STEAM Education: The Claim for Socially Innovative Practices

Educación STEAM: La reivindicación de prácticas socialmente innovadoras

ELISABETH UNTERFRAUNER
Centre for Social Innovation
unterfrauner@zsi.at
ORCID ID: 0000-0002-1656-1932

ANNALISA ADDIS
The Lisbon Council for Economic Competitiveness and Social Renewal
annalisa.addis@lisboncouncil.net
ORCID ID: 0009-0001-0352-4569

CLAUDIA MAGDALENA FABIAN
Centre for Social Innovation
fabian@zsi.at
ORCID ID: 0000-0002-8869-5841

LUCY YEOMANS
University of Exeter
l.e.yeomans@exeter.ac.uk
ORCID ID: 0000-0002-7409-0577

Abstract: This paper examines the potential of STEAM (Science, Technology, Engineering, Arts, Mathematics) education as a socially innovative approach to making STEM education more inclusive and creativity-driven. Traditional STEM (Science, Technology, Engineering, Mathematics) education is essential for global innovation but often reinforces societal inequities. The EU-funded Road-STEAMer project aims to integrate creative approaches into STEM, fostering a skill set that combines technical and creative capabilities. This study investigates STEAM's potential to address the skill gaps and inclusivity issues in STEM education, aiming to guide educational policies toward a more diverse and capable workforce. Employing a four-step framework for transformative social innovation the study assesses current STEM limitations and presents findings from the DO IT programme, a European initiative for youth social innovation through hands-on learning. Creativity and self-efficacy changes in students were measured via pre-and post-tests. Findings show that DO IT participants, especially older students and females in structured settings, significantly improved creativity and self-efficacy. These gains highlight STEAM's capacity to develop both technical and creative skills, making education more inclusive. Our results show that STEAM education holds promise for addressing educational gaps and workforce needs. Recommendations emphasise policy support for STEAM integration, educator training, and inclusive frameworks to prepare students for future societal challenges.

Keywords: STEAM Education, Social Innovation, Inclusive Education, Educational Policy

Resumen: Este artículo examina el potencial de la educación *STEAM* (Ciencia, Tecnología, Ingeniería, Artes y Matemáticas) como enfoque socialmente innovador para hacer que la educación *STEM* (Ciencia, Tecnología, Ingeniería y Matemáticas) sea más inclusiva y esté más impulsada por la creatividad. La educación *STEM* tradicional es esencial para la innovación global, pero a menudo refuerza las desigualdades sociales. El proyecto Road-STEAMer, financiado por la Unión Europea, pretende integrar enfoques creativos en *STEM*, fomentando un conjunto de habilidades que combine capacidades técnicas y creativas. Este estudio investiga el potencial de *STEAM* para abordar las carencias de competencias y los problemas de inclusión en la educación *STEM*, con el objetivo de orientar las políticas educativas hacia una mano de obra más diversa y capaz. Utilizando un marco de cuatro pasos para la innovación social transformadora, el estudio evalúa las limitaciones actuales de *STEM* y presenta los resultados del programa *DO IT*, una iniciativa europea para la innovación social juvenil a través del aprendizaje práctico. Los cambios en la creatividad y la autoeficacia de los estudiantes se midieron mediante pruebas previas y posteriores. Los resultados muestran que los participantes en *DO IT*, especialmente los estudiantes de más edad y las mujeres en entornos estructurados, mejoraron significativamente la creatividad y la autoeficacia. Estas mejoras ponen de relieve la capacidad de *STEAM* para desarrollar tanto las habilidades técnicas como las creativas, haciendo que la educación sea más inclusiva. Nuestros resultados muestran que la educación *STEAM* es prometedora para abordar las lagunas educativas y las necesidades de mano de obra. Las recomendaciones hacen hincapié en el apoyo político a la integración de *STEAM*, la formación de educadores y los marcos inclusivos para preparar a los estudiantes para los retos de la sociedad.

Palabras clave: Educación STEAM, innovación social, educación inclusiva, política educativa

1. INTRODUCTION

Science Technology Engineering Mathematics (STEM) education is regarded as essential to steer innovation and economic growth worldwide. However, numerous studies have identified STEM teaching practices which potentially reproduce unequal participation and attainment amongst students of underrepresented backgrounds. To address these issues, more innovative approaches are needed that reflect the diversity of individuals' needs. In this respect, STEAM education, which incorporates artistic and creative approaches, seems promising.

The Road-STEAMer project, an EU funded Horizon Europe project, aimed at developing a roadmap for STEAM education (Science Technology Engineering Arts Mathematics) in Europe, collaboratively defined a set of criteria for effective STEAM education, and mapped existing STEAM practices as part of the preliminary steps to defining a roadmap.

For this paper, the lens of transformative social innovation has been applied to STEAM education as a socially innovative education practice, given that *"social innovations are novel or more effective practices that prove capable to tackle societal issues and are adopted and successfully utilised by individuals, groups and organisations concerned"* (Centre for Social Innovation, n.d.[1]). Following this definition, STEAM educational practices are a social innovation, as they provide an effective alternative to current, mainstream STEM education. In this case, the societal issue to be tackled is the so-called 'talent gap'. In particular, they address the 'talent gap' by not only increasing the number of professionals and developing skillsets for complex, real-world challenges but also enhancing diversity within the talent pool.

Transformative social innovation (Avelino & Wittmayer, 2018; Pel et al., 2020) emphasises promoting systemic change. In this case within educational systems, which are known to be resistant to change due to entrenched bureaucratic structures; rigid

[1] Profile // ZSI - Centre for Social Innovation

curricula that are slow to adapt to societal needs; risk aversion among stakeholders; limited funding and resource constraints; and accountability frameworks focused on standardised testing rather than innovative practices (Fullan, 2015; Cuban, 2013). Additionally, cultural norms and long-standing traditions often prioritise stability over experimentation, while administrative processes and approval requirements can hinder the adoption of new methodologies and technologies in the classroom (Whittaker & Montgomery, 2022).

Drawing on foundational frameworks from systems thinking, social innovation theory and change management (e.g. Westley & Antadze, 2010; Pel, et al., 2020), we differentiate between four steps in transformative social innovation processes:

It starts with the (step 1) *system analysis*, followed by (step 2) *system design*, the (step 3) *process knowledge phase,* and finally (step 4) the *system assessment*. The paper follows these steps in its theoretical foundation and empirical analysis as well as discussion.

The objective of this paper is to showcase how STEAM (Science, Technology, Engineering, Arts, Mathematics) education can act as a socially innovative approach to address current limitations in STEM education. It aims to illustrate, through empirical examples and analysis, how STEAM practices can bridge skill gaps, enhance inclusivity, and guide educational policies to foster a more diverse and capable workforce. The paper also seeks to provide evidence to support policy-making that integrates these approaches effectively into educational systems.

2. THEORETICAL FRAMEWORK

Following Transformative social innovation (SI) pathway, in the first step, the system analysis is performed. The question to be answered is “what is it” with the aim to capture the *system’s knowledge*, the structural framework conditions and current challenges. In the second step, the system design, the focus lies on “what could be”, to address the *transformation knowledge*. In this step, research is performed to identify potential alternatives that are fair for society. In the third step, the *process knowledge* step, innovations are co-designed and explored. In the last step, the *system assessment*, the new practice is evaluated. In our paper, we follow this four-step approach, with the caveat that we will not be able to fully complete the last phase as STEAM practices are not yet widely adopted. Instead, we provide the evaluation of one STEAM initiative as anecdotal evidence for STEAM policy making. The first two steps, the system's knowledge step and the process knowledge step, are addressed in the theoretical framework, while the two latter ones are covered in the empirical part of the paper.

2.1 The issues with STEM Education and the need for STEAM – transformative SI (step 1): a system's knowledge

In the following we explore the system's knowledge, i.e. the barriers that prevent equitable access to STEM education, and which are deeply rooted in system structures on the one hand and the need for a (science-)literate society to tackle global challenges on the other hand (Unterfrauner et al., 2024).

Numerous studies have provided evidence that socio-cultural conditions — such as family income, parental educational attainment, and access to learning resources—heavily influence STEM engagement and outcomes (Betancur et al., 2018; Gorard & See, 2009, Seebacher et al., 2021; Archer et al., 2012, Falk et al., 2016). There are national disparities in educational funding, but interestingly, attainment and funding do not largely correlate; for instance, countries like Estonia achieve high PISA scores despite lower spending compared to other EU countries, indicating that financial investment alone is insufficient to bridge these gaps (OECD, 2019). Instead, structural changes are required to make STEM accessible to students from diverse socio-cultural backgrounds.

The "leaky pipeline" model describes the loss of potential STEM participants, particularly women, as they advance through education and career stages. This model, however, has evolved into the "hostile obstacle course" metaphor, emphasising structural barriers that disproportionately affect individuals from underrepresented groups e.g., lower socio-economic backgrounds and certain ethnic minorities (Unterfrauner et al., 2024). Research reveals that these disparities are rooted in early socialisation and reinforced through stereotypical perceptions of STEM as male dominated. Interventions involving inclusive pedagogies, diverse role models, and the adoption of more integrated STEM approaches are highlighted as strategies to dismantle stereotypes, improve accessibility, and promote equity in STEM (Giammarco, 2020; Perales & Aróstegui, 2021; Ametller & Ryder, 2014; Makarova et al., 2019). For now, inclusivity remains a core challenge in STEM education.

The need for fundamental changes in STEM education becomes apparent also when considering industry needs, with business sectors increasingly demanding graduates are equipped with technical as well as essential transferable skills, such as creativity, intercultural awareness, and ethical reasoning. As technological advancements reshape workforce requirements, the blend of technical expertise with arts-driven creativity which can be found in STEAM approaches becomes particularly valuable for fostering holistic problem-solving skills (Penprase, 2018). This need for comprehensive skills suggests that a purely STEM-focused approach may neglect aspects crucial for industry and economic growth, reinforcing the shift toward an interdisciplinary STEAM framework (European Commission: Joint Research Centre., 2020).

Finally, a (science-) literate society is vital for addressing global issues like climate change and public health. By integrating scientific inquiry with creative thinking, STEAM education fosters a mindset capable of understanding and engaging with complex societal challenges. Thus, interdisciplinary education that prepares students not only as future professionals, but also as informed citizens equipped to navigate and address pressing issues (Snow & Dibner, 2016) is crucial in education the next generation.

We are living in a time of big changes, with urgent climate challenges and rapid technological advancements that once seemed like science fiction. To manage these powerful changes and drive future innovations, a well-educated workforce and a shift in mindset are essential. Especially in Europe, there is a growing call to invest in education and skill development, creating a strong 'talent pipeline'[2] (Unterfrauner et al., 2024) in key areas like information technology, engineering, and STEM (Science, Technology, Engineering, and Mathematics) to stay competitive with companies outside Europe (DigitalEurope, 2024).

At the same time, a major challenge is the ongoing underrepresentation of women and marginalised groups in these educational and job fields. Addressing this requires structural changes to boost representation, reduce bias in education, and offer more

[2] For an in-depth critique of the "leaky pipeline" metaphor and a suggestion to move towards the concept of "hostile obstacle course" see Unterfrauner et al. (2024). STEAM context, concepts and conditions: Socio-economic context and relevant needs (Deliverable 2.1, v.2) (Version 2). Zenodo. https://doi.org/10.5281/zenodo.14000682

diverse role models for future generations. As part of their agenda for a second term as President of the European Commission in 2024, Ursula von der Leyen has proposed a 'STEM Education Strategic Plan' to address the shortage of qualified STEM teachers and attract more girls and women to these fields (Von der Leyen, 2024). Before this, the Digital Education Action Plan 2021-2027 (DEAP) (European Commission, 2020) had already laid out steps to increase women's participation in STEM. Occasionally, these calls also include 'STE(A)M,' which adds the arts and creative approaches to STEM.

Using the latest research on education and focusing on the intersection between secondary and tertiary education, the EU funded Horizon Europe project Road-STEAMer (https://www.road-steamer.eu) argues that it's time to make more ambitious steps in education. If the usual way of doing things no longer works, we should rethink traditional education, too. Education should go beyond strict subject boundaries and aim for 'future-making'—the ability to respond creatively and flexibly to ongoing changes, not just teaching skills and knowledge (Colucci-Gray & Burnard, 2019).

2.2 Transformative potential of STEAM education

The importance of creativity is increasingly getting recognition, to the point that since 2022, the OECD PISA assessments include a measure for creative thinking. It is worth noting that learners from future-forward countries like Singapore significantly outperformed those from EU member states (OECD, 2024) – something to take into consideration when reflecting on competitiveness of the EU. Crucially, creative thinking is not an innate ability but something that can be nurtured: this is why the arts and creative approaches should not be a side feature of learning curricula. Instead, they should be valued on their own as a key part of cross-disciplinary and innovative education (Pirrie, 2019) [3].

Another common pitfall is thinking that the 'A' in STEAM means the simple addition of some creative elements to STEM disciplines as a way to make them more "fun" and less intimidating, in order to attract more diverse students. This is an underestimation of the innovative potential of STEAM, and it is commonly found in policy documents. For

[3] For a comprehensive analysis of the limitations of a narrow view of STEAM, refer to Pirrie, A. (2019).

instance, in the Digital Education Action Plan 2021-2027 (DEAP), STEAM is mentioned in Action 13 as a way to increase women's participation in STEM studies and careers – in other words, as a mere instrument to improve the outcomes of STEM education, without making fundamental changes. In contrast, truly transformative and innovative STEAM practices embrace and promote change more openly. It is not just a matter of having more female students in science or engineering, but of creating an environment in which female-coded perspectives are welcome, one in which learners from different backgrounds are encouraged to bring their unique standpoints and problem definitions, and in doing so, to influence the way knowledge is produced (e.g. Díaz-García et al., 2013). In this sense, STEAM with interdisciplinarity, creativity and collaborative aspects, as worked out by the project (see below), has the potential not only to improve education, but to change how scientific research sets about finding solutions to long-standing problems.

3.METHODOLOGY

In the following we address the transformation knowledge step by providing a STEAM educational approach as a potential alternative to current STEM practices, for a fair society with more equitable education and with potentially more positive outcomes and impacts. We firstly introduce the STEAM approach and the Road-STEAMer project and secondly, describe an example of STEAM practices.

3.1 The STEAM approach – Transformative SI (step 2): transformation knowledge

The Road-STEAMer project promotes a truly ambitious view of STEAM approaches, one that goes beyond the addition of arts to a list of disciplines, towards promoting well-rounded learning. In doing so, STEAM supports development of both technical skills (such as those needed for digital technology) and of creative problem-solving for tackling complex, real-world issues.

3.1.1 Road-STEAMer criteria: To better understand the transformative potential of STEAM, it is important to clarify how it is understood within the Road-STEAMer project (Chappel & Hetherington, 2023; Chappel et al., unpublished). While there isn't one single definition of STEAM, the Road-STEAMer project framework offers guidance in the form of key recommended criteria (Yeomans et al., 2023; Yeomans et al., unpublished):

- ***Collaboration***: This involves teamwork among students, communication between teachers, and connections with people inside and outside the school. In STEAM, teachers guide rather than lecture.
- ***Disciplinary inter-relationships***: STEAM combines subjects instead of treating them separately. The arts and other fields are equally valued, and ideas should move across disciplines to solve problems and use technology.
- ***Thinking-Making-Doing***: This refers to connecting thinking, creating, and doing with STEAM practices, which helps to gain a more active and dynamic learning experience.
- ***Creativity***: Creativity is core to STEAM activities, allowing students to generate new ideas. In digital projects, creativity extends beyond ideas and includes making and designing or doing.
- ***Real-World Connection***: STEAM connects learning to real-life issues, like climate change, making learning meaningful and empowering students to see themselves as change-makers by tackling complex problems through problem-solving and inquiry-based learning.
- ***Inclusion/Personalisation/Empowerment***: Activities are designed so that all participants, no matter their confidence level, can participate fully. STEAM gives young people a space to develop their identities and see STEAM as something 'for them.' Focusing on personalisation and empowerment helps create a more inclusive and engaging learning environment.
- Road-STEAMer also emphasises '***Equity***' as a key value that runs through all STEAM practices, ensuring fairness in design, learning, and outcomes.

These criteria form the foundation of Road-STEAMer's framework for evaluating STEAM practices. Not all criteria need to be fully met for an educational practice to qualify as STEAM —different educational approaches may emphasise some criteria more than others, although significant gaps may highlight a need for further development and refinement of the practice.

3.1.2. Mapping of Road-STEAMer practices: Building on this framework, the Road-STEAMer project sought to apply these criteria to real-world STEAM practices through a comprehensive mapping exercise (Juillard & Aguirre, 2023). This effort aimed to capture a clear picture of STEAM education across Europe by identifying current trends, highlighting critical gaps, and pinpointing opportunities for growth. By doing so, Road-STEAMer hopes to establish a foundation for further developing digital and STEAM education to meet pressing socioeconomic needs.

The mapping exercise highlighted that STEAM education is rapidly evolving, with significant strides in "open schooling," personalised science learning, and community engagement, helping to link students with real-world STE(A)M applications. Current trends such as gamification, as seen in projects like GAPARS[4] and GREAT[5], are making STEAM more interactive and enjoyable, while many initiatives address gender disparities, with about 75% implementing gender equity policies.

However, there remains a need to broaden inclusion for LGBTQ+ individuals and migrants. These projects also tackle pressing socioeconomic issues like employment and sustainability, showing STEAM's role in addressing social needs. Key challenges persist, including limited integration of the arts as a core component, insufficient focus on early math and abstract skills development, and minimal use of industry data and entrepreneurship within STEAM, which limits students' preparation for a changing job market. Funding and accessibility remain concerns, as many projects receive EU support but lack local resources, particularly affecting disadvantaged communities. Moving forward, the Road-STEAMer's mapping analysis recommends stronger art's and creative approaches' integration, better support for entrepreneurship, and a more inclusive approach to STEAM. An interactive mapping[6] feature is being developed to showcase survey findings, facilitating greater collaboration and resource-sharing among educators, policymakers, and stakeholders.

In the following we will describe one prime example of a STEAM practice that aimed at promoting entrepreneurial education for children in school as well as extracurricular

[4] GAPARS project reference: https://cordis.europa.eu/project/id/732703
[5] GREAT project reference: https://www.greatproject.gg
[6] Road-STEAMer interactive mapping of STEAM practices: www.road-steamer.eu/interactive-map-of-steam-practices

activity. Following the logic of transformative social innovation, this step corresponds with process knowledge, i.e. innovations are co-designed and explored in practice.

3.2 A STEAM example: the DOIT programme – Transformative SI (step 3): process knowledge

The European project *DOIT* (Digital Fabrication and Making for Social Innovators) was a three-year initiative (October 2017 – September 2020), bringing together 13 partner organisations from ten European countries. Its main objective was to create and pilot an educational programme for young children that combined elements of maker culture, entrepreneurship, and social innovation. The programme emphasised developing innovations that serve the broader public interest, particularly in alignment with the United Nations Sustainable Development Goals (SDGs) (Rosa, 2017). These broad goals were simplified to resonate with children's everyday experiences, making the concepts more relatable and relevant for their life.

The DOIT programme's structure aligns with Eurydice's framework on entrepreneurship education, which encourages "learners to develop the skills and mind-set to be able to turn creative ideas into entrepreneurial action," viewed as essential for fostering personal development, active citizenship, social inclusion, and employability (Eurydice, 2016, p. 7).

The programme (see Table 1) comprised seven elements, with a recommended minimum duration of 15 hours (Geser et al., 2019).

Table 1. DOIT Learning Programme

DOIT Learning Programme Element	Social Innovation and Entrepreneurial Aspect
1. Do it because you can (sensitise)	Awareness of a social problem; motivation to address it
2. Do what matters (explore)	Identifying the challenge; exploring needs; brainstorming ideas
3. Do it together (work together)	Team-building; elaborating and selecting ideas collaboratively
4. Do it now (create)	Initial prototyping; presentation and iterative improvement
5. Do more of it (scale up)	Planning realisation; business planning; developing marketing support
6. Do inspire others (share)	Public presentation; sharing project outcomes and stories
7. Do it because you can (sensitise)	Awareness of a social problem; motivation to address it

The DOIT programme began with sensitisation activities, where students envisioned potential roles in addressing SDG-related challenges within their own contexts. The subsequent exploration phase encouraged students to investigate and identify a challenge, followed by co-design activities to generate and refine innovative ideas collaboratively. In the creation phase, teams prototyped initial versions of their ideas, iterating to enhance their functionality. During the scaling-up phase, students developed plans for implementing their final prototypes. Finally, in the outreach phase, students tested the robustness of their designs with a broader audience and presented their projects publicly (Rosa, 2017; Geser et al., 2019).

For example, students prototyped an alarm system to detect flooding risks from a mountain creek or a machine that could repurpose waste into usable items. The programme's emphasis was less on achieving fully operational prototypes and more on empowering students to conceive, believe in, and collaboratively work on tangible representations of their ideas in a transdisciplinary, interdisciplinary and collaborative way.

The DOIT programme was implemented across ten European countries, utilising both school-based and extracurricular settings, often through pop-up makerspaces or existing makerspaces, offering flexible, hands-on environments to cultivate young students' social and entrepreneurial innovation skills (Geser et al., 2019).

Mapped against the Road-STEAMer criteria (Juillard & Aguirre, 2023), many of these are fulfilled, according to a multi-expert rating (100 being the maximum score), as the table below shows. The DOIT programme is one of 3o STEAM practices that were mapped according to the Road-STEAMer criteria.

Table 2. STEAM criteria applied to DOIT programme

Criterion	Rating score	DOIT programme – Justification of rating score
Collaboration	100/100	Facilitators: act as advisors or counsellors, collaboration with external stakeholders is sought at different phases of the DOIT programme Tools used: maker technology, DIY learning, creative practice, Environment
Disciplinary Inter-Relationships	85/100	Transdisciplinarity and interdisciplinarity: creativity & arts, entrepreneurship, manufacturing, creativity, design thinking, aesthetics
Thinking-Making-Doing (TMD)	100/100	Allowing flexibility in the balance between thinking, making, and doing aspects; critical learning, problem solving, active behaviour; observational skills, object-based learning; environment
Creativity	100/100	Innovation, TMD, Interdisciplinary and collaborating support
Real-world Connection	85/100	Children were familiarised with SDGs and found related specific problem in their environment; Technological/Entrepreneurship/Interdisciplinary skills, Personal development, uncertainty management, career aspirations
Inclusion / Personalisation / Empowerment	100/100	Increasing self-expression/esteem/empowerment/confidence and wellbeing of participants, personal development, broadening the mindset of participants, career aspirations

3.3 Transformative Social Innovation (Step 4): System assessment

In the fourth step, the transformative socially innovative practise is assessed and as much as evidence would be needed for STEAM approaches overall, a systematic assessment of all STEAM practices cannot be completed until STEAM practices are adopted and implemented on bigger scale.

To provide evidence, the evaluation of single initiatives however can provide empirical basis that is much needed for a discourse on educational policy level. Thus, in the following with DOIT as an example for STEAM education, we will share the evaluation results of the DOIT programme.

3.4 Instruments for data collection

To assess the DOIT programme's impact on participants, a one-group pre/post quasi-experimental design was used, following the approach of Levine and Parkinson (2014), though lacking a control group due to logistical challenges in schools and community settings. This design tracks changes from pre- to post-test but cannot fully control for external influences, a common issue in quasi-experimental research (Bauman & Nutbeam, 2013). Participants completing at least 15 hours were designated as the experimental group, while those with fewer hours formed a comparison group.

Creativity was measured using the TCT-DP (Test for Creative Thinking-Drawing Production) (Urban & Jellen, 2010), a standardised, culture-fair test with pre- and post-test forms to control learning effects (Weiner et al., 2012). The TCT-DP assesses creativity through various qualitative components (composition, unconventionality, and risk-taking) without emphasising drawing skills and has been used in similar studies (e.g., Greb et al., 2007; Karwowski & Soszynski, 2008; Maksić & Tenjović, 2008).

For self-efficacy, an adapted 15-item questionnaire was developed, focusing on peer relations, personal capability, and problem-solving, plus entrepreneurial intention, drawing on various standardised instruments (Deusinger, 1986; Krampen, 1991; Midgley et al., 1998; Seitz & Rausche, 2004). The EntreComp framework (Bacigalupo et al., 2016) was also considered but did not align with the study's younger age group. After pre-tests with children, a 5-point Likert scale was selected, as visual scales created confusion, corroborating Mellor and Moore's (2014) findings. Translations underwent backward translation to ensure accuracy and consistency across languages.

3.5. Sample: the DOIT programme participants

Between September 2018 and December 2019, overall, 1,002 children in ten European countries participated in the DOIT programme. For the analysis of self-efficacy and creativity, only participants with at least 15 hours of engagement and complete pre- and post-test data were included, resulting in 759 self-efficacy and 618 creativity datasets. Incomplete responses were excluded from the final analysis.

4. RESULTS

In the DOIT study, the TCT-DP creativity test was administered under controlled conditions: participants were provided with only a pencil or black felt pen, with no additional tools (e.g., erasers or rulers), and were given 15 minutes to complete their drawings. Facilitators followed detailed instructions to standardise the environment, which ensured consistency across different testing locations and contributed to the reliability of the results. Each completed test was evaluated across 14 criteria, allowing a nuanced view of creativity dimensions from problem-solving approaches to aesthetic organisation and originality in the drawings.

4.1 Key Results in Creativity Development

The analysis of pre- and post-test scores indicated an average increase of 1.59 points, a statistically significant improvement, which underscores the positive impact of the DOIT programme on participants' creativity levels. When breaking down the analysis further by demographic variables and programme settings, several patterns emerged:

Age Differences: The older age group (11–16 years) showed a significantly greater increase in creativity scores than the younger age group (6–10 years), with effect sizes indicating that older children, likely due to greater cognitive and emotional development, could harness the DOIT programme's collaborative and problem-solving aspects more effectively. For instance, while the younger group showed some creativity gains, their improvements were less pronounced (Cohen's d for the older group was 0.28 compared to 0.03 in the younger group). This finding aligns with research by Chan and Zhao (2010) and Claxton et al. (2005), which suggests that older children benefit more from creativity-stimulating interventions, as they are better equipped to engage in complex problem-solving tasks and abstract thinking required in creative projects.

Gender Differences: Both male and female participants improved their scores; however, the increase was notably higher for females. On average, females moved from a mean score of 18.81 in the pre-test to 21.98 in the post-test, compared to males who progressed from 18.73 to 19.68. The larger effect size for females (Cohen's d = 0.28) suggests that the DOIT programme may have provided a particularly supportive environment for female students, enabling them to develop confidence in expressing creativity within structured tasks, whereas males showed a smaller yet statistically significant improvement (Cohen's d = 0.12).

Setting (School vs. Extracurricular): Participants in school-based DOIT programmes demonstrated a more substantial increase in creativity than those participating outside school settings. In-school participants moved from an average of 18.42 in the pre-test to 20.27 in the post-test, showing a Cohen's d of 0.24. The extracurricular group, however, displayed minimal gains, potentially reflecting a ceiling effect, as these students had higher baseline creativity scores. The initial high scores could be due to self-selection, as children with a pre-existing interest in creative activities are more likely to join non-mandatory, extracurricular programs (Wainer, 2000).

This setting-specific impact aligns with studies indicating that creativity can be influenced by the learning environment and perceived peer support (Harkins, 2001). The structured nature of school programmes, where creativity tasks are embedded within a familiar learning environment, may create conditions conducive to creativity gains. In contrast, the extracurricular group's performance plateau suggests that a highly creative baseline limits measurable improvements, especially in short-term interventions.

Analysis by Setting and Demographics: The data also revealed that the DOIT programme was particularly effective in enhancing creativity when tailored to the specific needs and dynamics of participants. In older students, especially females in school-based programs, the structured, hands-on activities led to measurable increases in creative thinking and originality. This is consistent with past findings that structured environments can foster creative expression by providing both the tools and social encouragement necessary for creativity, especially in demographic groups that may feel less inclined toward expressive, hands-on tasks (Hwang, 2017).

In contrast, participants in extracurricular settings, despite initially higher creativity levels, displayed less substantial growth, which could reflect a "ceiling effect," a common phenomenon where participants at the top end of a measurement scale have limited room for improvement (Harkins, 2001). Therefore, this pattern reinforces the importance of integrating creativity-fostering interventions within school settings, where they can reach a broader demographic and achieve significant improvements.

4.2 Key Findings in Self-Efficacy Development

The analysis of self-efficacy results shows a statistically significant increase in overall self-efficacy scores from the pre-test to the post-test, with an average improvement of 0.56 points. This shift indicates that the DOIT programme positively impacted participants' confidence and self-belief, crucial qualities for entrepreneurial and problem-solving mindsets. When examining demographic and contextual differences in self-efficacy development, several insights emerged:

Age Differences: The younger age group (6–10 years) demonstrated a higher baseline self-efficacy score in the pre-test compared to older participants, aligning with studies that suggest younger children often have more optimistic views of their capabilities (Pajares & Urdan, 2006). Interestingly, while both age groups showed score increases, the older age group (11–16 years) saw a more notable gain in self-efficacy from pre-test (54.77) to post-test (55.25), with a statistically significant effect size (Cohen's d = 0.07). The younger group's self-efficacy scores also improved, albeit less dramatically, supporting findings that early self-efficacy perceptions can remain stable but also benefit from reinforcement through hands-on, success-driven activities.

Gender Differences: The self-efficacy data revealed slight variations in how males and females responded to the DOIT programme. Initially, boys had a slightly higher average score in the pre-test (55.44) compared to girls (54.50). While both groups showed increased self-efficacy post-programme, the gain for boys (0.66 points, $p < 0.01$) was more significant than for girls (0.41 points, $p < 0.08$). This could indicate that the collaborative, maker-centred tasks resonated more strongly with boys in terms of self-perceived competence in problem-solving, which is often emphasised in traditional entrepreneurial education as well. However, girls' scores increased significantly too, underscoring the programme's ability to enhance self-efficacy across genders.

Setting (School vs. Extracurricular): Participants involved in the DOIT programme within a school setting demonstrated a modest increase in self-efficacy (53.79 pre-test to 54.19 post-test). In contrast, those participating in extracurricular, voluntary settings began with a notably higher baseline self-efficacy score (58.24) and showed a more substantial improvement (to 59.26 post-test), with an effect size (Cohen's d = 0.13) indicating a significant impact. This pattern might reflect a positive self-selection bias in extracurricular settings, where children with an existing interest or confidence in project-based or maker activities chose to join. As with the creativity results, the high initial score in these participants could suggest that extracurricular programmes draw individuals who are already somewhat self-efficacious, and yet the programme further reinforced this trait.

The DOIT programme's results for creativity and self-efficacy were compared to a quasi-control group of 27 participants who engaged in fewer than the required 15 hours of the programme. This control group completed both pre- and post-tests but participated only minimally, which allowed a comparison to evaluate if the observed improvements could be attributed to the programme rather than external factors.

For creativity, the experimental group (those completing at least 15 hours) showed a statistically significant increase in TCT-DP scores from pre-test to post-test, with an average gain of 1.59 points. In contrast, the control group's creativity scores did not increase significantly ($p = 0.286$), suggesting that the creativity gains in the experimental group were likely due to the programme's interventions. This comparison reinforces that the structured, maker-oriented activities in the DOIT programme contributed meaningfully to creativity development.

In terms of self-efficacy, the experimental group also demonstrated a statistically significant increase in overall scores, whereas the control group's self-efficacy scores remained largely unchanged ($p = 0.724$). This pattern indicates that the DOIT programme's activities positively influenced participants' confidence and problem-solving capabilities, supporting the effectiveness of the programme in bolstering self-efficacy.

The lack of significant score changes in the control group supports the conclusion that the DOIT programme's effects on creativity and self-efficacy were not due to external influences or the mere passage of time. Instead, these results suggest that the hands-on, collaborative, and problem-solving activities intrinsic to the programme were instrumental in driving measurable improvements in these entrepreneurial competencies.

5. DISCUSSION AND CONCLUSION

While the DOIT programme refers to entrepreneurial education, many of the programme elements have STEAM focus and, as the mapping exercise showed, the STEAM criteria match the DOIT programme to a high extent.

The results confirm that the DOIT programme as an example of effective STEAM education has a statistically significant effect on participants' creativity development, with varying outcomes across age, gender, and programme setting. The findings suggest that embedding maker education within formal school contexts may maximise creative growth, particularly among older children and female students, who showed the most substantial gains. These insights point to the potential for maker education not only to stimulate creativity but also to empower students by nurturing an environment that encourages risk-taking, unconventional thinking, and collaborative problem-solving, all crucial skills for STEAM careers.

These self-efficacy results emphasise that the DOIT programme's combination of maker and entrepreneurial education successfully supports skill development in key self-efficacy areas. By increasing participants' confidence in their capabilities and problem-solving abilities, the programme contributes to foundational entrepreneurial qualities, such as initiative, resilience, and adaptability. Interestingly, the lack of significant improvement in peer-related self-efficacy suggests an area for future programme enhancement. More explicitly collaborative or feedback-oriented activities could help bolster peer confidence, potentially leading to more robust improvements in this facet of self-efficacy.

5.1 Limitation of the study

While the DOIT programme provides valuable insights into the potential of STEAM education, several limitations should be considered. First, the study used a quasi-experimental design without a control group in the stricter sense due to logistical constraints, limiting the ability to attribute all observed effects exclusively to the programme. Although a quasi-control group was included, further randomised controlled studies could strengthen the causal claims. Additionally, the study relied partly on self-reported measures, which may introduce bias, particularly in assessing self-efficacy. The short duration of the intervention also limits insights into long-term impacts on creativity and self-efficacy, calling for longitudinal studies to evaluate sustained effects over time. Finally, while the DOIT programme spanned multiple countries, variations in implementation across different educational and cultural contexts could affect comparability and generalisability.

The DOIT programme's findings on creativity and self-efficacy growth underscore the critical role of integrated STEAM education in cultivating skills vital for both personal and societal development. This section discusses the implications of these findings for STEAM education policy, especially considering the transformative social innovation potential of STEAM for fostering inclusive and innovative learning environments.

5.2 Rethinking STEAM Integration for Broader Educational Impact

The DOIT programme's impact on creativity and self-efficacy highlights STEAM's potential to bridge the gap between technical and soft skills, essential for addressing today's complex societal issues. The significant improvements in creativity and problem-solving among participants reinforce the importance of arts integration in STEM, underscoring the need for STEAM approaches that go beyond simply making STEM subjects more appealing. For policy, this suggests the necessity of framing STEAM not merely as a strategy to attract diverse students but as a core approach to develop well-rounded, adaptable thinkers capable of innovative and ethical decision-making.

5.3 Fostering Equity and Inclusion in STEAM Education

The results show that structured, school-based STEAM initiatives, like those in the DOIT programme, were particularly effective in supporting the creativity and self-efficacy of traditionally underrepresented groups, including female students. This finding aligns with studies that emphasise the importance of inclusive pedagogies and diverse role models within STEAM fields (e.g. Makarova et al., 2019). Policy initiatives should thus prioritise equitable access to STEAM education, ensuring resources and support for schools and educators to embed arts-driven creativity within STEM, especially in under-resourced or socio-economically challenged regions.

5.4 Strengthening Teacher Support for STEAM Implementation

To effectively integrate STEAM practices, educators need robust training and ongoing support. Policies should focus on developing teacher training programmes that emphasise interdisciplinary teaching methods and STEAM-focused professional development. The DOIT programme's structured, hands-on learning modules highlight the effectiveness of programmes that guide teachers in using active, student-centred learning strategies. Moreover, encouraging educators to view arts and creative approaches not as supplementary but as essential for fostering creativity in scientific and technical disciplines can amplify the benefits of STEAM for diverse learners.

5.5 Long-Term STEAM Policy Commitments

Sustainable STEAM initiatives require consistent policy backing and funding. While projects like DOIT have demonstrated impact, a broader policy commitment is essential to ensure that such programmes can be scaled and sustained. National and regional educational policies should create frameworks that support STEAM education long-term, integrating it into core curricula rather than positioning it as an extracurricular or experimental approach. Additionally, supporting research and data collection on STEAM outcomes can help to build the evidence base needed to refine and advocate for STEAM policy.

5.6 Promoting Real-World Connection and Social Innovation in STEAM

By encouraging students to engage with real-world issues, STEAM education can foster social innovation skills and empower students to become proactive, engaged citizens. The DOIT programme's focus on addressing sustainable development goals demonstrates the value of connecting STEAM education to global issues such as climate change, public health, and social equity. Policies should incentivise STEAM curricula that incorporate these elements, emphasising problem-based learning and student-led projects that are closely linked to real-world contexts.

5.7 Further research

To build on the findings of the DOIT programme, future research should focus on larger-scale studies with controlled designs that compare STEAM education outcomes across diverse educational settings and demographic groups. Longitudinal studies tracking students' development over time would be valuable for assessing the sustained impact of STEAM interventions on creativity, problem-solving, and self-efficacy. Further research could also explore specific elements of the "A" in STEAM, identifying which aspects of arts integration as defined in Road-STEAMer's criteria for STEAM most effectively foster inclusive learning and skill development. Additionally, studies that examine the broader societal impacts of STEAM education, particularly in preparing students for future digital and socio-economic challenges, could inform policy to ensure that STEAM approaches meet both educational and societal needs comprehensively.

5.8 Conclusion

The DOIT programme serves as a strong example of how structured, arts-integrated STEM education can yield positive outcomes in creativity and self-efficacy. However, broader adoption of such STEAM initiatives across educational systems will require targeted policy changes, including dedicated funding, equitable access, and teacher support. As policymakers aim to foster a future-ready workforce, STEAM should be central to strategies aimed at preparing students not only for evolving job markets but also for active and informed citizenship.

ACKNOWLEDGEMENTS / FUNDING

The Road-STEAMer project has received funding from the European Union's Horizon Europe programme under grant agreement No 101058405, coordinated by the Lisbon Council, and implemented with the following partners: Association Européenne des Expositions Scientifiques, Techniques et Industrielles (ECSITE), Copernicus Science Centre (CSC), Junior Academy of Sciences of Ukraine (JAS), Association TRACES Théories et Réflexions sur l'Apprendre, la Communication et l'Éducation Scientifiques (TR), Science View (SV), Ellinogermaniki Agogi (EA), Engineering - Ingegneria Informatica (ENG), European School Heads Association (ESHA), Panteion University (PAN), Politecnico di Milano (PO), University of Malta (UM), Centre for Social Innovation (ZSI), University of Exeter (UoE).

DOIT has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 770063. The DOIT programme was piloted in ten different European countries with the following practice partner organisations involved: Salzburg Research- overall coordinators of the project (SRFG), Stichting Waag Society (WAAG), Lappeenranta University of Technology (LUT), Mediale Pfade - Verein für Medienbildung e.V. (MEPF), eduCentrum (eduC), ZAVOD Kersnikova (ZAK), Polyhedra d.o.o. (POLY), Capital of Children A/S (CoC), University of Zagreb (UZAF), Institut d'Arquitectura Avançada de Catalunya (IAAC) (FabLab Barcelona), and Pædagoguddannelsen i Kolding (UC SYD).

6. REFERENCES

Archer, L., DeWitt, J., Osborne, J., Dillon, J., Willis, B., & Wong, B. (2012). Science Aspirations, Capital, and Family Habitus: How Families Shape Children's Engagement and Identification with Science. *American Educational Research Journal*, *49*(5), 881-908. https://doi.org/10.3102/0002831211433290

Avelino, F., & Wittmayer, J. (2018). Transformative social innovation and its multi-actor nature. *Atlas of Social Innovation–New Practices for a Better Future, J. Howaldt, C.*

Kaletka, A. Schröder, and M. Zirngiebl, Eds. Dortmund: Sozialforschungsstelle, TU Dortmund University, 47-50. https://doi.org/10.14512/9783962386887

Bacigalupo, M., Kampylis, P., Punie, Y., & Van den Brande, G. (2016). EntreComp: The entrepreneurship competence framework. *Luxembourg: Publication Office of the European Union*, 10, 593884. https://doi.org/10.2791/160811

Bauman, A., & Nutbeam, D. (2013). *Evaluation in a nutshell: a practical guide to the evaluation of health promotion programs*. McGraw-hill. Australia. https://doi.org/10.1002/j.2201-1617.2007.tb00733.x

Betancur, L., Votruba-Drzal, E., & Schunn, C. (2018). Socioeconomic gaps in science achievement. *International Journal of STEM Education*, *5*, 1-25. https://doi.org/10.1186/s40594-018-0132-5

Chan, D. W., & Zhao, Y. (2010). The relationship between drawing skill and artistic creativity: do age and artistic involvement make a difference? *Creativity Research Journal*, *22*(1), 27-36. http://dx.doi.org/10.1080/10400410903579528

Chappell, K., & Hetherington, L. (2023). ROAD-STEAMER Deliverable 4.1 Research Framework. Zenodo. https://doi.org/10.5281/zenodo.10634931

Chappel, K., Hetherington, L., Juillard, S., Duca, E. & Aguirre, C. (in 2nd review). A framework for effective STEAM education: Pedagogy for responding to wicked problems. International Journal of Education Research Open. STEAM special issue.

Claxton, A. F., Pannells, T. C., & Rhoads, P. A. (2005). Developmental trends in the creativity of school-age children. *Creativity Research Journal*, *17*(4), 327-335. http://dx.doi.org/10.1207/s15326934crj1704_4

Colucci-Gray, L., & Burnard, P. (2019). (Re-) Configuring STEAM in Future-Making Education. In *Why science and art creativities matter* (pp. 1-13). Brill. (https://brill.com/display/book/9789004421585/BP000009.xml)

Cuban, L. (2013). *Inside the black box of classroom practice: Change without reform in American education*. Harvard Education Press. https://doi.org/10.5860/choice.51-2206

Díaz-García, C., González-Moreno, A., & Jose Sáez-Martínez, F. (2013). Gender diversity within R&D teams: Its impact on radicalness of innovation. *Innovation*, *15*(2), 149-160. https://doi.org/10.5172/impp.2013.15.2.149

DigitalEurope (2024), THE EU'S CRITICAL TECH GAP. Rethinking Economic Security to put Europe back on the map, July 2024 https://cdn.digitaleurope.org/uploads/2024/07/DIGITALEUROPE-CRITICAL-TECHNOLOGIES-REPORT-FINAL_JULY_WEB.pdf

Deusinger, I. M. (1986). *Die Frankfurter Selbstkonzeptskalen: (FSKN)*. Hogrefe, Verlag für Psychologie.

European Commission (2020), COM(2020) 624 final, Communication From the Commission to the European Parliament, the Council, the European Economic and Social Committee and The Committee of the Regions, Digital Education Action Plan 2021-2027 *Resetting education and training for the digital age* (https://education.ec.europa.eu/sites/default/files/document-library-docs/deap-factsheet-sept2020_en.pdf)

European Commission: Joint Research Centre, Di Pietro, G., Biagi, F., & Castaño Muñoz, J. (2020). *Mismatch between demand and supply among higher education graduates in the EU*, Publications Office. https://data.europa.eu/doi/10.2760/003134

Eurydice. (2016). *Entrepreneurship Education at School in Europe: Eurydice Report*. Publications Office of the European Union. https://data.europa.eu/doi/10.2797/301610

Falk, J. H., Staus, N., Dierking, L. D., Penuel, W., Wyld, J., & Bailey, D. (2016). Understanding youth STEM interest pathways within a single community: The Synergies project. *International Journal of Science Education, Part B*, *6*(4), 369-384. https://doi.org/10.1080/21548455.2015.1093670

Fullan, M. (2015). *The new meaning of educational change (5th ed.)*. Teachers college press. ISBN-10.0807756806, ISBN-13. 978-0807756805

Geser, G., Hollauf, E. M., Hornung-Prähauser, V., Schön, S., & Vloet, F. (2019). Makerspaces as social innovation and entrepreneurship learning environments: The DOIT learning program. *Discourse and Communication for Sustainable Education*, *10*(2), 60-71. https://doi.org/10.2478/dcse-2019-0018

Giammarco, M., Higham, S., & McKean, M. (2020). The future is social and emotional: Evolving skills needs in the 21st century. In *The Conference Board of Canada*.

Gorard, S., & See, B. H. (2009). The impact of socio-economic status on participation and attainment in science. *Studies in Science Education*, *45*(1), 93-129. https://doi.org/10.1080/03057260802681821

Greb, K., Faust, G., & Lipowsky, F. (2007). Projekt PERLE: Persönlichkeits-und Lernentwicklung von Grundschulkindern. *Diskurs Kindheits-und Jugendforschung*, *2*(1), 100-104.

Harkins, S. G. (Ed.). (2001). *Multiple perspectives on the effects of evaluation on performance: Toward an integration*. Springer Science & Business Media. http://dx.doi.org/10.1007/978-1-4615-0801-4

Hwang, JP. (2017). Maker Movement Influence on Students' Learning Motivation and Learning Achievement – A Learning Style Perspective. In: Huang, T.C., Lau, R., Huang, Y.M., Spaniol, M., Yuen, C.H. (eds) *Emerging Technologies for Education*. SETE 2017. Lecture Notes in Computer Science(), vol 10676. Springer, Cham. https://doi.org/10.1007/978-3-319-71084-6_53

Juillard, S., & Aguirre Rios, C. (2023). Road-STEAMer Mapping of existing STEAM practices (deliverable 4.2). Zenodo. https://doi.org/10.5281/zenodo.14041462

Karwowski, M., & Soszynski, M. (2008). How to develop creative imagination?: Assumptions, aims and effectiveness of Role Play Training in Creativity (RPTC). *Thinking Skills and Creativity*, *3*(2), 163-171. https://doi.org/10.1016/j.tsc.2008.07.001

Krampen, G. (1991). FKK Fragebogen zu Kompetenz und Kontrollüberzeugungen. Göttingen. Hogrefe.

Levine, G., & Parkinson, S. (2014). *Experimental methods in psychology*. Psychology Press. https://doi.org/10.4324/9781315806600

Makarova, E., Aeschlimann, B., & Herzog, W. (2019). The gender gap in STEM fields: The impact of the gender stereotype of math and science on secondary students' career aspirations. In *Frontiers in Education* (Vol. 4, p. 60). Frontiers Media SA. https://doi.org/10.3389/feduc.2019.00060

Maksić, S., & Tenjović, L. (2008). Temporal stability of scores on Urban-Jellen test for creative Thinking in Childhood. *From giftedness to successful intelligence. Proceedings of 11th Conference of European Council for High Ability (ECHA), Prague*, 24-32.

Mellor, D., & Moore, K. A. (2014). The use of Likert scales with children. *Journal of pediatric psychology*, *39*(3), 369-379. https://doi.org/10.1093/jpepsy/jst079

Midgley, C., Kaplan, A., Middleton, M., Maehr, M. L., Urdan, T., Anderman, L. H., Anderman, E., & Roeser, R. (1998). *Patterns of Adaptive Learning Scales (PALS)* [Database record]. APA PsycTests. https://doi.org/10.1037/t19870-000

OECD (2019), *PISA 2018 Results (Volume I): What Students Know and Can Do*, PISA, OECD Publishing, Paris, https://doi.org/10.1787/5f07c754-en.

OECD (2024), *PISA 2022 Results (Volume III): Creative Minds, Creative Schools*, PISA, OECD Publishing, Paris, https://doi.org/10.1787/765ee8c2-en. https://doi.org/10.1080/21548455.2015.1093670

Pajares, F. & Urdan, T. C. (Eds.). (2006). *Self-efficacy beliefs of adolescents*. IAP - Information Age Pub. ISBN: 9781593113674

Pel, B., Haxeltine, A., Avelino, F., Dumitru, A., Kemp, R., Bauler, T., Kunze, I., Dorland, J., Wittmayer, J., & Søgaard Jørgensen M. (2020). Towards a theory of transformative social innovation: A relational framework and 12 propositions, *Research Policy, Volume 49, Issue 8, 2020*, 104080, ISSN 0048-7333, https://doi.org/10.1016/j.respol.2020.104080.

Penprase, B.E. (2018). The Fourth Industrial Revolution and Higher Education. In: Gleason, N. (eds) *Higher Education in the Era of the Fourth Industrial Revolution*. Palgrave Macmillan, Singapore. https://doi.org/10.1007/978-981-13-0194-0_9

Perales, F. J., & Aróstegui, J. L. (2021). The STEAM approach: Implementation and educational, social, and economic consequences. *Arts Education Policy Review*, 0(0), 1–9. https://doi.org/10.1080/10632913.2021.1974997

Pirrie, A. (2019). Where Science Ends, Art Begins?: Critical Perspectives on the Development of STEAM in the New Climatic Regime. In: *Why science and art creativities matter* (pp. 19-34). Brill. https://doi.org/10.1163/9789004421585_003

Rosa, W. (2017). Transforming Our World: The 2030 Agenda for Sustainable Development. In: *A New Era in Global Health*. Springer Publishing Company. https://doi.org/10.1891/9780826190123.ap02

Seebacher, L. M., Vana, I., Voigt, C., & Tschank, J. (2021). Is Science for Everyone? Exploring Intersectional Inequalities in Connecting With Science. *Frontiers in Education*, Vol. 6. Frontiers Media SA. https://www.frontiersin.org/articles/10.3389/feduc.2021.673850

Seitz, W. & Rausche, A. (2004): Persönlichkeitsfragebogen für Kinder zwischen 9 und 14 Jahren: PFK 9 – 14. Hogrefe. Ref-ID:55770; P-ID:55769.

Snow, C. E. & Dibner, K. A. (Eds.). (2016). Science literacy: Concepts, contexts, and consequences. National Academies of Science, Engineering, and Medicine. https://doi.org/10.17226/23595

Unterfrauner, E., Fabian, C. M., Yeomans, L., Voulgari, I., Sotiriou, M., Sotiropoulos, D., Cherouvis, S., Koulouris, P., & Bresciani, S. (2024). STEAM context, concepts and conditions: Socio-economic context and relevant needs (Deliverable 2.1, v.2) (Version 2). Zenodo. https://doi.org/10.5281/zenodo.14000682

Urban, K. K. & Jellen, H. G. (2010). Test zum Schöpferischen Denken – Zeichnerisch: (TSD-Z). Pearson Assessment & Information GmbH. Ref-ID:20503; P-ID:19131.

Von der Leyen, U. (2024). EUROPE'S CHOICE - Political Guidelines For The Next European Commission 2024–2029. Straßbourg.

Wainer, H. (Ed.). (2000). Drawing Inferences From Self-selected Samples (1st ed.). Routledge. https://doi.org/10.4324/9780203774786

Weiner, I. B., Graham, J. R., & Naglieri, J. A. (2012). *Handbook of psychology, assessment psychology* (Vol. 10). John Wiley & Sons. ISBN: 978-0-470-89127-8

Westley, F., & Antadze, N. (2010). Making a difference: Strategies for scaling social innovation for greater impact. In: *The Innovation Journal: The Public Sector Innovation Journal*, *15*(2), Article 2.

Whittaker, J.A., & Montgomery, B.L. (2022). Advancing a cultural change agenda in higher education: issues and values related to reimagining academic leadership. *Discov Sustain* **3**, 10. https://doi.org/10.1007/s43621-022-00079-6

Yeomans, L., Chappell, K., Hetherington, L., Bresciani, S., Unterfrauner, E., Fabian, C. M., & Koulouris, P. (2023). Road-STEAMer conceptual framework (deliverable 2.2). Zenodo. https://doi.org/10.5281/zenodo.14041556

Yeomans, L., Chappell, K., Hetherington, L., Bresciani, S., Unterfrauner, E., Fabian, C. M. & Kouloris, P. (under review). Practice or Praxis? A theoretical classification system for STEAM education. *Education Sciences.* STEAM special issue

ANNEX

Name
Date
Workshop
Location

Entrepreneurial skills for young social innovators in an open digital world

Please read each question carefully and indicate what applies to you.

	Question	not at all --	rather no -	undecided 0	rather yes +	yes totally ++
1	Are you afraid of doing things you have never done before?	O	O	O	O	O
2	Are you as clever as other girls and boys?	O	O	O	O	O
3	Can you do most things without the help of others?	O	O	O	O	O
4	Do you know which things you can do well?	O	O	O	O	O
5	Can you do a task even if it is hard?	O	O	O	O	O
6	Can you do as much as other girls and boys?	O	O	O	O	O
7	Do other children know more than you?	O	O	O	O	O
8	Can you do most things as long as you do not give up?	O	O	O	O	O
9	Are you afraid of doing tricky things?	O	O	O	O	O
10	Do you often succeed better than others?	O	O	O	O	O
11	Can you figure out new things even if they are very tricky?	O	O	O	O	O
12	Do you prefer trying new things to things you are used to?	O	O	O	O	O
13	Can you learn new things that are shown to you?	O	O	O	O	O
14	Do other girls and boys often have better ideas than you?	O	O	O	O	O
15	Do you prefer not to learn many new things?	O	O	O	O	O

THANK YOU!!!