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Envisioning and Co-designing the Future of STE(A)M Education and Research in Europe

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Abstract
While STEM graduates are on high demand, the interest of students to uptake STEM education is not matching industry need, creating a growing gap of experts. Enriching STEM with the Arts, creativity and interdisciplinary approaches (STEAM) seems a promising avenue. This research, part of an EU-funded project to develop policies and recommendations for STE(A)M research in the Horizon Europe funding program, is based on a foresight methodology conducted through twelve workshops with a broad range of stakeholders. Results provide evidence of current and future trends and needs in the context of higher education, including career design support and exploration along the learning continuum, more collaborations with industry and civic organization for a systemic change toward challenge-based education, potentially facilitated by AI, hybrid and blended learning, and the need to offer and test a variety of interdisciplinary learning opportunities to accommodate learners' diversity.

Keywords: *STEM; policies; participatory approach; foresight; inclusivity; research.*

1. Introduction

The demand for graduates in Science, Technology, Engineering, and Mathematics (STEM) disciplines within Europe has become a focal point of policy discussions, given its implications for economic growth, innovation, and competitiveness (Widya, Rifandi & Rahmi, 2019).

A 2024 report from the European Commission's Joint Research Centre (Mazzeo Ortolani, Pokropek, Karpinksi & Biagi, 2024; EC, 22 Jan 2025) emphasized that many students across the EU fail to achieve minimum proficiency levels in key Science, Technology, Engineering, and Mathematics (STEM) areas, particularly mathematics and science. The report also highlighted a shortage of qualified mathematics and science teachers at all educational stages, underscoring the need for enhanced policy efforts and research to address these challenges (Mazzeo Ortolani, Pokropek, Karpinksi & Biagi, 2024), as well as regional differences within the EU. The same report highlights that "Integrated STEM and STEAM (adding arts)

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approaches are becoming more common, focusing on developing skills such as creativity and problem-solving. Although integrated STEAM approaches are appealing and theoretically sound, they are defined and applied inconsistently. This complicates curriculum design, evaluation, and scientific studies." (EC, 22 Jan 2025). The report concludes with a call for more research on the topic.

With this research, we aim to start answering this call to action for more research on STE(A)M, specifically focusing on understanding the future needs of STEM and STEAM for the next 10 years, with a 2035-time horizon. This work is part of the EU-funded project Road-STEAMer (No. 101058405) aiming at developing recommendations for policies and in Horizon Europe fundings for increasing the relevance and uptake of STEAM in secondary and tertiary education. The methodology adopted to investigate the needs for STE(A)M education in Europe, is foresight, conducting workshops with a variety of relevant stakeholders including students, lecturers, industry players, policymakers, subjects with disabilities and from vulnerable groups. Specifically, the technology roadmapping (Phaal, R., & Muller, G., 2009) technique, already deployed for policy making (Yasunaga, Watanabe & Korenaga, 2009; Ahlqvist, Valovirta & Loikkanen, 2012) is adapted for the context of STEM policy making and enriched with the methodology of massive codesign (Meroni, Rossi & Selloni, 2018), with visually pre-filled canvases (Comi & Whyte, 2018). Twelve workshops have been conducted, and the results aggregated to derive emerging themes. Such results have implications for theory and practice. In terms of policies, insights from the workshops can provide valuable input for shaping EU, national and international policy recommendations. Implications for research include directions for future studies to systematically test a variety of STE(A)M and interdisciplinary and transdisciplinary STE(A)M learning options to support diverse learning preferences, for example with randomized experiments (Banerjee & Duflo, 2009). For teaching and learning practice, the insights derived from the foresight workshops provide tertiary education and program managers with suggestions for enhancing STEM programs and subjects to become more interdisciplinary, challenge-based and skills-focused, arts-enriched, as well as future-proofing programs by embedding AI tools, topics and technologies, in particular for tailoring learning programs to a variety of learners' needs.

2. The context of STEM and STEAM education research

The STEM acronym refers to Science, Technology, Engineering, and Mathematics education and has, in the last decades, developed to indicate an interdisciplinary approach that integrates the four disciplines to foster critical thinking, problem-solving, and innovation among students (Martín-Páez, Aguilera, Perales-Palacios & Vílchez-González, 2019; Tytler, 2020). In more recent years, the inclusion of the Arts and creativity has led to the evolution of STEM into STEAM, emphasizing arts, creativity and design alongside technical subjects to enable learners to address complex interdisciplinary real-world challenges. Even within the field of STEM, multiple interpretations exist of what constitutes STEM education, not always involve the integrated presence of all four disciplines (Martín-Páez et al., 2019) underscoring the need for a clearer and more consistent definition of STEM education in academic literature. Core to the STEM academic discourse is the attention to the gender gap and female participation in STEM education and careers (Tandrayen-Ragoobur & Gokulsing, 2022). Aguilera and Ortiz-Revilla (2021) conducted a systematic literature review to compare STEM and STEAM education in relation to student creativity. Their analysis revealed that both STEM and STEAM approaches, tend to foster higher levels of creativity among students. Tytler (2020) outlines the issue of the STEM acronym in diverse languages and contexts (including STEAM). He argued that traditional siloed disciplinary teaching is insufficient for preparing students to tackle contemporary challenges, proposing instead, educational strategies that emphasize not only knowledge but also skills (aligned for example with the OECD Learning Framework 2030; OECD, 2018), attitudes and values. The progression from STEM to STEAM education is conceptualized by Razi and Zhou (2022), by discussing the potential for further integrating disciplines such as humanities and social sciences, and thus proposing a more holistic educational framework. This expanded approach aims to address complex societal issues by fostering interdisciplinary collaboration. The authors argued that such an inclusive model could better prepare students for the multifaceted challenges of the future equipping them with a relevant skill set. Empirical evidence seems still lacking. In recent years, the application and investigation of Artificial Intelligence (AI) is brining an unprecedented change in the field of education, in particular STEM education (Xu, & Ouyang, 2022), that is not yet fully understood.

From a more theoretical perspective, Yeomans et al. (2025) conducted a literature review on STEAM research to derive a classification of theories deployed in the field, identifying 26 frameworks and clustering them into four approaches: ‘experiential real-world interactions’, ‘human psychological and cognitive’, ‘social, spatial, and material interconnectivity’, and ‘cultural and equity’. For the emergent STEAM education field to move forward, a critical evaluation of STE(A)M research assumptions is necessary. The present study, building on extant research, aims to contribute to the advancement of the discipline by empirically investigating stakeholders’ current and future needs and challenges of STEM secondary and tertiary education, with a 10-year time frame. Specifically, this study aims to answer to the following research question: “What are the priorities, needs and challenges of stakeholders for STEAM education research policies in the next 10 years?”

3. STE(A)M Education Foresight

3.1. Methodology and Sample

With the aim to contribute to STE(A)M literature and educational practices, the technology roadmapping (Phaal & Muller, 2009) methodology is adapted to STEAM research policies. This widely utilized technique has already been successfully applied to policy making (Yasunaga, Watanabe & Korenaga, 2009; Ahlqvist, Valovirta & Loikkanen, 2012). The original technology roadmapping canvas, with a 10-year time horizon, is adapted to the research questions by including dedicated areas for: policies in Education (sub-classification: National, Eu and Extra-EU), research, EU funding programs, education (sub-classification: primary, secondary, tertiary and informal), and subtopics of the geopolitical context (grand challenges as defined by the European Commission, and STEM, arts, humanities, social sciences).

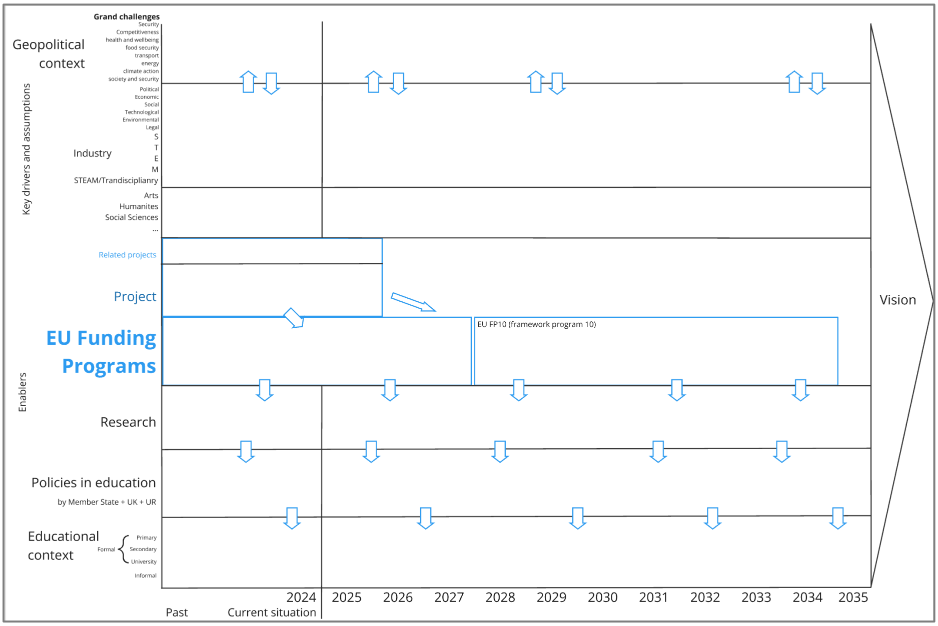

Figure 1. The canvas utilized for foresight workshops

For this research, the classic roadmapping synchronous methodology is extended to deploy an asynchronous massive codesign approach (Meroni, Rossi & Selloni, 2018): a series of twelve workshop have been conducted with a diverse range of stakeholders: university students, university lecturers, program managers, entrepreneurs, students with disabilities and from vulnerable groups, non-formal education, a governmental organization, researchers and policymakers. The total sample is composed of 59 subjects from over 15 countries conducted from May 2024 to January 2025. The workshops have been conducted sequentially, progressively pre-filling the canvas to provide support for visual thinking (Comi & Whyte, 2018). The detailed methodology is described in (Bresciani, Jiang and Rizzo, 2025). All contributions are captured by the participants or by the facilitator as sticky notes on the canvas and tagged according to the type of the stakeholder. Input from all workshops are overlayed on a single board and semantically aggregated. Emerging themes are identified and outlined in the next section. For more details see https://www.road-steamer.eu/ (D5.1 and D5.2).

3.2. Results

3.2.1. Meta level: naming STE(A)M

The issue of the naming and definition has emerged strongly, with subjects of different nationalities not being familiar with "STEAM" and sometimes not even with "STEM". When familiar with the acronyms, the understanding was mostly narrowly perceived to an aggregation of four technical/scientific discipline, not understanding what the "arts" could provide and being reluctant to such topics.

3.2.2. Coherent STEAM education policies and strategies at EU and national level

Stakeholders identify as a major challenge the variety of definitions of STEM/STEAM and advice having a transnational definition of STE(A)M education at EU level. It is recommended that the EU suggest Member States to adopt the unified policy and strategy at national level.

3.2.3. Making an economic case for STEAM education

To support the EU and nations in defining and adopting a unified STE(A)M education strategy, it is suggested to develop studies to make an economic case for STEAM and interdisciplinary education to replace or heavily revise traditional national education paradigms: interdisciplinary competence- or skills-based (rather than knowledge-based) education, focused on real word challenges, could provide several economic benefits to nations and to individuals, off-setting the cost of the necessary systemic changes of the educational system required for implementation. Research should test (i.e., with experimental trials) a variety of STE(A)M and transdisciplinary (existing or new) learning paradigms to achieve systemic change (not just teaching practices) and evaluate which paradigm is most effective for which type of learner, including students with disabilities or belonging to vulnerable groups (and intersectionality).

3.2.4. Systemic change of the educational system and assessment: AI and inclusivity

The next decade (2025-2035) is expected to exacerbate the current disconnect between the knowledge-focused siloed school system and the skills needed to address societal challenges (i.e., sustainability, competitiveness and security), industry needs (i.e., of technologically literate but also socially competent workforce) and personal development (i.e., the mental health emergency and continuous learning). A systemic reform of the educational field seems needed, allowing flexibility in the national curricula and for tertiary education lecturers to work together across disciplinary domains and degrees, on cross-disciplinary projects. According to respondents, in the era of AI – after having ensured a strong basis of basic reading, writing and mathematics - education should focus on developing skills (such as critical thinking, computational thinking, communication, collaboration, etc.) rather than knowledge. Assessment must change accordingly. Artificial Intelligence does not only affect the type of knowledge and abilities needed by the future workforce, but provides the opportunity for a fundamental innovation in the educational sector, providing the opportunity for personalized learning that humans have never experienced in history. As traditional class teaching and even tutoring and corrections of assignment can be delegated to AI, lecturers have to be re-trained to harness the possibilities of AI in education, providing value to learners by focusing on tasks that AI cannot perform. Future research should experiment and test the effectiveness of novel teaching approaches that include skills and support career exploration. More research is needed to optimize the use of AI for the different educational level, and understand how technology can provide more flexible and inclusive education opportunities for vulnerable groups and learners with diverse abilities, such as through online, blended and hybrid learning.

3.2.5. Multi-stakeholder collaborations through open-schooling

Participants highlighted the need for the educational system at all levels to better ground teaching to societal and industry needs thought collaborations with profit, civic and governmental organizations, such as with the open school approach and participation in living labs, sharing or sponsoring spaces and equipment, or by offering joint diplomas and degrees (i.e., companies with credited secondary education institutes and universities).

3.2.6. Develop and test STEAM and transdisciplinary learning material

Teachers, lecturers and program managers highlighted the need to develop and test the pedagogical efficacy of STE(A)M and interdisciplinary learning material that is based on real-life challenges and skills development, and related to a range of careers exploration (in collaboration with external stakeholders including companies and governmental organizations). Such material should be available in national languages and systematized in a one-stop-shop digital space where lecturers can easily find materials, share and have peer-to-peer support.

3.2.7. Life and career design along the learning continuum

The choice of pursuing secondary or tertiary education in a STEAM discipline -or not- seems not to be based on students' solid and realistic understanding of the actual lived experience and career implications. A promising research avenue can be established in life design, investigating how to support learners along the learning continuum, from primary school to retirement, to understand concretely what it entails to take a STEAM-related course of studies and career. Longitudinal studies could to develop and test life and career design support (i.e., structured activities between secondary and tertiary education, or teachers/university lecturers training on career design support to students).

4. Implications for theory, practice and policies

The empirical research conducted with a variety of stakeholders supported by a roadmapping canvas, provides some preliminary results to the research question, aimed at investigating the priorities, needs and challenges of stakeholder for STEAM education research policies in the next 10 years, in the European context. At policy level, topics emerged from the codesign activities provide directions to EU funding schemes and policies, as well as to national policy makers. In terms of higher education research, and specifically for STE(A)M, results outline some discrepancy between the literature and stakeholders' priorities, that provide valuable input for a range of future research topics. Such potentially uncovered research areas include the development and systemic testing of a variety of interdisciplinary learning paradigms and their effectiveness for diverse types of learners, with a particular focus to intersectionality, disability and the role of AI in providing customized learning experience, specifically testing online, hybrid and blended learning for a radical systemic change of Europe's education. Stakeholders unanimously agree on the need to focus on competence and skills rather than knowledge, demanding a reform of current educational and assessment. Another promising avenue for research is life and career design, exploring effective modalities to support career choice.

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