Picking up STEAM

A Road–STEAMer policy brief

1. Executive summary

Europe is currently facing a lack of skilled employees, particularly in sectors such as Science, Technology, Engineering and Mathematics (STEM), and the situation is not much different elsewhere in the world. Beyond the overall scarcity of STEM professionals, another issue is the persistent underrepresentation of women and marginalised groups in these fields of employment. This is not just a problem for those who are excluded. Increased diversity could provide different understandings of scientific and technological problems, leading to pursuing alternative solutions and more inclusive products – ultimately, society as a whole could benefit. Furthermore, a solid background in science education could be beneficial for all citizens (regardless of occupation), in order to better support them in an increasingly complex and digitised world.

This poses huge demands on educational systems, unlikely to be met with instruction-as-usual. Education pioneers and experts advocate for up-to-date approaches to science and related subjects such as "out-of-school science activities," open schooling, and the use of arts and creative thinking (the "A" in STEAM), which have the potential to increase student engagement, be more inclusive of marginalised groups, and foster the development of soft skills and interdisciplinary practices.

This is where the Road-STEAMer project comes into play, as its main objective is to develop a roadmap for STEAM education in Europe. The roadmap will support decision makers in mainstreaming STEAM and ultimately stand better chances to address the pressing societal needs mentioned above.

With this policy brief, we take stock of the work carried out during the first year of the project, focusing in particular on the context and needs, and we outline the work that will inform the development of the roadmap. While the identification of best practices and of policy challenges are yet to be completed, it is already possible to identify four main areas for the development of specific policy recommendations:

- **Encourage the uptake of STE(A)M careers** to counter the skills crisis;
- **Increase diversity in STE(A)M**, both to counter the skills crisis and enrich the field with a wider range of perspectives;
- **Increase science and arts literacy for all** so that no citizens are left behind in an increasingly technological world;
- **Align education with tomorrow's societal needs**, to build a society that can tackle the complex problems it is set out to face.

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2. The benefits of STEAM approaches

2.1 Background

Europe is facing a skills crisis, with many people struggling to find employment and succeed in today's interconnected world, all while employers complain about the shortage of suitably qualified professionals (see 2.2 below). Education systems appear to be struggling to provide students with the skills that would allow them to flourish, especially in sectors such as Science, Technology, Engineering and Mathematics (STEM). As a society, we do not have enough scientists to meet current needs, let alone to lead the so-called twin transition (digital and green) in the near future.

Beyond the overall scarcity of STEM professionals, women and marginalised groups remain largely underrepresented in the sector. This is not just an issue of a glaring lack of equal opportunities and social justice. It can be argued that more diversity would enrich the field with a wider range of perspectives, which in turn could help broaden the understanding of scientific and technological problems, and explore different solutions and inclusive products and services. Ultimately, society as a whole would benefit from more diversity.

What is more, it is becoming increasingly important that all citizens have a solid understanding of science and technology, as well as advanced digital skills, to flourish and make more informed decisions in their

About Road–STEAMer

The overall aim of the project is to develop a STEAM roadmap for science education in Horizon Europe, i.e. a plan of action that will provide guidance to EU's key funding programme for research and innovation on how to encourage more interest in STEM through the use of artistic approaches, involving creative thinking and applied arts (the "A" in 'STEAM'). The consortium aims to provide Europe with this roadmap, through:

- Collaboration and co-creation with the stakeholder communities of science education, research, innovation and creativity, through intensive exchange, dialogue and mutual learning among them which will produce better knowledge and shared understandings of the relevant opportunities, challenges and needs.
- A bottom-up approach emphasizing educational practice and practitioners' agency rather than high-level conceptualizations of STEAM and generic top-down plans for its adoption in science education.
- A specific focus on ways to leverage the power of STEAM approaches, as manifested through exemplary cases and best practices, so as to enable a bridging of open science and open schooling which can catalyse an increased impact for science education as a crucial tool for addressing Europe's current scientific and societal challenges.

About this policy brief

This policy brief constitutes Deliverable 7.4 of the Road-STEAMer project, and it is part of Work Package 7, the objectives of which include coordinating and monitoring the technological and scientific work of the project. This first policy brief aims to convey the results of the first year of the project to policy makers, with special attention to the European context, in a way that is easily understandable and approachable, in order to boost the agenda of STEAM in Europe. In particular, this policy brief builds on deliverables 2.1 - Socio-economic context and relevant needs, 4.1 – Research framework, and 2.2 – Conceptual framework for STEAM.

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lives. This is true regardless of sector of employment, and it is yet another reason to ensure that high quality science education is available to everyone. Meeting these societal needs poses huge demands on educational systems, and instruction-as-usual is unlikely to be enough. Education pioneers and experts advocate for up-to-date approaches to science and related subjects such as "out-of-school science activities," open schooling, and the use of arts and creative thinking (adding an "A" to STEM) to advance STEAM education. There are cases and scientific studies showing that these approaches can help increase student engagement with science education, including among groups that are traditionally under-represented, potentially leading to better outcomes across the board.

Even more importantly, STEAM approaches can teach crucial soft skills, such as cultural awareness and creative thinking. While today's technology could quickly become obsolete, the capacity of understanding problems and envisioning new solutions will remain relevant in tomorrow's world. To this effect, it will be important to support the development of wider societal understanding of the benefits of the arts in conjunction with other disciplines. Ultimately, a strong focus on soft skills and interdisciplinarity may help in building a society ready to tackle wicked problems such as the climate crisis and social injustice.

2.2 Exploring the skills crisis in Europe

It is widely recognised that Europe as a whole needs more scientists and STEM professionals. The Employment and Social Developments in Europe report 2023, in the context of the European Year of Skills, noted labour shortages in various sectors, including STEM, and particularly in Information and Communication Technology (ICT). Previously, the European Commission Joint Research Centre (2020) had also identified mismatches in the tertiary graduate labour market, with a large number of companies unable to fill vacancies, despite a large pool of highly educated individuals unable to find suitable employment. The report pointed to issues in quality of education, with graduates' skills not quite matching the expectations of prospective employers, and the fact that important "soft skills" appear to be overlooked in STEM education.

The pressing demand for achieving a climate-neutral Europe and adapting to the digital transformation only adds to this mismatch, sparking a renewed emphasis on scientific, technological and mathematical skills. This emphasis is clearly reflected in a number of policy initiatives. For instance, Action 7 of the European Skills Agenda (European Commission 2020 p. 14) focuses on bolstering the number of STEM graduates, while the European Pillar of Social Rights Action Plan (European Commission Directorate-General for Employment, Social Affairs and Inclusion, 2021) aims to ensure that at least 80 percent of individuals aged 16-74 possess basic digital skills.

In a rapidly evolving technological landscape, digital skills are of paramount importance as society gains greater access to information. Broad-based digital

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literacy is crucial for fostering trust in digital products and online services, as well as identifying and protecting against cyber threats, scams, and disinformation. These skills are essential for collective resilience and active participation in the Digital Decade. And yet, according to the 2020 Digital Economy and Society Index (DESI), although 85% of European citizens have used the internet prior to the COVID-19 pandemic, only 58% possess basic digital skills, defined as those skills "without which one cannot fully benefit from digital technologies". As for professionals in this sector, there were 7.8 million ICT specialists employed in Europe in 2019, when the projected need for 2030 is 20 million. There is however a degree of variation among Member States, with some countries like Ireland and Germany projected to have a surplus of graduates, whereas others like Czechia are expected to have a shortage of ICT, science, and engineering graduates by 2030.

Apart from ensuring a sufficient number of graduates in the relevant fields, another challenge is to anticipate further technological developments and ensure that future generations will be able to manage them. With regards to so-called artificial intelligence (AI), UNESCO Assistant Director-General for Education Stefania Giannini recently wrote: "we need education systems that help our societies construct ideas about what AI is and should be, what we want to do with it, and where we want to construct guardrails and draw red lines" (Giannini 2023, p.8). This means going beyond purely technical skills, to embrace a more holistic approach to science and technology - something that is at the core of STEAM education.

Employment statistics point to lower labour market participation along lines of gender, low socio-economic background, ethnicity, disability, among other bases for marginalisation. Crucially, labour shortages are particularly stark in the most gender-imbalanced sectors, including notably STEM professions, linked with gender segregation in the relevant fields of study. Ensuring more STEM graduates among women and other marginalised groups could increase the pool of potential employees in shortage occupations. Not just that, but increased diversity could also bring alternative perspectives and solutions that cater a larger and more inclusive user base.

2.3 The socio-economic context: A tale of exclusion

As part of the first year of the Road-STEAMer project, considerable attention has been dedicated to better understanding the socio-economic context and the needs related to STE(A)M education. What emerged from this line of research is that family, social and economic background in addition to science and educational capital (i.e.: the accumulation of knowledge, skills and attitudes that a student can draw upon to get ahead in life) deeply influence the capacity of individuals to achieve full participation in STEM. The literature review carried out in the project has also shown the fundamental relevance of intersectional inequalities (gender, race, class, migration background and others) that

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hinder the creation of inclusive educational and work environments (Unterfrauner et al., 2023).

In other words, the vast majority of those who work in these fields tend to be male, and white. Despite women constituting the majority of tertiary graduates in the EU, women in STEM fields still represent slightly less than a third of students at bachelor and master level, and 37% of doctoral candidates (Directorate-General for Research and Innovation, 2021). The gender divide in STEM education is evident in the UK as well, with fewer women choosing to study STEM subjects at A-Level and vocational training (McDool & Morris, 2020). Gender divides and inequalities within the education system also tend to disproportionately affect marginalised girls (Sánchez-Tapia & Alam, 2020).

Students from less privileged backgrounds continue to face underrepresentation in STEM. Studies reveal that STEM participation is significantly influenced by an individual's family socio-economic conditions and their level of educational and science capital. Although decisions related to pursuing STEM careers seem individual and voluntary, various structural factors come into play (Unterfrauen et al., 2023). Although the European Commission acknowledges the marginalisation of disadvantaged groups in STEM, there is limited institutional disaggregated data on the ethnic makeup of students in secondary and tertiary education or in the workforce. The OECD (2012) have highlighted that parents from better-off backgrounds tend to avoid schools with disadvantaged students, like Roma predominant schools, and prefer schools with populations ethnically similar to their own family, leading to issues of segregation in education.

Additionally, other factors closely correlate with socio-economic background, such as ethnicity, family structures, language spoken at home, and urbanicity. These issues seem to manifest early on, with higher-income families seemingly capable of compensating for other negative STEM predictors, such as gender and ethnicity. Moreover, there exists a strong correlation between parental attitudes towards science and youths' interest in STEM. Thus, the socio-economic background of the individual and family plays a crucial role in STEM identities (Unterfrauen et al., 2023).

The impact of inequalities in the STEM participation and achievements of historically marginalised communities and genders are not just motivated by individual dispositions or lack of role models. Rather, the phenomenon called the “hostile obstacle course” explains the existence of (symbolic or overt) systematic barriers at different levels (Berhe et al., 2021). These barriers may include scientific racism and systemic biases that permeate disciplines and institutions, stereotypes on what a STEM professional should look like, the existence of a gender pay gap (The Digital Economy and Society Index, DESI) and racial pay gap, existing limitations on parental leave distribution, not having received support in their professional career evolution, harassment and sexual harassment, limited access to leadership roles and systematic internalisation of reduced value and self-worth. Overcoming the interpretation of such inequalities as a “leaky pipeline” mechanism causing passive loss of talent in

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STEM sectors along the way allows tackling the lack of diversity and the existence of discrimination at a more systemic level as discriminatory and exclusionary practices (Berhe et al., 2021). Such a shift permits changing the framework and identifying the need for social and epistemic justice, rather than simply working towards improving participation (Intemann, 2009). Negative socio-cultural norms and systemic barriers often lead to the marginalisation of disadvantaged groups.

Research suggests that women, as well as some ethnic minorities, are particularly underrepresented in those fields perceived to require some form of "innate genius", which is stereotypically associated with white men (Leslie et al., 2015). What is more, such cultural stereotypes are acquired during childhood, at around six years of age (Bian et al., 2017). Several studies indicate that persistent stereotype threats and promises influence individuals' perception of themselves as "*STEM-persons*" (Maier-Zucchino, 2021). Additionally, the 2020 All-Party Parliamentary Group (APPG) report on Diversity and Inclusion in Science, Technology, Engineering and Maths also found that inequalities in science identities and aspirations were evident in primary school and exacerbated through secondary school. UNESCO (2016) has highlighted a significant lack of female science and mathematics teachers globally, which they attribute to the low representation of women in these fields at higher education levels. Moreover, girls internalise stereotypes that dissuade them from pursuing degrees in STEM, exacerbating the gender gap in these fields.

Reay asserts that social identities formed through institutional interactions with peers play a significant role in shaping students' educational identities, with students potentially sensitive to gender and ethnoracial biased patterns of discourse or representation in STEM environments (Reay, 2010). Building on Bourdieu's concept of social capital, Maier-Zucchino highlights how schools institutionally value and reflect European white male culture, while the cultural capital of marginalised groups often is not recognised by these schools (Maier-Zucchino, 2021). A school's failure to recognise, affirm, or validate marginalised students' cultural capital contributes to their lack of school "*attachment*", and becomes a powerful force driving differential academic achievement.

Intersectional aspects, such as the interplay of gender, migration background, or ethnic origin, can perpetuate the under-representation of diverse groups, yet they are often overlooked in studies and policies. An intersectional analysis of inequalities needs to take into account how identities do not exist in isolated silos and requires data and statistical analyses with more than one variable (Vargas-Solar, 2022). In the EU, the lack of intersectional lenses in STEM studies, research, and industry is evident due to the scarcity of disaggregated data and research incorporation (Directorate-General for Research and Innovation, 2021).

In the UK, a 2021 inquiry showed that inequities in education and society worsen at every level of the STEM career pathway, particularly when multiple layers of discrimination and exclusion combine, such as gender, ethnicity, and socio-economic

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background. The challenges faced by individuals with disabilities also contribute to the lack of diversity in STEM fields. Workers with disabilities, particularly women with disabilities, remain underrepresented. Limited self-reporting further masks the experiences of disabled workers and underscores the importance of addressing barriers and discrimination faced by individuals with disabilities in STEM education and careers. Similarly, the LGBTQ+ community encounters inequities in the STEM workforce. Discrimination and fear of discrimination in STEM fields have been reported by LGBTQ+ individuals, although the representation of this community remains unclear due to insufficient data (All-Party Parliamentary Group (APPG) on Diversity and Inclusion in Science, Technology, Engineering and Maths, 2021).

Building on the analysis of the socio-economic context, the Road-STEAMer consortium has then identified a number of pressing societal needs related to STE(A)M education, which can be summarised as follows:

- **Improving science literacy for all**, to ensure that younger generations have the necessary skills to make informed decisions, critically evaluate claims, and understand scientific knowledge;

- **Increasing uptake of science careers**, to have the necessary workforce to lead the "twin transitions";

- **Improving alignment between educational outcomes and industry needs**, to reduce current mismatches in the labour market;

- **Increasing diversity in STE(A)M** to move towards greater social justice, offering more opportunities to currently underrepresented groups, and benefitting from their perspective.

It can be argued that shifting from STEM to STEAM education could help address these needs – but first, it is important to understand what STEAM is (and what it is not).

2.4 Conceptualising STEAM

If it is reasonably clear what is meant by STEM, the concept of STEAM remains more vague, as there is not a single definition used across the board. In a recent Horizon Europe call topic – the one under which the Road-STEAMer project is being funded - STEAM is defined as "*the use of artistic approaches to STEM involving creative thinking and applied arts (the "A" in STEAM)*" (European Commission 2021). The analysis of existing literature on STEAM education carried out in the first year of the Road-STEAMer project (more on this below) further highlights how the field is complex and multi-faceted. What is certain is that advocates of STEAM education do not merely promote the inclusion of the Arts as a discrete discipline to the list comprising Science, Technology, Engineering, and Mathematics. The focus is often on interdisciplinarity and creative thinking, and the benefits that a more holistic approach to education could bring. STEAM education could be defined as an interdisciplinary and transdisciplinary approach equipping people

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with a more holistic view of the world, building on convergent and divergent thinking skills (Land, 2013).

As part of the first year of activities of the Road-STEAMer project, considerable attention has been given to the identification of a research framework (Chappell & Hetherington, 2023) and of a conceptual framework for STEAM (Yeomans et al., 2023). Below, the processes and their outcomes are briefly summarised.

First, as part of the work on the research framework, a thematic analysis was carried out, combining literature review and contributions from practitioners in the consortium. Through a co-creation workshop, an initial "long-list" of eleven tentative criteria for connection and Inclusion/ Personalisation/ Empowerment. These principles are all underpinned by the core principle/value of Equity. The latter refers, on the one hand, to the rejection of hierarchies among disciplines, and also within the classroom, with students taking a more proactive role in learning, guided by teachers-facilitators (Allina, 2018). On the other hand, equity is also presented as a possible outcome of STEAM practices (Carter et al, 2018) though this claim would need further corroboration. It is relevant to point out that other concepts, related for instance to digital technologies, problem solving, and open-ended activities, or the role of arts, while not making the final cut as top-level criteria, are still encompassed by the six key ones. To pick one example linked to the European Digital Decade, all six criteria could involve the use of digital technologies, as well as promote a better understanding of the digital environment (Chappell & Hetherington, 2023).

Further to the identification of the six criteria, the Road-STEAMer consortium proceeded to work on an overarching conceptual framework that will guide the development of the roadmap. To this effect, the University of Exeter carried out a rigorous literature review of articles describing theoretical and/or conceptual frameworks used in STEAM education, focusing on the use of artistic approaches involving creative thinking and applied arts (the "A" in STEAM); connecting to open schooling and open science, as well as the secondary-tertiary interconnection. A collaborative dialogue among project partners led to singling out relationality as a core element underpinning the development of the Road-STEAMer framework. This concept is intended as the fundamental importance of human relations in education, drawing the principle that there can be 'no education without relation' (Bingham & Sidorkin, 2004), first and foremost between teachers and students, but also in a broader sense to encompass relations across different disciplines, settings, and so on.

The following step of the development of the framework involved an iterative process to group the identified frameworks into four broad sets of theoretical approaches. These sets have been defined as:

- **Experiential real world interactions approaches,** which emphasise elements of active experience, and they are often

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grounded in real world problems, focusing on felt knowledge and interaction with the world;

- **Human psychological and cognitive approaches,** which are grounded in the psychological tradition, and demonstrate different theorisations regarding cognitive processes, i.e. how learning happens;
- **Social, spatial and material interconnectivity approaches,** which put their emphasis on interconnectivity, considering human beings in relation to many kinds of 'others', including material elements, space, time, affect;
- **Cultural and Equity approaches**, using cultural theorisations (considering collective ideas, customs and behaviours) which often stress equity of inclusion (Yeomans et al., 2023).

These four sets of approaches are visually represented as the four sides of a pyramid (see figure 1 below), to highlight the fact that each covers a different aspect of STEAM education, while at the same time remaining connected with the others. The theoretical framework and its visualisation was then validated and further refined during a co-creation workshop with stakeholders held in May 2023.

The four types of approaches are intended to be used in combination with the previously identified criteria, with each set of approaches manifesting

Figure 1 The Road–STEAMer conceptual framework — aerial view (source: Yeomans et al., 2023)

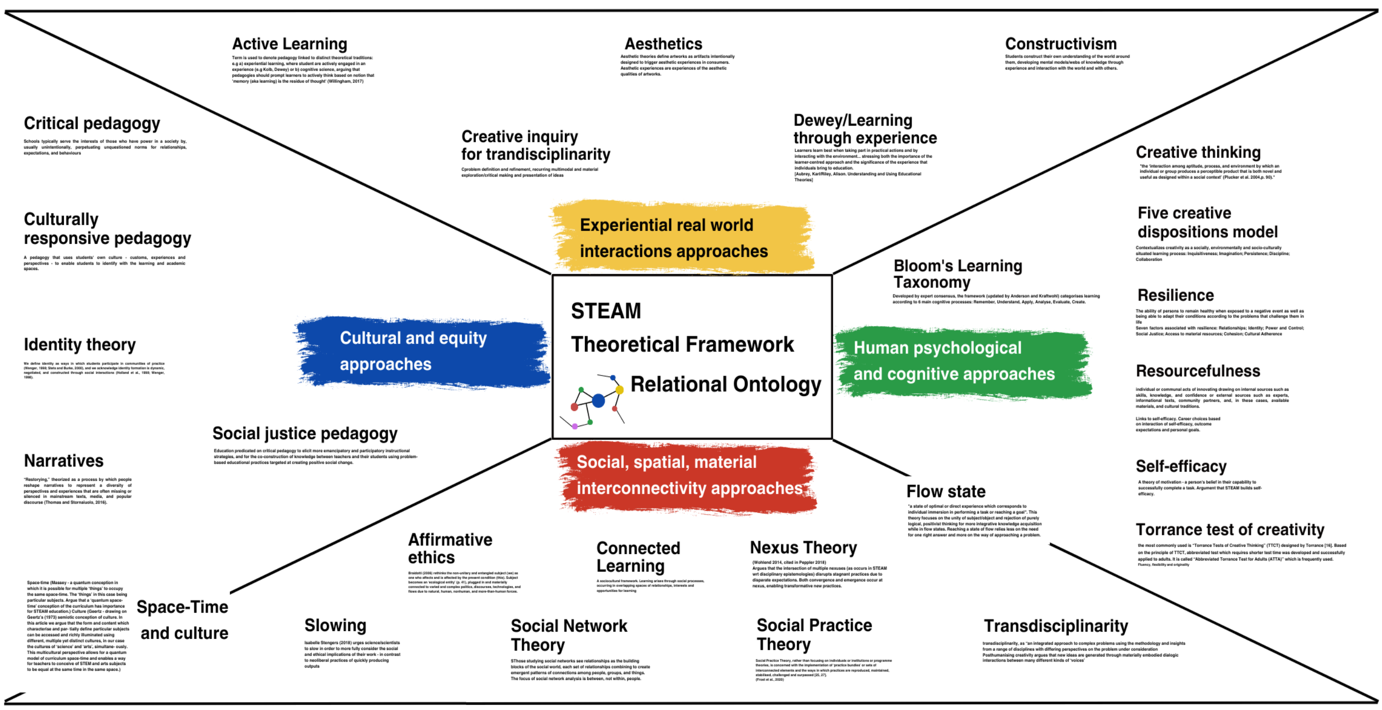

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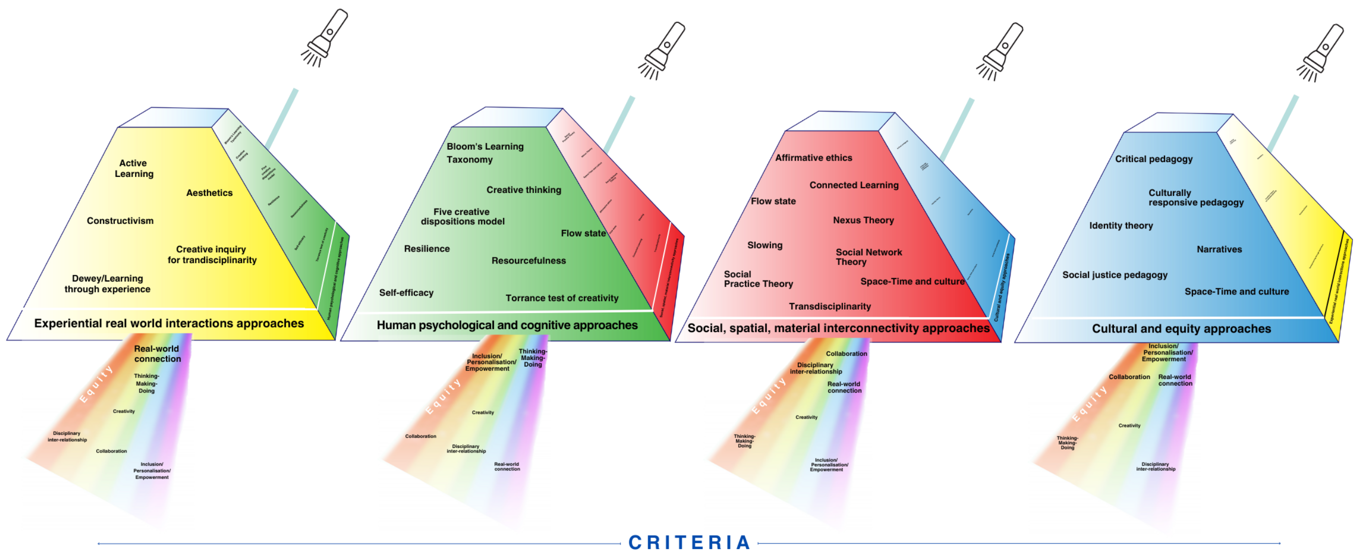
Figure 2 *Different manifestations of the criteria through the four sets of approaches (source: Yeomans et al., 2023)*



different criteria. This is represented visually as a light that passes through each side of the pyramid, and by doing so, it creates a different manifestation (figure 2). For instance, "Real world connections" manifest at their strongest in the "Experiential real-world interactions" approaches, whereas the "Human Psychological and cognitive approaches" give prominence to "Thinking - making - doing" and "Inclusion / personalisation / empowerment" (Yeomans et al., 2023). Beyond the specifics of each case, this also serves to showcase the multiplicity of manifestations of STEAM practices. To borrow the motto of the European Union, it appears that the STEAM field is also "United in Diversity".

Finally, it is also important to highlight that the approaches included in the analysis are by no means the only ones relevant for STEAM education, but a selection that was deemed to be most relevant for the Road-STEAMer project, taking into account the key criteria defined above, and that further developments or a refinement of the approaches could be considered going forward (Yeomans et al., 2023).

These criteria and the conceptual framework are beginning to coalesce arguments for why STEAM is not only important to address the STEM skills shortage but also forefront arguments for STEAM as key to developing STEM/STEAM professionals' and citizens' soft skills for life-wide application; developing wider societal understanding and application of the value and benefits of the arts working with other disciplines; which taken together can contribute to creating societies which are better able to work across disciplines to solve wicked

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problems such as the climate crisis, social injustices etc.

2.5 Beyond hard science: Unlocking Europe's full potential

It has been suggested that breaking disciplinary silos in STEM teaching, challenging gender stereotypes, and grounding teaching in real-world applications – core elements of STEAM approaches – are key to promoting a more gender-responsive and inclusive education (Sánchez-Tapia & Alam, 2020). This in turn could help contribute to increased labour market participation in crucial areas for women and other currently marginalised groups. Addressing the structural issues of inequity within STEM is not solely an economic imperative, but a step toward building a more just and innovative society; this is particularly emphasised above in the Road STEAMer underpinning criteria of Equity. When underrepresented students pursue STE(A)M education, they could make significant contributions to their communities by researching issues relevant to their ethnic backgrounds, whereas a lack of representation hampers innovation and perpetuates societal inequities (Bennett, 2016). Embracing diversity is thus vital for STE(A)M education and industry. Diverse research and learning environments are known to be more creative and stimulating, resulting in improved outcomes. Thus, promoting diversity, equity, and inclusion strengthens institutional capacity and better meets the needs of society. By cultivating a diverse and inclusive STE(A)M landscape, Europe can harness the full potential of underrepresented talents, drive innovation, increase citizens' understanding of science and the arts, and foster a stronger, fairer, and more prosperous future for all.

As conceptualised above, STEAM approaches based on equity appear to be particularly suited to foster diverse perspectives. Including artistic perspectives from various cultural groups could promote fairness, equality of opportunity, and contribute to the advancement of science and technology (All-Party Parliamentary Group on Diversity and Inclusion in Science, Technology, Engineering and Maths, 2020). These interdisciplinary and transdisciplinary approaches equip individuals with both convergent and divergent thinking skills, nurturing a more comprehensive outlook (Land, 2013).

Furthermore, STEAM education has been shown to encourage active learning and develop inventiveness, creativity, and critical thinking, along with collaboration and self-management skills. By nurturing these qualities, students become informed citizens and effective leaders, better prepared for the challenges of the technological age (Sánchez-Tapia & Alam, 2020). The "*Fourth Industrial Revolution*", a term used to describe the rapid technological changes and societal shifts driven by interconnectivity and smart automation, necessitates a focus on both technical and soft skills. Higher education must support adaptability in rapidly evolving areas like data science and genomics, while emphasising computer science as a new form of literacy and integrating interdisciplinary fields to advance science and technology.

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Additionally, fostering intercultural and interpersonal skills, such as ethical thinking, critical thinking, creativity, and intercultural understanding, is imperative for thoughtful and informed applications of technologies in a sustainable and ethical manner (Penprase, 2018).

Climate change is another grand challenge which would benefit from promoting holistic approaches encompassing critical thinking, creativity, and ethical awareness. A STEAM approach to climate change education could develop students' action competence and drive meaningful engagement, empowering learners with the conceptual understanding, skills, values, and attitudes needed for impactful climate actions (Wong Yu Yeung & Yip, 2020). A critical lens is essential to address the complex, interconnected socio-economic shifts and global challenges we face. A STEAM approach appears to be an effective way to reformulate a more inclusive, creative, and critical approach. However, although STEAM is touted to attract underrepresented students, it can fail to represent their cultures by focusing on European culture and arts in STEAM (Bennett, 2016). To bridge this gap, the integration of artistic heritage from underrepresented communities into STEM education as a form of computational agency is imperative.

Increasing attention is given in the STE(A)M field to the need for such disciplines to move beyond "hard science" to encompass pedagogical innovations that accompany learners and future generations in imagining, designing, building, evaluating and disposing of current and future technologies in socially and environmentally responsible ways (Das, 2023). If we consider STEAM disciplines to be "socio-technical" fields - that is - intimately connected with social contexts and consequences (Niles et al., 2020), there is a need for STEAM education to critically engage with society, its ethics and values. In this sense, technology is not neutral. The so called "universalist" design principles are often deeply imbued with dominant values and interlocking systems of structural inequality, erasing certain groups of people, specifically those who are intersectionally disadvantaged or multiply burdened (Costanza-Chock, 2020). Understanding how society and science, technology and engineering co-construct one another is a critical skill for today and tomorrow's STEAM professionals, and STEAM education has great pedagogical potential on this subject. Who participated in the ideation of a technological asset? Who is benefiting from it? Who is harmed? What are the social, political and environmental consequences of such innovation? (Costanza-Chock, 2020). The importance of the social and democratic aspects of STEAM and of a critical engagement with the world is also explored through the research findings of the Road-STEAMer early project outputs that focus on the necessity of widespread scientific literacy in societies - that is - *"the ability to engage with science-related issues, and with the ideas of science, as a reflective citizen"* (OECD 2018, p.15).

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3. Conclusion: The way forward

While the Road-STEAMer project is still in its early stages, it is nevertheless possible to outline how moving to STEAM education could help tackle the societal needs that were previously identified.

Encourage the uptake of STE(A)M careers

This has mostly to do with increasing students' engagement, particularly at the critical stage between secondary (high school) and tertiary education (university), challenging widespread perceptions of scientific subjects and careers being "difficult". There are indications that a STEAM approach could be more inclusive and appealing than traditional STEM instruction, potentially broadening the number of aspiring scientists. In particular, STEAM could challenge the perception of science as "difficult" and tedious, whereas the inclusion of arts and creativity could foster confidence and motivation. More research is needed to confirm the effectiveness of STEAM as opposed to STEM, and more in detail, which specific STEAM approaches will emerge as the beacons of good practice, worthy of being mainstreamed into educational curricula (and teachers' training). A related aspect is that of increasing societal understanding of the need of going beyond disciplinary silos to embrace interdisciplinarity and soft-skills development across the board, including for scientists and tech workers.

Increase diversity in STE(A)M

It is almost universally acknowledged that women and ethnic minorities are generally under-represented in scientific professions. Simply by tapping into a wider pool of potential scientists, increasing the number of women and other underrepresented groups STEAM will increase the total number of STEAM professionals, which is in general desirable (see point 1 above). But there is more to it. It can be argued that overcoming exclusionary employment practices in STEAM would bring an added value by broadening horizons and frames of reference, and reducing the risks of biased technology and research. In this sense, all other factors remaining equal, more diversity would be better for society. Adopting more participatory educational approaches is not only conducive to increasing minority students' engagement with STEAM, but can provide first-hand examples of how science does not necessarily have to be a monolith, but can be multifaceted and rich with nuances.

Increase science and arts literacy for all

Not everybody needs to be a scientist or artist professionally, but pretty much everybody would benefit from improved science and arts literacy. Everyone will eventually need to make informed decisions about their own health or that of their relatives, or energy efficiency, or be able to better communicate relationally to solve problems together or understand global issues through multiple cultural lenses, just to mention a few. Being

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able to make sense of available data, and weeding out unsupported claims, requires critical thinking and an understanding of the scientific method; changing minds in relation to how to ethically respond to e.g. the climate crisis requires understanding of creative, collaborative, cultural and aesthetic values. Giving everyone the tools to understand and competently navigate an increasingly digital, often much more visually represented and automated world is another example of an area where better technological and artistic skills would be helpful, regardless of sector of employment. Again, STEAM education – with its focus on equity and participation – can help ensure that no one is left behind, and that citizens understand the importance of science and arts literacies working together.

Align education with tomorrow's societal needs

This means thinking beyond what is needed by industry in the "here and now", focusing instead on what will remain relevant in the decades to come for society - and people within it - to flourish. From this perspective, encouraging the development of soft skills, critical thinking and creativity, interwoven with mastery of the method of scientific inquiry, appear to be of crucial importance. Tackling real-world problems - oftentimes working across disciplinary boundaries - appears to be a promising path to making education more relevant. Again, STEAM appears to lend itself well to the transdisciplinary nature of these problems. Specific recommendations might revolve around open schooling, focusing in particular on how this participatory approach to education based on real-world interactions could foster the capacity to address changing needs as well as fostering a sense of ownership. As mentioned above, ensuring wider societal understanding and support for interdisciplinary approaches will be key for these approaches to be mainstreamed.

Taken together, these four strands of policy action are expected to contribute to the development of a society that is better prepared to tackle complex, thorny issues such as climate change. Exploring specific policy recommendations for each of these critical policy areas for STEAM education will be the focus of the Road-STEAMer project in the years to come. Through a co-creation approach, the project team will develop and synthesise a policy roadmap for STEAM in Europe.

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