated funds for schools to set up STEM labs and have so-called "digital facilitators" in each school as foreseen by the National Plan for the Digital School.

More recently, in 2023, two further ministerial decrees allocated funds from the National Recovery and Resilience Plan (PNRR) to schools nationwide: one envelope (under DM 65/2023) meant to be used for integration of activities, methodologies and contents aimed at developing STEM and (foreign) language competences, whereas the other (under DM 66/2023) is aimed at digital transition, and most specifically to ensure continuous learning for staff in each school.

Additionally, there are a number of other initiatives and funding opportunities available to schools and/or individual educators to adopt STEAM approaches. These include, for instance, the "Avanguardie Educative" (Educational Vanguards) movement for educational innovation promoted by INDIRE – the National Institute for Documentation, Innovation and Educational Research, a public research institution part of the Ministry of Education and Research. It is worth noting that *Avanguardie Educative* is not strictly about STE(A)M, but some if its initiatives are aligned with the STEAM framework developed as part of

[24] Ministero dell'Istruzione Università e Ricerca (2015), *Piano Nazionale Scuola Digitale* https://www.miur.gov.it/documents/20182/50615/Piano+nazionale+scuola+digitale.pdf/5b1a7e34-b678-40c5-8d26-e7b646708d70?version=1.1&t=1496170125686 Last consulted on 1 March 2024

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Road-STEAMer, for instance those that promote learning beyond disciplinary boundaries, Technology Enhanced Active Learning, and personalisation of learning pathways. Another interesting initiative is “Tutti a Iscol@”, which means “All (back) to school”, funded by the Sardinian Autonomous Region, which includes the option to have lab-based extra-curricular activities, such as educational robotics labs that promote learning-by-doing.

An initiative deserving special recognition is The 'Art and Science across Italy' program. The 'Art and Science across Italy' program, organised by the Italian National Institute for Nuclear Physics (INFN) in collaboration with CERN and supported by the CREATIONS project, aims to engage high-school students in Italy with scientific discoveries and technological innovations from particle physics, astroparticle physics, and cosmology. This initiative serves as a bridge between schools and research infrastructures, integrating formal and informal learning settings to foster students' creativity, inquiry, and enjoyment in science education within the STEAM movement. Through a hybrid approach combining face-to-face and virtual activities enriched with technology, the program unfolds over four phases spanning approximately 16 months. Initially, students participate in out-of-school activities including visits to science and art centres, seminars, and workshops to interact with scientists, educators, artists, and art educators. They engage in workshops using real open data simulations and visit interactive exhibits to conceptualise similarities and differences between scientific and artistic creativity. In the project-based learning phase, students work collaboratively to create artistic compositions inspired by scientific topics of their choice. These artworks are then showcased in local art and science exhibitions, leading to a national competition where winning teams are awarded a week-long art-science Masterclass at CERN or one of the INFN institutes in Italy (Alexopoulos et al, 2021).

In **Greece**, the education system is characterised by a centralised structure, which restricts autonomy in schools and mandates common curricula and textbooks. While recent reductions in syllabus content have allowed for more flexibility in teaching methods, there is still a lack of formal integration of interdisciplinary methodologies in primary school education. Nonetheless, modern curricula have been developed to include activities aligned with STEM

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education principles. The "Open Schools for Open Societies (OSOS)"[25] project, initiated in 2017, aimed to pilot STEM and STEAM approaches in schools. Initially, thirteen (13) schools were selected for participation, and expanded to 101 more schools in the coming years. Research has shown positive outcomes from STEM and STEAM approaches, such as enhanced educational processes and improved student performance in coding but also involving arts and creativity. It's crucial that the Institute of Educational Policy, operating under the Ministry of Education, has been engaged as the National Coordinator for Greek schools. Additionally, the Institute of Educational Policy has overseen and facilitated Greek schools' participation in two additional projects focusing on STEM/STEAM approaches: Reflecting for Change[26] and Learning from the Extremes[27], involving an additional 120 schools. Despite these initiatives, the implementation of STEM activities in Greek schools remained fragmented and isolated, lacking systematic and long-term integration.

The Skills Labs (2020) is an innovative school module focused on developing soft and digital skills essential for an evolving world. It emphasises fundamental life skills, such as health and social interactions, alongside advanced skills like communication and critical thinking. Aligned with UN Sustainable Development Goals, particularly Goal 4.7, it has received recognition from international bodies like UNESCO and the Global Education Network Europe. The Labs consist of four thematic cycles, each addressing contemporary issues through student-centred activities. It's integrated into the national curriculum, with kindergartens and elementary schools dedicating 3 hours per week and lower secondary schools 1 hour per week. Education materials, developed by various civil society organisations, are curated by the Institute of Educational Policy and shared on an online platform for collaboration among teachers. This approach decentralises and pluralizes the education system, empowering teachers and schools in curriculum design. A pilot program involving 2,500 teachers in 217 schools was conducted in 2020/21, and since September 2021, the Skills Labs have been implemented nationwide. Furthermore, nearly all targeted teachers have completed or enrolled in the 32-hour online workshop for Skills Labs module teacher training.

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[25] https://www.openschools.eu/
[26] https://reflecting4change.eu/
[27] https://learningfromtheextremes.eu/

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In **Poland**, the Laboratories of the Future program (Laboratoria Przyszłości) has been running from 2021 to 2024, focusing on primary schools. The initiative, with a reported budget exceeding 1 billion PLN, achieved effective promotion and widespread participation across primary schools in Poland, with 99% of municipal schools involved. Schools had autonomy in selecting and purchasing equipment tailored to their needs, without requiring contributions from local governments, ensuring accessibility across regions. Teachers and even students played a role in decision-making regarding equipment selection. Participating schools created specialised workshops and classes, utilising the equipment in various subjects and extracurricular activities. While schools are required to submit implementation reports, there's no compilation of these results available. The program also stimulated companies in the educational aid market, with a wide range of offerings for purchasing workshop equipment, sets, instructional materials, and methodological support. Among the problems that were posed was a lack of competence from teachers to effectively use the purchased equipment. To address this issue, stakeholders will advocate for a new educational organisational model, incorporating innovative methodologies to facilitate an interdisciplinary, cross-curricular approach. Additionally, they propose the introduction of a new position, such as a "digital coach," tasked with ensuring the efficiency and updating of systems, equipment, software, facilities, security, and other related aspects.

On the other hand, stakeholders have emphasised that the Laboratories of the Future program has played a crucial role in providing students from smaller towns with access to new technologies, such as robotics classes, which were previously more readily available to their counterparts in larger cities. This initiative has enabled students in smaller towns to now experience such advancements firsthand at school, thereby making a significant contribution to educational inclusivity.

Among the programs implemented where:

- The Mobile Future Labs (launched in September 2022) consist of 16 buses equipped with state-of-the-art educational tools. Educators demonstrate practical applications of equipment obtained through the Future Laboratories program.

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- The Robot League, conducted within the framework of the Laboratories of the Future program, is a nationwide robotics competition aimed at fostering interest in robotics and contemporary technologies among students in grades 4–8 of primary schools.

One of the primary challenges facing STEM education in Poland is the deficiency in digital education competencies among teachers, hindering their ability to effectively utilise the provided equipment and develop methodologies for integrating technologies into their teaching practices.

Lithuania is another country that falls into this category due to a specific policy initiative in place, particularly from 2015-2020 (STEAM action plan), albeit without continuity. The STEAM action plan aimed to reform the national educational system around STEAM areas, focusing on enhancing secondary level students' achievements and supporting teachers through professional development. Another key aspect was raising awareness about STEAM.

The new educational development program for 2021-2030 prioritises three areas: mathematics, basic skills, and inclusion, while also aiming to enhance ICT teacher competencies. However, challenges such as the effective organisation and implementation of STE(A)M programs, a highly standardised educational system that limits creativity, lack of equipment in classrooms, and unbalanced curricula (Cibulskaitė & Augustinovič, 2020) hinder the implementation of a STEM educational program.

Through the Lithuanian National Educational Agency, students have the opportunity to assess STEM education in their schools using the STEMSchool Label tool.

Similarly, **Estonia**, among EU countries, has relatively limited but present initiatives in terms of STEM policies. The Estonian Lifelong Learning Strategy 2014-2020 establishes a framework for transitioning to an innovation and knowledge-driven educational environment, emphasising equal and tailored learning opportunities for all, with a preference for experiential learning approaches. While key indicators for achieving overarching goals

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include student performance in mathematics, reading, and science, specific STEM approaches are not explicitly incorporated.

The recent Estonian Educational Strategy 2021-2035 aims to address challenges such as the ageing teacher community, including those in STEM education, by providing opportunities for new teachers. Additionally, a science TV show titled “Rocket69[28]”, dedicated to STEM education and practices, funded by the Estonian Research Council and broadcasted nationally, has played a role in popularising STEM.

The Netherlands has a targeted policy on STEAM education. Integrating Science, Technology, Engineering, Arts and Mathematics into education is a priority for many countries, including the Netherlands.

In the Netherlands, STEAM education is stimulated by various initiatives and programs, both at national and local levels. An example is the Technology Pact, a collaboration between educational institutions, the business community and the government to promote and improve technology education. This pact focuses on encouraging technology education at both primary and secondary education levels, which is an important part of STEAM education.

In addition, various subsidies and funds have been made available for schools and educational institutions that want to develop initiatives in the field of STEAM education. There are also programs that are specifically aimed at promoting digital skills and technological knowledge among both teachers and students.

Although there is no specific 'STEAM policy' as in some other countries, there are certainly initiatives and programs aimed at promoting STEAM education in the Netherlands.

How STEAM education in the Netherlands is becoming increasingly important and is being integrated into the educational landscape in various ways shows in some of the following examples: There are ‘STEAM Schools and Programs. They are schools and educational

[28] https://researchinestonia.eu/rocket69/

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programs that specifically focus on STEAM education. These schools integrate science, technology, engineering, arts and maths into their curriculum and approach learning in a more interdisciplinary way. Many mainstream schools integrate STEAM elements into their existing curriculum. This can be achieved through project-based learning, where students, for example, collaborate on projects that span different STEAM disciplines. Outside the regular curriculum, extracurricular STEAM activities are often offered, such as after-school clubs, workshops, and competitions such as FIRST LEGO League[29] and the Dutch Mathematical Olympiad[30]. Also schools partner with companies, museums, universities and other institutions to expose students to hands-on STEAM experiences and to help them understand the relevance of STEAM topics in the real world..

There is a growing emphasis on the professional development of teachers in STEAM education to equip them with the necessary skills and knowledge for integrating STEAM principles effectively into their classrooms. Such initiatives play a crucial role in promoting STEAM education in the Netherlands, aiming to prepare students for the skills and challenges of the 21st century.

Latvia's efforts toward STEM practices and education are primarily driven by labour market demands and OECD key figures[31]. In 2019, state funding was directed towards university STEM fields, resulting in increased enrolments. An important milestone in Latvia's educational development occurred through a national program, supported by funding from the European Union, spanning from 2005 to 2008. This initiative focused on enhancing the upper secondary science and mathematics curriculum, leading to the provision of updated study resources in chemistry, biology, physics, mathematics, and related sciences for grades 10 through 12 in all secondary schools. Since the academic year 2008/09, secondary school students have been engaging with science and mathematics education aligned with these refreshed standards.

[29] https://firstlegoleague.nl/
[30] https://www.wiskundeolympiade.nl/docenten/info-in-english
[31] https://www.oecd.org/education/policy-outlook/country-profile-Latvia-2020.pdf

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Moreover, one of the key goals outlined in Latvia's National Development Plan 2020 (NDP2020)[32] is to enhance students' proficiency in mathematics and fundamental skills in science and technology. To achieve this objective, various actions will be implemented, including the incorporation of innovative curriculum content and activities in primary and secondary education to foster students' creativity and entrepreneurial skills. Additionally, efforts will be made to establish a digital learning environment, enhance the quality of natural science curricula, and strengthen career guidance services within the education system. Furthermore, initiatives will be undertaken to identify and nurture students' talents, which may involve supporting youth science and technology centres, organising academic summer camps, and facilitating science workshops, competitions, and research projects.

3.2.3 Countries may not prioritise STE(A)M education or may be in the process of developing such initiatives.

EU countries that fall into this category are Czech Republic, Slovenia, Hungary and Slovakia.

The Czech Republic falls into this category due to the lack of specific policy initiatives and available data indicating a STEM-specific strategy. An example of this is the Strategy for Education Policy of the Czech Republic[33], which was in effect until 2020 and had a basic technological orientation, focusing on preschool, elementary, and secondary education.

In **Slovenia,** there isn't a targeted policy specifically focused on STE(A)M. In March 2023, the country adopted the “Digital Slovenia Strategy 2030”[34], with the goal of achieving a national digital transformation through digital infrastructures, ICT education, and digital literacy. Notably, STEM education is not explicitly mentioned in this strategy.

As for **Slovakia,** STEM education is a relatively new but increasingly important area of policy action. Currently, initiatives are primarily driven by individual teachers, with practical challenges being encountered along the way (Brečka & Valentová, 2024).

[32] https://www.pkc.gov.lv/images/NAP2020%20dokumenti/NDP2020_English_Final.pdf
[33] https://www.msmt.cz/uploads/brozura_S2030_en_fin_online.pdf
[34] https://nio.gov.si/nio/asset/strategija+digitalna+slovenija+2030?lang=en

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In **Hungary** (partially as the response to the great science teacher shortages) a recent development is a new teacher training course, called Teacher of Science and Environment that trains teachers to be able to teach chemistry, physics, biology, and general natural sciences in lower grades. It is also compulsory to either pick a science subject (additionally to Mathematics, Hungarian Literature and Grammar, History, a Foreign Language) as part of the general high school end exam, or count the grades of one science subject to apply for higher education. According to Balázs Hankó, State Secretary of the Ministry of Culture and Innovation "The government's goal is for the share of mathematics, natural sciences, engineering and IT fields in higher education to reach 50 percent by 2030, so every second student would be choosing a STEM course"[35].

The State Secretary mentioned that the government's strategic goal is for the country to become one of the top 10 innovators in Europe, with the number of developers reaching 90,000, and for this to happen, research and development (R&D) expenditures relative to GDP must be increased to 3 percent by the end of the decade.

STEAM as a concept is not something that exists in general Hungarian education, arts are taught completely separately from STEM subjects.

3.3 Countries outside Europe and STE(A)M national policies

In this section, we include an overview of some national STE(A)M policies in European countries that are not part of the EU, but that have long standing relationships with EU members and can serve as a comparison with other countries.

The **UK -** which was an EU member until the end of 2020 - boasts a rich history of STEM policy with very small-scale references to STEAM in recent years.The UK government Science and Innovation Investment Framework report 2004–2014, laid out key proposals regarding STEM skills for a decade of policy action. Around this time, In 2005, a Science Forum was established which provided a platform for discussing critical issues, including

[35] https://budapestcollege.hu/the-hungarian-government-doubles-down-on-stem-education/

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STEM skills and fostering future collaborations among diverse stakeholders. The UK governmentScience and Innovation Investment Framework report, "Next Steps"[36] aimed to refine specific points and bolster metrics. This has recently been followed by the UK Science and Technology Framework: Update on progress (updated Feb 2024) which highlights a long term vision for STEM in the UK, but does not emphasise STEAM as part of this approach. Whilst STEM has been well supported in the UK with respect to government policy, STEAM has been much less strongly emphasised.

In 2016, the Cultural Learning Alliance[37], a coalition advocating for arts, creativity, and innovation, emphasised the importance of integrating arts into STEM education to create a sustainable workforce and conducive learning environments. They suggested that this shift from STEM to STEAM could be facilitated through new models of collaboration, innovative teaching methods, and adequate public funding. They proposed next steps including the creation of a national network of practitioners and experts, a digital STEM resource bank, and the establishment of an All-Party Parliamentary Group (APPG) for STEAM to garner necessary political consensus. Additionally, the Labour Policy Forum in 2016 provided another avenue for policy advocacy, stressing the importance of STEAM over STEM, emphasising traits like openness, critical thinking, and adaptability to address upcoming challenges.

The UK Government, in response to the Science and Technology House of Commons Select Committee's Fifth Report on Diversity and Inclusion in STEM (2022-2023), emphasised the imperative of fostering inclusivity and diversity within STEM education, research, and employment sectors to maintain the UK's position as a science and technology leader. This commitment is reflected in initiatives outlined in the UK Science and Technology Framework, which prioritises innovation to promote diversity and inclusion. Efforts, such as the R&D People and Culture Strategy and the Innovation Strategy[38], aim to attract and retain top STEM talent and drive economic growth through innovation. Whilst this does not directly reference STEAM, a recent 2022 House of Lords[39] strategy focus briefing identifies the

[36] https://dera.ioe.ac.uk/id/eprint/14223/1/file31810.pdf
[37] https://www.culturallearningalliance.org.uk/
[38] https://www.gov.uk/government/publications/research-and-development-rd-people-and-culture-strategy
[39] https://lordslibrary.parliament.uk/arts-and-creative-industries-the-case-for-a-strategy/

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creative industries and arts as a driver of economic growth and as an identified priority area alongside STEM that requires future support in wider UK strategy.

The Department for Education is charged with developing a cross-government action plan to address the shortage of STEM skills, ensuring equitable access to STEM careers for all individuals. By 2030, the government aims to increase participation in STEM fields and enhance diversity in the science and technology workforce through data analysis, prioritised mathematics education, expansion of computing and digital sectors, global AI talent attraction, and the establishment of employer-led Institutes of Technology. Overall, the UK policy is clearly focused on a STEM approach within formal education, with the National Science Learning Centre and the Network of Regional Science Learning Centres serving as foundational platforms supporting STEM education nationwide; STEAM has received relatively little formal policy attention.

In **Ukraine** numerous initiatives have been launched in Ukraine to align with current educational trends, spurred by the Institute of Gifted Child of the National Academy of Educational Sciences of Ukraine[40], the Junior Academy of Sciences[41] - which is also an affiliated entity of Road-STEAMer - , and the UNESCO Chair on Science Education[42]. Among these initiatives, notable ones include the Conceptual Principles of Secondary School Reform known as "The New Ukrainian School," the Standard of Specialized Science-Oriented Education, the Concept of the Development of STEM Education until 2027, and The Great Transformation Program "Education 4.0: Ukrainian Sunrise”. Stakeholders highlight the significance of numerous educational initiatives across various levels of policymaking, including:

- STEM Education Department at the Institute of Modernization of Education of the Ministry of Education and Science of Ukraine foundation
- Working Group on implementation of STEM education in Ukraine

[40] https://www.iod.gov.ua/news.php
[41] https://man.gov.ua/en
[42] https://unesco.udu.edu.ua/en

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- MES Order of May 17, 2017 No. 708 “Creating and functioning of the All-Ukrainian Scientific and Methodological Virtual STEM Centre
- Order of the Ministry of Education and Science of Ukraine of April 29, 2020 No. 574 “On Approval of the Model List of Teaching Means and Equipment for Classroom and STEM Laboratories” Action plan for implementation Concepts of development of natural and mathematical education (STEM EDUCATION) by 2027.

Other type of initiatives include:

- An annotated catalogue titled “STEM EDUCATION: Problems and Prospects” containing: the list of regulatory support for the implementation and development of STEM education; list of scientific and practical publications covering the results of theoretical and experimental studies in STEM education; catalogue of educational and methodical literature; recommended network resources to support students' research activities.
- The STEM-week event is held annually within the framework of the All-Ukrainian Stem-Spring Festival in order to implement the provisions of the Concept of STEM-Education, the exchange of experience in the development of STEM-education directions in Ukraine and participation in April European STEM- events.

In the Ukrainian context, emphasising STEM education is seen as a core element of education, incorporated into public policy to boost economic competitiveness and cultivate human capital. Serving as a key driver for advancing educational innovation, STEM education is critical for meeting the changing needs of today's economy and society, and achieving sustainable development (Buturlina et al, 2021).

The ambitious Great Ministerial Transformation Program "Education 4.0: Ukrainian Sunrise," launched in 2022 with a horizon extending until 2032, outlined comprehensive plans for modernising education. These plans included prioritising the development of STEM education, updating teacher training programs, and enhancing educational infrastructure such as techno parks. However, stakeholders note that financial constraints resulting from military aggression have hampered the active implementation of this policy.

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3.4 STE(A)M policy in EU and non EU countries: Further Notes

Countries prioritising STE(A)M education in their policy agendas have implemented various strategies tailored to different target audiences. Following recent EU recommendations advocating for a comprehensive governmental approach to STE(A)M education, several EU nations, including Belgium, France, Malta, Lithuania, Bulgaria, Finland, and Germany have positioned STE(A)M education at the forefront of their national policies. These countries have established long-term objectives aligned with European roadmaps to foster sustainable digital and green economies, with a particular emphasis on addressing inequalities. Additionally, they recognize the pivotal role of STE(A)M education across all levels of education, providing support for professionals, teachers, and societal engagement initiatives. However, even in cases where the national policy context deviates from the whole-governmental approach recommended by official EU documents, countries such as Malta and Estonia have implemented initiatives targeting a wide range of audiences, from primary and secondary educational levels to the general public.

However, most EU countries have primarily focused on educational reform and enhancing students' digital skills through extracurricular activities or the integration of STEM into the school curriculum. Common trends among countries like Italy, Romania, the Czech Republic, the Netherlands, and Malta include project-based learning, collaborative projects, and partnerships with institutions, museums, and the scientific community. Their target audience for these initiatives is primarily primary and secondary education, with specific programs aimed at supporting teachers in STE(A)M education. The broad approach aimed at all levels of education through various means reflects the post-pandemic aftermath and the evolving role of education. Specifically, education is increasingly seen as a platform to address significant societal challenges and to prepare students for an ever-changing world (Reimers, 2021, p. 3). Before 2019 and the COVID-19 pandemic, EU policy texts focused on citizenship competence and promoted values such as social cohesion, cultural diversity, and EU citizens' participation in decision-making. However, post-2019 and amid the pandemic, there has been a notable shift towards accelerating digital transition, with STE(A)M education emerging as a key driver of change[43].

[43] https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52020DC0274

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On the contrary, some countries appear to have more defined target audiences. Poland, Croatia, and Greece have directed their efforts towards primary education, Latvia and Lithuania towards secondary education whereas Austria, Hungary and Denmark have set their sights on goals more oriented towards teachers and STE(A)M professionals. Especially concerning cases where policies are oriented towards professionals, STE(A)M education appears to be associated with talent scarcity and national shortages in labour demand.

Social inequalities, particularly concerning the inclusion of women and girls in STE(A)M education, are central pillars in the policy agendas of EU countries. Most countries have initiated specialised programs aimed at increasing the participation of women in STE(A)M fields, recognizing it as a crucial issue that requires systematic attention. Notable examples include Bulgaria, Finland, Belgium, Germany, France, Spain, Switzerland, UK, Estonia, Italy, Spain and Austria.

Finally, while the role of arts and humanities in STEM fields has not been explicitly outlined in EU official policy texts and is often utilised as a method to specifically attract women to STEM, we witness interesting policy implementations at the national level. The “Arts and Science across Italy” program, promoting collaboration between scientists and artists and resulting in the creation of artistic compositions inspired by scientific topics of their choice, is a notable example. Creative education and art-rich schools, where "adding the 'A' of arts to the STEM subjects will enable the arts to fulfil their role in developing pupils' ability to innovate and think creatively in the sciences, technology, engineering, and mathematics," are emphasised in the UK's policy advocacy discourse[44]. Senior high schools in Denmark offer STEAM-specific courses in areas such as aquaculture and video game design. Other countries, such as Bulgaria, Belgium, and Finland, emphasise the importance of art in STEM education as part of their policy objectives.

[44] https://www.culturallearningalliance.org.uk/

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4. Beyond policies: Bottom-up initiatives on STEAM

4.1 STEAM programs in the performing arts

Although the connection between the performing arts and STEM (Science, Technology, Engineering, and Mathematics) may not be as immediately apparent as the link between STEM and visual communication (McGrath and Brown), the significance of performance abilities in various aspects of a scientific career is readily acknowledged in bottom-up initiatives that include teaching, presenting, collaboration, and the process of learning itself. Initiatives that amalgamate STEM with the performing arts serve to refine communication skills, which are an essential supplement to an individual's scientific expertise. Furthermore, the interactive essence of performance activities engenders dynamic, socially engaging, and entertaining projects. These projects are beneficial not only for science students and professionals but also for interdisciplinary teams and individuals without a scientific background.

Theater

Utilising theater as an educational instrument can motivate students to discover innovative methods for assimilating and expressing their comprehension of complex and abstract natural phenomena as well as science notions. Theater's efficacy in engaging students at various academic levels is notably significant, due to its incorporation of active participation, discussion, knowledge acquisition, and creativity. Consequently, theater can facilitate the development of a learning environment centred around students' needs and perspectives, as highlighted in Urbaniak et al.

One particular application of theatre in the educational context is referred to as "Reader's Theater."[45] This approach involves students endeavouring to narrate a compelling story by

[45] https://www.readingrockets.org/classroom/classroom-strategies/readers-theater

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reading from a script provided by educators. The script focuses on the relevant educational content. Although traditionally this method has been employed to enhance students' fluency and expressiveness in reading, its role transforms when students are tasked with script creation. In this scenario, Reader's Theater evolves into a medium for fostering scientific narration, enabling students to condense, examine, and conceptualize the subject matter. Additionally, improvisational and applied theater techniques have been recognized as valuable assets in the classroom setting. These methods aid in enhancing students' abilities to think spontaneously and to effectively articulate and amalgamate scientific concepts.

In Learning Science Through Theater[46] (LSTT), students innovate, create and learn by performing scientific notions. LSTT is an educational activity embraced at both Greek and European level, promoting Science Communication & Education in a way that connects the school with the local community as well as the research community through an innovative and creative approach. It was initiated by Science View in 2014 and is carried out annually in cooperation with several institutions (Ellinogermaniki Agogi, National and Kapodistrian University of Athens, The Institute for Educational Policy of the Greek Ministry of Education).
In the context of the initiative, students from all grades (primary & secondary schools) are expected to dramatize scientific notions and knowledge drawn from their school curriculum having also as a scope to provide solutions or motivate the community around the school.

The LSTT initiative is based on the development and operation of the STEAM IDEAS' Square (SIS) that is based on the Design Thinking Approach. SIS is a place, a facility, a meeting place between science, art and the society to connect all the stakeholders and draw ideas that will be realised with a common purpose, the well-being of the local/national/international community. It will FEEL societal needs, will explore and IMAGINE novel solutions for the future so to CREATE these within the school and SHARE them with the community. As an interdisciplinary approach, LSTT aims to add its contribution to the current efforts of a creative and innovative school by focusing on two key areas that could support the realization of suitable initiatives in every single school. Is building on a whole school approach to learning and setting up a roadmap for the transformation of the school classrooms to creative and innovative learning spaces. LSTT involves. every year, more than

[46] www.lstt.eu

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1000 students, 100 teachers from 100 schools from all over Greece and European Countries (e.g. Spain, Italy, Portugal).

The Global Science Opera (GSO)[47] is another innovative initiative that intertwines science, art, and education in a global collaborative framework. Established as a network encompassing scientists, art institutions, schools, and universities from all inhabited continents, GSO aims to explore and present the interconnections between these fields through the medium of opera. This unique approach not only promotes learning and engagement in science but also underscores the creative processes involved in artistic expressions like opera. GSO was conceived in May 2014 during the First International Conference on "New Developments in Science and Technology Education" in Greece. The idea materialized with the support of various educational and scientific initiatives, such as the CREAT-IT project and the International Astronomical Union, leading to the launch of its first production "SkyLight" in 2015. "SkyLight" marked the beginning of GSO's journey and was an official part of the UNESCO International Year of Light 2015, involving participants from 38 countries in a democratic and creative global effort.

Each year, GSO produces an opera based on a scientific theme. For instance, past productions have explored themes such as particle physics ("Ghost Particles"), space exploration ("Moon Village"), and environmental issues ("Thrive", focused on ecosystem restoration). The productions are not only artistic performances but also educational experiences, as they involve students from kindergarten to university level, along with teachers, artists, and scientists. This educational aspect is further reinforced through initiatives like the Erasmus+ GSO4SCHOOL project, which aims to train teachers in the GSO methodology.

A key aspect of GSO is its focus on sustainability, both as a conceptual theme in its operas and as a practice in its productions. The initiative integrates sustainability in various ways, from choosing scientific topics that align with the UN's Sustainability Goals to adopting sustainable practices in set design and production ("Ecoscenography"). This approach is in line with the ecological worldview that recognizes the interdependence of humans and

[47] Global Science Opera, https://globalscienceopera.com/

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nature. GSO's use of digital tools has also been instrumental, especially during the pandemic, allowing for the continuation of its global collaborative projects. Through digital interactions and live-streaming, GSO manages to support simultaneous performances and maintain a global community feel in its productions.

In summary, the Global Science Opera represents a successful blend of science, art, and education, fostering a global community that collaborates creatively to explore and express scientific themes through opera. Its emphasis on sustainability and digital collaboration further enhances its relevance in contemporary educational and artistic landscapes.

Science on Stage[48] represents Europe's largest network created by and for STEM (Science, Technology, Engineering, and Mathematics) teachers, encompassing destinations in over 30 countries across the continent. The fundamental objective of this network is to fortify the community of dedicated STEM educators throughout Europe. This goal is achieved by facilitating the professional development of teachers, primarily through the personal exchange of exemplary teaching practices and innovative ideas across national borders. By fostering such international collaboration and sharing of best practices, Science on Stage aims to enrich the educational experience in STEM fields and to empower educators to bring the best possible teaching methodologies and approaches into their classrooms. The network serves as a valuable resource for teachers seeking inspiration, knowledge, and connections with like-minded professionals across Europe.

Science on Stage Greece, an organisation founded in the year 2000 and headquartered in Athens, plays a pivotal role in fostering science education in Greece. Every two years, this organisation orchestrates a national selection event with the primary objective of assembling the Greek delegation for the European Science on Stage festival. The principal event under the Science on Stage[49] (SonS) program in Greece is characterised by an exhibition and competition centred around laboratory constructions and educational materials. This contest is notably inclusive, welcoming participation from teams comprising both students and teachers from all Greek schools. Spanning over two days, the event showcases all selected

[48] Science on stage, https://www.science-on-stage.eu/
[49] https://www.science-on-stage.eu/science-stage-greece

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projects to a diverse audience that includes students, educators, and the general public, providing a platform for innovation and exchange in the field of science education. In addition to the biennial event, Science on Stage Greece is actively involved in organising conferences, workshops, and teacher training sessions covering a broad spectrum of topics. These initiatives are designed to enhance the professional development of educators and to enrich the teaching and learning experience in the field of science. Importantly, the teaching materials developed as a result of these activities are made freely available, not only to teachers in Greece but also to the wider community of Greek-speaking educators. This commitment to the dissemination of educational resources underscores the organisation's dedication to advancing science education both nationally and within the Greek-speaking diaspora.

Dance

Dance and choreographically structured movement can serve as effective mediums for illustrating the complexities inherent in human scientific discoveries and knowledge[50]. An exemplary instance of this practice is Dance Exchange[51], a company that has been instrumental in fostering collaborative endeavours between artists and scientists. The works produced by this company stimulate contemplation and discussion, framing science as a fundamentally human endeavour. A notable work, "Ferocious Beauty: Genome,"[52] exemplifies this approach. In this choreographed production, dancers delve into the history and breakthroughs of human genetic research. Additionally, the associated educational curriculum engages students in hands-on modelling of biological concepts.

Beyond Dance Exchange, other initiatives at the intersection of dance and academia have emerged, such as "Dance Your Thesis" and "STEM Danceology"[53]. These initiatives integrate dance with academic themes, demonstrating the versatility and communicative power of dance in an educational context. A specific example of this innovative fusion is the

[50] See also: http://sciencechoreography.wesleyan.edu/toolbox/, Dance Your PhD Contest, http://gonzolabs.org/dance/
[51] http://danceexchange.org/about/mission-vision/
[52] https://lizlerman.com/ferocious-beauty-genome/
[53] http://stemdanceology.strikingly.com/

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collaboration between David Odde and the Black Label dance company. They created a TED Talk focusing on symmetry breaking and cell migration, showcasing the unique ability of dance to elucidate and animate scientific ideas.

Music

A notable instance of integrating music with scientific content is the work conducted by Gene 2 Music. In their unique methodology, Miller and collaborators have pioneered a technique wherein genome-encoded protein sequences are translated into musical notes. This conversion allows for the auditory representation and analysis of protein patterns, providing a novel sensory dimension to understanding genomic data. Overall, the integration of performance arts and various forms of artistic expression within STEM (Science, Technology, Engineering, and Mathematics) education and research has gained increased visibility and recognition, as observed by Miller. This burgeoning awareness and appreciation of the interdisciplinary nexus have been particularly evident through the formation and growth of a community around the conference series known as "Cultivating Ensembles in STEM Education and Research" (CESTEMER)[54]; CESTEMER serves as a platform for exploring and celebrating the confluence of the performing arts and STEM fields, highlighting the enriching and transformative potential of this interdisciplinary approach.

iMuSciCA[55], an innovative educational platform, merging music and science into an immersive learning experience. Navigating through virtual environments, learners engage in hands-on activities, manipulating musical elements to uncover scientific principles and phenomena. The main objectives of the project iMuSciCA are to develop and explore innovative technologies that facilitate co-creation tools in music activities to support STEM learning. These technologies include virtual 3D environments for designing personalised musical instruments, computer-generated sound based on physics and mathematics, and interactive interfaces for music performance. The project aims to provide practical activities for learners to explore various scientific phenomena through creative music activities, encouraging cross-disciplinary learning. It also seeks to engage students in interactive music

[54] www.cestemer.org/
[55] http://www.imuscica.eu/

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activities to enhance their interest in science and technology, while empowering teachers to design and implement project-based STEAM learning activities effectively. The project's outputs include a Workbench of Music Activities, cross-disciplinary lesson plans, and professional development materials for educators to adopt innovative teaching methodologies.

4.2 Science engagement initiatives promoting STEAM

Science festivals and contests

A science festival is an event that displays science and technology in a manner akin to an arts or music festival, cultivating an atmosphere that is both educational and festive, primarily aimed at engaging the general public. These events are designed to make science accessible and intriguing to a wide audience and can take various forms, including lectures, exhibitions, workshops, and live demonstrations of experiments. Guided tours and panel discussions often feature as part of the programming, enhancing the interactive and educational aspect of the festival. Moreover, science festivals frequently incorporate elements that link science with other disciplines such as the arts or history. This interdisciplinary approach can manifest in the form of plays, dramatised readings, and musical productions, illustrating the interconnectedness of science with broader cultural and historical contexts. While the core content of these festivals is rooted in science and technology, the presentation and style are heavily influenced by the arts. This fusion creates a unique platform that not only educates but also entertains, thereby broadening the appeal and impact of science in society.

The critical role of science festivals in promoting public understanding of both the results and broader relevance of science has been increasingly recognized by science organisations and funding bodies. This acknowledgment is reflected in the growing emphasis on outreach activities that aim to foster a deeper public engagement with science. Recent years have witnessed the establishment of numerous new science festivals, which are emerging as effective platforms for public engagement and science communication. In response to this growing trend, the European Science Events Association (EUSEA) was established in 2001

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as an umbrella organisation. EUSEA serves to coordinate and support science festivals and other science communication events across Europe. As of now, EUSEA boasts approximately 100 member organisations, representing 36 different countries. This wide network underscores the expanding scope and significance of science festivals as key vehicles for disseminating scientific knowledge and fostering a culture of science literacy and appreciation among the general public. The association plays a pivotal role in facilitating the exchange of ideas, best practices, and innovations among its members, further enhancing the quality and impact of science festivals and events across Europe.

Researchers' Night

European Researchers' Night[56] is a pan-European event, funded under the Marie Skłodowska-Curie actions, that celebrates science and research, taking place annually on the last Friday of September. This event is significant because it brings researchers closer to the general public and showcases the diversity of science and its impact on citizens' daily lives. During European Researchers' Night, a variety of activities are organised across Europe, allowing people of all ages to interact with researchers, participate in science activities, and gain a deeper understanding of the role science plays in society. These activities typically include experiments, demonstrations, debates, workshops, and guided tours, often presented in an entertaining and engaging manner. The event aims to demystify scientific research and build public awareness about the contributions researchers make to society. It also seeks to inspire young people to embark on scientific careers and to showcase the cultural and societal aspects of science. This celebration of science and research contributes to creating a stronger public connection with science, encouraging curiosity, and fostering a more informed and science-literate society.

Science is Wonderful!

"Science is Wonderful!"[57] is a noteworthy initiative that aims to bring the wonders of science closer to the general public. This event typically features a range of interactive exhibitions

[56] https://www.forth.gr/en/content/Researchers-Night.141/
[57] https://marie-sklodowska-curie-actions.ec.europa.eu/science-is-wonderful

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and activities designed to showcase the fascinating world of scientific research and its impact on our daily lives. It serves as a platform for researchers and scientists to engage directly with the public, including students, educators, and families, demonstrating how their work contributes to societal advancement. The activities in "Science is Wonderful!" often include hands-on experiments, demonstrations, games, and quizzes, all geared towards making science accessible, understandable, and enjoyable for people of all ages and backgrounds. The event highlights the diversity of scientific disciplines and emphasises the importance of research and innovation in addressing global challenges such as health, environment, and technology.

By bridging the gap between the scientific community and the public, "Science is Wonderful!" plays a crucial role in fostering a greater appreciation and understanding of science. It aims to inspire future generations to pursue scientific careers and to raise awareness about the role of science in shaping a better future. Through such engagement, the event contributes to building a more science-literate society and encourages informed dialogue about scientific issues.

Open Schools

"Open Schools" was an initiative where public school facilities were opened up to the local community outside of regular school hours. This program was designed to strengthen community engagement and to provide a range of educational, cultural, recreational, and social activities to residents of all ages. Under this initiative, school buildings become community hubs during afternoons, weekends, or school holidays. The activities offered in these open schools included workshops, sports, arts and music classes, language courses, and various community events. The idea was to maximise the use of public school facilities for the benefit of the local community, turning schools into vibrant centres that offer learning and development opportunities beyond the traditional school curriculum.

This approach not only optimised the use of public spaces but also fostered a sense of community, inclusion, and lifelong learning. It provided a safe and accessible environment for residents to gather, learn new skills, and participate in various activities. Additionally, the

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Open Schools initiative in Athens[58] and similar programs elsewhere can play a crucial role in promoting social cohesion, cultural exchange, and community development.

Famelab

FameLab is an international science communication competition designed to find, train, and mentor scientists and engineers to share their enthusiasm for their work with the public. Founded in 2005 by Cheltenham Festivals in partnership with the British Council, it has grown into a global phenomenon held in over 30 countries. In FameLab, participants have just three minutes to present a scientific topic of their choice. They are judged on the content, clarity, and charisma of their presentation. The use of PowerPoint is prohibited, but props are encouraged as long as they are not too elaborate. The challenge is to make their talk as engaging and informative as possible, using only the resources they can carry onto the stage. The competition is open to anyone aged 21 or over working in or studying technology, engineering, medicine, biology, chemistry, physics, or maths. This includes people working in the private sector, academic researchers, and undergraduate or postgraduate students. FameLab aims to encourage scientists to inspire and excite public imagination with a vision of science in the 21st century. It provides a platform for researchers to showcase their area of expertise in a fun and engaging way. The competition is an excellent opportunity for budding communicators to develop their skills, network with other science enthusiasts, and gain visibility in the science and communication fields.

Three minute thesis

The Three Minute Thesis (3MT)[59] is an academic competition developed by the University of Queensland, Australia, in 2008. It provides a unique platform for Ph.D. students to present their original research and its significance to a non-specialist audience in just three minutes, using only one static PowerPoint slide. The key aspects of 3MT include brevity and clarity, engagement, scope and audience, lack of visual aids, and discipline diversity. 3MT competitions are now held in over 600 universities across more than 65 countries worldwide.

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58 https://athensopenschools.gr/en/open-schools/
59 https://threeminutethesis.uq.edu.au/

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The event celebrates the exciting research conducted by Ph.D. students and offers a window into the world of academic research for the general public.

Pint of Science

Pint of Science[60] is an innovative global initiative that brings scientific discussions into the relaxed atmosphere of pubs, bars, and cafes. This annual event, originating in the UK in 2012, has quickly gained popularity and expanded internationally, showcasing the informal and accessible nature of science communication. Unlike traditional academic environments, Pint of Science encourages casual interactions between scientists and the public, making science approachable and engaging for everyone. At these events, researchers present their latest findings and insights in a way that's easy for a general audience to grasp. The range of topics is broad, encompassing various fields such as biology, physics, chemistry, and psychology, appealing to a diverse audience with different interests. The relaxed setting helps break down barriers, allowing attendees to ask questions and interact directly with the experts in a conversational manner.

One of the key strengths of Pint of Science is its ability to demystify science. It challenges the stereotypes of scientists and science being out of reach for the average person. The event plays a crucial role in making complex scientific concepts understandable and enjoyable for everyone. Furthermore, it serves as a platform for community building, connecting people with shared interests in science and learning. This aspect not only fosters a greater public understanding of science but also promotes a sense of community both within the scientific circles and the general public. Through its global reach, Pint of Science demonstrates the universal appeal of science. It underscores the idea that learning about scientific advancements and discussions can be as enjoyable and engaging as having a pint with friends. This initiative contributes significantly to public engagement with science, making it an integral part of everyday conversations and understanding.

[60] https://pintofscience.com/

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Falling Walls Lab

Falling Walls Lab[61] serves as a global stage for aspiring scientists, innovators, entrepreneurs, and professionals from various fields to showcase their groundbreaking ideas, research projects, and initiatives. The essence of this platform lies in its ability to foster exceptional ideas and to establish a network connecting promising talents across all disciplines. Participants, drawn from a spectrum of fields including science, technology, humanities, and social sciences, are presented with the challenge of succinctly conveying their innovative concepts, research findings, or business models in just three minutes. This format not only demands clarity and conciseness but also the compelling presentation of their work. The audience and jury, comprising experts from diverse sectors, add to the event's prestige and competitive edge.

Held in numerous locations around the world and culminating in the annual Falling Walls Conference in Berlin, Falling Walls Lab creates an expansive global network. This network offers participants a rare opportunity to present their ideas on a global stage, facilitating the exchange of perspectives and fostering interdisciplinary dialogue. The platform's commitment to interdisciplinary exchange is particularly noteworthy. It encourages dialogues between different disciplines, creating an environment conducive to developing innovative solutions to global challenges. For young professionals and researchers, Falling Walls Lab is more than just a competition; it is a career-defining opportunity that provides visibility, encourages networking with peers and established experts, and opens doors to new opportunities and collaborations.

Science Slam

Science Slam[62] is a unique and increasingly popular concept that blends the excitement of scientific research with the engaging format of a slam poetry or stand-up comedy performance. In a Science Slam, scientists step out of the traditional academic environment and onto a stage, typically in a casual setting like a bar or café, to present their research to a general audience. Each participant, or "slammer," is given a limited amount of time, often

[61] https://falling-walls.com/lab/
[62] https://www.scienceslam.de/

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around five to ten minutes, to captivate the audience with a talk about their work. The essence of a Science Slam is its emphasis on entertainment and accessibility. Slammers are encouraged to be creative and humorous, using storytelling, visuals, and sometimes even props or musical instruments to bring their research to life. The goal is not just to explain scientific concepts, but to do so in a way that is engaging, understandable, and fun for a non-specialist audience.

What sets Science Slams apart is the involvement of the audience. Not only do attendees get to enjoy a variety of scientific topics presented in an unconventional and lively manner, but they also typically play a role in judging the presentations. This interactive element adds an extra layer of excitement to the event and encourages presenters to be particularly dynamic and engaging. Science Slams provide a platform for scientists to showcase their work in a relaxed and friendly atmosphere, breaking down barriers between academia and the public. These events foster a greater appreciation and understanding of science in everyday life, making them an effective tool for science communication. By combining the rigour of scientific research with the art of performance, Science Slams create an enjoyable and enlightening experience for both the presenters and the audience.

Stand-up science

Stand-up science combines the wit and charm of stand-up comedy with scientific exploration. In this unique form of educational entertainment, scientists become comedians and take to the stage to deliver hilarious routines intertwined with fascinating scientific facts, theories, and anecdotes. Through humour and storytelling, stand-up scientists engage audiences in topics ranging from astrophysics to psychology, making complex concepts accessible and enjoyable for all. Stand-up science has gained popularity in numerous countries around the world, including but not limited to the United States, Canada, the United Kingdom, Australia, and various European nations, among which Germany, Spain and Greece. As the intersection of comedy and science continues to evolve, its reach expands globally, with comedians and scientists from diverse cultural backgrounds contributing to this innovative form of entertainment and education.

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5. Discussion and conclusion

This report represents the initial deliverable of Work Package 3 within the Road-STEAMer research program, which aims to conduct policy analysis of STE(A)M education in the EU. The first phase involved gathering and analysing EU and national policies, as well as select grassroots initiatives, to delineate the current policy landscape. This process sought to comprehend the evolution of official policy-making over time, as well as to examine the objectives, general policy frameworks, and integration of art as a distinct discipline within national initiatives. The findings of this report will facilitate a more comprehensive analysis of the continuities and discontinuities in policy-making regarding STE(A)M education, ultimately culminating in specific proposals aligned with the Road-STEAMer framework.

In conclusion, the evolution of European policy documents concerning STE(A)M education reflects a concerted effort to address contemporary societal and digital challenges while promoting inclusivity and lifelong learning, especially after the pandemic era. Beginning with the influential "Science Education for Responsible Citizenship" report in 2015, which laid the groundwork for nurturing interest in science and fostering a broader sense of societal responsibility, subsequent policy documents have predominantly focused on STEM and its role in developing digital competence. However, there has been only a sporadic mention of transitioning to STEAM, incorporating arts and humanities into science education in a more action-oriented manner.

On the other hand and on a more national level, countries prioritise STE(A)M education with diverse strategies. Belgium, France, Malta, Lithuania, Bulgaria, Finland, and Germany have placed STE(A)M education at the forefront of their national policies, aligning with European roadmaps for sustainable digital and green economies. Most EU countries focus on educational reform, reflecting a shift post-2019 to accelerate digital transition. Social inequalities persist, but numerous countries address them through specialised programs. Arts integration in STEM, while more prevalent in bottom-up initiatives than in EU policy, can be observed in programs such as Italy's "Arts and Science across Italy" initiative, Denmark's STEAM courses, and (outside of the EU) the UK's STEAM approach.

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The concept of STE(A)M education within the framework of the Road-STEAMer program embodies a holistic educational approach that prioritises fostering critical thinking and self-development through interdisciplinary methods. At the national level, governments are increasingly turning to STEM disciplines to address broader societal challenges such as digital transition and social welfare. However, the systematic integration of arts remains a significant question for policymakers and practitioners, as evidenced by the lack of comprehensive approaches in policy texts. Official EU policies either mention arts as part of the STEAM framework alongside other disciplines like design and innovation, or provide weak or absent directives for action. Analysing how national governments have implemented STE(A)M programs targeting diverse audiences enables us to grasp their overarching policy objectives.This understanding will guide us in identifying significant policy gaps on a larger scale, ultimately leading to the development of Deliverable 3.2.

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