WP4 The landscape of STEAM practices

Deliverable 4.3 Report on real-life use-cases

Deliverable 4.3

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List of abbreviations

AI	Artificial Intelligence
EOTC	Education Outside the Classroom
LSTT	Learning Science Through Theatre
RLUC	Real-Life Use Cases
STEAM	Science, Technology, Engineering, the Arts, and Mathematics
STEM	Science, Technology, Engineering, and Mathematics

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Abstract

This report examines the work carried out in the context of Task 4.3 “Real-life use cases” (T4.3). In this task, the desk research of Task 4.2 “Mapping of existing STEAM practices” (as well as Task 4.1 “Research Framework”) has been complemented by a series of participatory action research workshops. The workshops explored a number STEAM projects and practices (captured by Task 4.2) as examples of Real-Life Use-Cases (RLUC). The emphasis of this paper is put on how such STEAM practices are delivered in real settings, what the necessary conditions are for their implementation, the skills needed by teachers and facilitators, and the skills provided (to learners). Most importantly, the workshops have attempted to capture how the criteria for STEAM practices established in the Deliverable 4.1 “Research Framework” (Chappell & Hetherington, 2023) emerge in the various contexts of delivery.

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1. Introduction

1.1. 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 (in reality often just vague statements of intention) 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.

1.2. About this deliverable

As part of T4.3, Deliverable D4.3 – Report on real-life use-cases represents a complement to previous Deliverables D4.1 – Research framework (Chappell & Hetherington, 2023) and D4.2 – Mapping of existing STEAM practices (Aguirre et al., 2023). The document provides detailed descriptions on implementation and results of the 'participatory action research workshops' organised from month 6 to month 20 of the project (February 2023 to April 2024). The main purpose of these events, organised for education practitioners and experts in the field, was to capture how the identified Road-STEAMer criteria for STEAM emerge in the various contexts of education delivery. At the core of this enquiry through the conducted workshop, we specifically aimed to investigate a) the necessary conditions for meaningful STEAM delivery,

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b) the skill set possessed by educators and facilitators who deliver STEAM activities, c) the extent to which STEAM initiatives address a holistic development of students' skill sets, d) and the capacity of this delivery to bridge the gap between theoretical learning and real-world application.

These workshops were based on existing projects and practices that emerged as worth being thoroughly analysed and integrated into the broader understanding of the Road-STEAMer project. These activities of collaborative research were at times embedded in project dialogue events (like in the case of the workshop which occurred in the context of the Learning Science Through Theatre). The type of format used therefore differed depending on the case. There were five workshops of this kind in total, and these will be further elaborated on in Section 5 of this report.

2. The Socio-economic context

With the findings collected in D2.1 - Socio-economic context and relevant needs (Unterfrauner et al., 2023), Road-STEAMer explored wider socio-economic contexts and needs for STEAM education in Europe. These efforts encompassed different perspectives such as societal needs, the need for inclusion and diversity in STEAM education, fostering the interest in STEAM as (a) school subject(s), and related career choices. Based on a rigorous thematic literature review complemented by inputs given by the project consortium during a co-creation workshop held in January 2023, this methodological analysis provided deeper insights on certain specific priority areas - enriched with preliminary recommendations on how to address them. The needs/recommendations identified during this exploration are as follow:

1. **Need:** A science literate European society to ensure that younger generations have the necessary skills to make informed decisions, critically evaluate claims, and understand scientific knowledge;
   Proposed recommendations: promoting interest in science by focusing on societal challenges and real-world problems; developing digital literacies beyond computer science; promoting attitudes towards STEAM approaches and solving imbalance of financial supports for ‘Arts’ within STEAM education; and better connection between the needs of the labour market and lifelong learning;

2. **Need:** Increase the uptake of science careers
   Proposed recommendations: increasing the level of research on STEAM education effectiveness; making science learning inclusive and appealing; communicating to

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schools and teachers the values of the STEAM approach; exposing students to science careers from the early years; underling the value of STEAM approach supporting young people to bring these subjects together; and a holistic and subject integrative view

3. **Need:** Alignment of industry and societal needs with education (including both 'technical' and 'soft' STEAM-related skills)
   Proposed recommendations: implementing open schooling and other real-world approaches, supporting entrepreneurship and self-employment; promoting multidisciplinary and interdisciplinary project

4. **Need:** Increasing diversity in STEAM to move towards greater social justice, offering more opportunities to currently underrepresented groups, and benefitting from their perspective;
   Proposed recommendations: affecting structural changes; addressing gaps in abstract thinking/maths from the primary school years; re-shaping role models to define identities and change culture; analysing impact of national differences in school systems; performing more research on moderating factors and career paths to optimise policies.

3. Criteria for STEAM

Using the Road-STEAMer co-creation methodology, both published literature and projects were identified with a combination of literature searching and contributions from the project consortium. In D4.1 – Research framework (Chappell & Hetherington, 2023), the items were analysed thematically and categorised according to key areas of interest identified for the project. This was done to ensure relevance to the focus areas of open science-open schooling, the role of the Arts, the boundary between secondary and tertiary education, and the interaction with the real world. The following criteria were identified: Collaboration, Disciplinary Inter-relationships, Thinking-Making-Doing, Creativity, Real-world Connection, and Inclusion/Personalisation/Empowerment. Equity was recognized as an underlying value in all STEAM practices. The elaboration of these six criteria, including the underlying value of equity, is briefly detailed in the sub-sections below. It is worth noting that, while we provide brief descriptions of these criteria, their primary function in this report is to frame and make sense of the insights generated from our 'participatory action research workshops'. For one, the mention of the 6 (plus one) Road-STEAMer criteria in this document serves as a tool to better understand and contextualise the discussion undertaken during these activities of collaborative

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research (as the criteria are 'lenses' through which to interpret these findings). For the other, using our criteria as the means to explain and decode the outcomes of the workshops also has the objective to strengthen the theoretical validity of said criteria, providing examples of how these theoretical notions find actual use in the field.

3.1. Collaboration

'Collaboration' puts an emphasis on multiple different elements that are involved in STEAM practices i.e. teachers, students, external partners, varied STEAM disciplines, local communities, educational stakeholders, and local citizens, their inter-connection, and respective roles (Columbano et al., 2021; CREAM, 2022; OSHub Open Science Hub Network, 2022; Liston et al., 2022; ACE STEAM toolkit). In these contexts, teachers' roles facilitate connected learning (without unilaterally directing it) through classroom environments. With this, students can solve problems, make choices, use technology, learn with games, and comprehend the importance of communication and the connection between creativity and communication (Carter et al., 2018).

3.2. Disciplinary inter-relationships

This criterion has several conceptualisations in the identified literature such as the inclusion of mixed disciplines within STEAM practices, the familiarisation with content outside of the discipline (Foundations of STEAM website), freedom to move between disciplines (Dredd et al., 2021), or integration of the arts into curriculum and instruction in Science, Technology, Engineering, and Mathematics (Katz-Buonincontro, 2018). More elaborated articulations of this concept would imply some new connection between subjects or skill areas within STEAM practice (Colucci-Gray et al., 2017), interaction between disciplines (Liu & Wu, 2022), or the learners' ability to transfer their knowledge cross-disciplines. Some argue instead that this connection is related to problem-based, authentic tasks, student choice, technology integration and teacher facilitation (Quigley et al., 2019). In either case, STEAM approaches featuring this aspect are considered particularly important: as they can facilitate the alignment of industry with education, thus contributing complementary 'technical' and STEM-related skills with 'soft' skills (Unterfrauner and al., 2023) – identified as a priority area by the project.

3.3. Thinking-making-doing

The 'thinking-making-doing' concept underlines the interactivity of these three elements instead of considering them taking place separately or in parallel within STEAM. This criterion

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does not conceptualise ‘thinking’ as an isolated ‘brain-based’ activity but re-contextualises it as interacting with more ‘hands-on' making/doing practices like multi-modality, unlearning (Columbano et al., 2021), uncertainty management (Shatunova et al.), and inquiry-based and real-world learning (Chung & Li, 2021). The emphasis here is placed on the importance of giving students an active, constructive, and critical role in their learning (Bautista, 2021), and an overall object-based learning. It stresses the use of critique and exhibition and the practice of critical making all derived from the notion of signature pedagogies in the arts (Costantino, 2018).

3.4. Creativity

Creativity is linked to innovation and the production of something novel (Colucci-Gray et al, 2017; Liao et al, 2017), to playfulness (Martinez, 2017), and to the concept of “flow” or immersion in and focus on a particular activity (Dredd et al, 2021). Creativity can also be seen as active, linked to the ‘thinking-making-doing' criteria, or as the practice of using creative activities within STEAM (innovative tools and pedagogies like digital technologies and design thinking) to make connections between disciplines. Deliverable 4.1 also underlined that elements like problem-solving and open-ended engagement with problems as aspects of creativity are linked to STEAM practices (Chappell & Hetherington, 2023). In essence, creativity can both support other features of STEAM practices (e.g., problem-solving activities within STEAM) and represent an outcome promoted by such activities.

3.5. Real-world connection

Real-world connections represent a widely-spread feature of STEAM practices. It can occur through exploration of cutting-edge issues or ‘wicked problems’ like climate change (SciCulture, nd) and offer points of connection with wider EU policy such as the EU Strategy for Enhancing Green Skills (European Commission, 2020). Real-world contexts are often associated with problem-solving and inquiry, and offer authenticity and purpose to disciplinary connections. With real-world connections, learners can connect their knowledge (within and between disciplines) to external contexts (Zhbanova, 2017). This process further fosters identity development: for instance, girls would tend to identify themselves as change-makers more (Wan et al, 2020). Overall, connection to the real-world in STEAM practices is particularly important while considering one of the needs to meet set out in the Road-STEAMer Deliverable 2.1 – Socio-economic context and how to address it, i.e., to increase science and arts literacy in Europe as one of the recommendations provided. Similarly, STEAM practices incorporating

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real-world approaches will facilitate the alignment of industry and societal needs with education (Unterfrauner and al., 2023).

3.6. Inclusion/Personalisation/Empowerment

The shift from STEM to STEAM promotes a broader spectrum of interests beyond just Science, Technology, Engineering, and Mathematics, incorporating artistic and creative approaches beyond disciplinary boundaries. This integration emphasizes a collaborative partnership that values the unique contributions of the arts, rather than treating them merely as supplementary tools to other disciplines. STEAM fosters a language of partnership and co-learning, encouraging a diverse range of interests and perspectives that enrich both the arts and STEM fields. The collaborative essence of STEAM ensures that arts and sciences are co-integrated, rather than hierarchical, promoting holistic and innovative approaches to learning and problem-solving. Emphasizing inclusive and appealing science education is crucial, as it can increase the uptake of science careers (Unterfrauner et al., 2023) by making them more accessible. Additionally, together with inclusion, the notion of personalisation offers a context where learners are more likely to develop their identity, implying that STEAM is 'for them'. In turn, students' active construction of personal meaning through STEAM leads to greater self-efficacy, confidence and motivation towards socio-scientific learning, leading to empowerment (Bautista, 2018). STEAM approaches not only empower young people but also enhance engagement through the open-ended nature of many STEAM activities. This increased inclusion and empowerment can help individuals from underrepresented groups, such as girls, develop identities as change-makers (Wan et al., 2020), addressing the pressing need for greater diversity in STEAM fields and advancing social justice (Unterfrauner et al., 2023) in Europe.

3.7. Equity as an underlying value

Road-STEAMer underscores equity as a foundational value in STEAM education, challenging dominant disciplinary approaches and embodying an affirmative ethical stance (Burnard & Colucci-Gray, 2020; Guyotte, 2020). STEAM activities are designed to flatten hierarchies between disciplines, recognizing the arts as core subjects alongside STEM with equitable access to time and resources. This approach empowers students to lead learning, positioning teachers as facilitators and guides, fostering more equitable power relations (Allina, 2018). While equity-driven outcomes, such as socially equitable responses to global challenges, are

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aspirational and more prevalent at the tertiary level, they highlight STEAM's potential for promoting inclusive and equitable practices (Carter et al, 2018).

4. Criteria in action

4.1 STEAM in Real-life Use Cases (RLUC)

In our attempt to scrutinise STEAM practices as RLUC, our focus lies primarily on the actual development and implementation of STEAM methodologies within educational environments, extending beyond the confines of the traditional classroom setting. This investigation is anchored in our foundational understanding of the above-mentioned six (plus one) criteria or characteristics of STEAM, established during the initial stages of our project. In addition, integral to our inquiry are considerations such as:

- **Necessary Conditions for Meaningful Delivery**: Central to the effective execution of a STEAM practice is the identification and cultivation of requisite conditions that foster authentic learning experiences. These conditions encompass a myriad of factors, including but not limited to access to resources, conducive learning environments, and supportive institutional frameworks.

- **Teacher and Facilitator Skills**: A critical aspect of successful STEAM implementation revolves around the skill set possessed by educators and facilitators. Beyond subject matter expertise, educators must demonstrate proficiency in pedagogical strategies that promote interdisciplinary thinking, collaborative problem-solving, inquiry-based learning, etc.

- **Skills Addressed**: A fundamental objective of STEAM practices is the holistic development of students' skill sets, encompassing not only disciplinary knowledge but also essential competencies such as creativity, critical thinking, and communication, and understanding of how to integrate disciplines in different ways. Our inquiry seeks to elucidate the extent to which STEAM initiatives effectively address these multifaceted skill domains.

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- **Incorporation of the Arts**: The integration of the arts within STEAM practices represents a dynamic interplay between disparate disciplines, each contributing unique perspectives and methodologies. Our investigation seeks to unpack the role of the arts within STEAM, interrogating whether they serve as supplemental elements, equal partners, or instrumental tools for enhancing scientific inquiry and fostering interdisciplinary connections, and what the value of these different roles might be.

- **Real-World Connection Criterion**: A defining feature of STEAM practices is their capacity to bridge the gap between theoretical learning and real-world application. By contextualising scientific concepts within societal challenges such as the climate crisis, STEAM initiatives imbue learning with purpose and relevance, thereby transcending the confines of conventional academic discourse. Our exploration endeavours to ascertain the pivotal role of real-world connections in elevating STEAM practices from mere learning activities to bona fide use-case scenarios, thereby empowering students to enact meaningful change within their communities.

Through rigorous examination of these key dimensions, our report offers insights into the intricacies of STEAM practices, elucidating pathways for cultivating innovative pedagogies that nurture the next generation of critical thinkers, problem solvers, and changemakers.

5. The workshops

5.1. Introduction

This section presents the five (5) workshops conducted from February 2023 to May 2024. Four (4) of the workshops were delivered online and one (1) in-person. Two (2) workshops were part of other larger STEAM-related events.

5.2. Workshop 1: Setting the stage

5.2.1. The context

The first Road-STEAMer workshop on STEAM practices as RLUC explored the dynamic intersection of education, innovation, and societal relevance. It was delivered online on February 2023. Convened among Road-STEAMer partners, including an external STEAM

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expert that was invited by the leader of WP4 (TRACES), this first session served as a catalyst for in-depth deliberations on the multifaceted dimensions of STEAM implementation within real-world contexts. The 25 participants were invited to work collaboratively (using a Mural Board) on aspects of STEAM practices that shed light on real-life settings and considerations. In particular they were invited to work in small online groups to explore the connection between STEAM and societal/world challenges; how particular pedagogical approaches are more suitable for STEAM practices as RLUC; the skills needed and role of delivery settings.

5.2.2. The workshop

Structured around four particular elements shaping the delivery of STEAM activities, the workshop fostered rich dialogue and collaborative exploration:

- **World Challenges Addressed by the Practice**: Participants collectively identified and critically engaged with a spectrum of pressing global issues, ranging from political violence and extremism to climate change and sustainable development. Through the lens of STEAM, these challenges emerged not merely as topics for academic study but as catalysts for meaningful inquiry and action.

- **Approaches Employed**: Deliberations encompassed a diverse array of pedagogical approaches tailored to address complex societal issues. From open schooling and living labs to problem-based learning and hackathons, participants grappled with the merits and nuances of each approach in fostering interdisciplinary collaboration and innovation.

- **Skills Addressed**: Recognizing the transformative potential of STEAM education, participants elucidated a comprehensive spectrum of skills that could be cultivated through RLUC practices. These encompassed art-related skills, computer science and digital literacy, making skills, design thinking, intercultural competence, and a suite of soft skills essential for navigating the complexities of the modern world.

- **Delivery Settings**: The workshop underscored the importance of considering diverse delivery settings for RLUC practices, ranging from traditional classroom environments to community-based initiatives and digital platforms. Participants explored how the

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choice of setting can profoundly influence the efficacy and impact of STEAM interventions.

Central to the workshop's methodology was the utilization of a Mural Board (see figure 1), which served as a dynamic visual platform for collaborative ideation and knowledge exchange. Through this interactive tool, participants collectively curated insights and perspectives, fostering a holistic understanding of the myriad factors shaping STEAM implementation.

Overall, the importance of addressing societal challenges (and making these real-world connections) and being in a position to respond to the demands of such an approach both in terms of skills and delivery settings surfaced as a rather crucial matter of a STEAM practice.

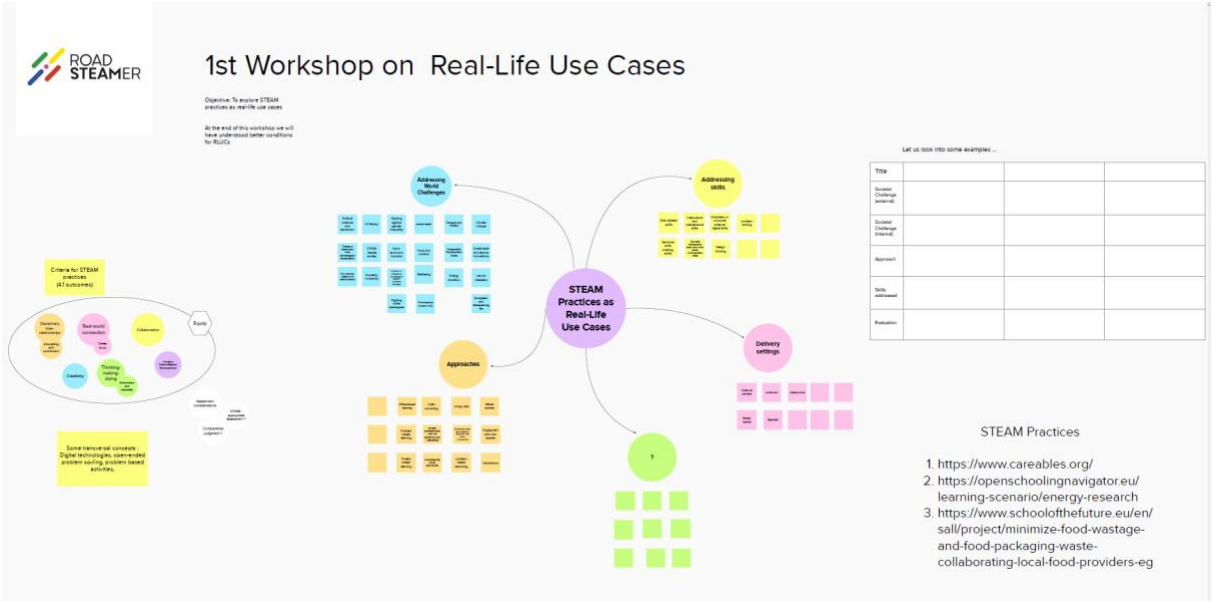

Figure 1: 1st workshop on STEAM Real-life use-cases

5.3. Workshop 2: Addressing societal challenges and transferable skills to tertiary education

5.3.1. Context

The second workshop (in-person) was conducted in the framework of the OTTER project's "Beyond the classroom: rethinking STEAM education" final event which took place in February 2024. The OTTER project, also funded by the European Union, explored Education Outside

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the Classroom (EOTC) as a pivotal method for holistic and experiential learning. By transcending the confines of conventional classroom settings, OTTER sought to harness the transformative potential of real-world experiences in diverse environments to enhance scientific knowledge, foster STEAM engagement, and cultivate active citizenship among students across the European Union. According to the OTTER team, traditional classroom-based learning, while foundational, often falls short in engaging learners in meaningful, real-world contexts. OTTER recognised that genuine learning occurs through active participation and experiential encounters, rather than passive reception of textbook knowledge. By facilitating learning experiences in varied settings such as museums, heritage sites, adventure camps, and urban environments, OTTER aimed to empower students with a new spectrum of skills and competencies essential for success in the 21st century. Despite the demonstrated efficacy of EOTC methodologies, they remain largely underutilized and lack standardized accreditation across the EU. OTTER sought to address this disparity by advocating for the widespread adoption of EOTC practices and supporting educators in designing innovative learning experiences that transcend traditional pedagogical boundaries. Through a collaborative and participatory approach, OTTER engaged educators and scientists across Finland, Spain, Hungary, Ireland, and the Netherlands in a series of focus groups, meetings, and discussions. Drawing on the expertise of diverse stakeholders, including schools, museums, and youth associations, OTTER co-designed EOTC experiences that are tailored to the unique needs and contexts of each participating region.

In this context, Road-STEAMer was invited to contribute to a panel, present a poster, and conduct a workshop focusing on STEAM practices as RLUC. The workshop was delivered in a world-café style, with around 30 participants joining our Road-STEAMer table. The participants came from a variety of backgrounds, including research, academia, school education, non-formal and informal STEAM practice and policy making.

The World Café workshop method is a dynamic and participatory approach to fostering meaningful dialogue and collaborative exploration on complex topics. Participants are organized into small groups and engage in a series of structured conversations, often rotating between tables or stations, akin to a café setting. Each round of conversation focuses on a specific aspect of the topic at hand, building upon insights and ideas generated in previous discussions. Through facilitated dialogue and collective sense-making, participants draw upon diverse perspectives, experiences, and expertise to co-create shared understanding and

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innovative solutions. The World Café method emphasizes active listening, open inquiry, and inclusivity, creating an inclusive space for creativity, connection, and collaborative problem-solving.

5.3.2. The workshop

The workshop adhered to the familiar structure of discussing findings from the research component of Road-STEAMer, specifically focusing on the defined STEAM criteria and the interplay with socio-economic contexts. Building upon this groundwork, the session transitioned into a practical exploration of various STEAM practices previously examined in section 4.1 of our research.

Through illustrative examples drawn from real-life contexts, participants were given the opportunity to scrutinize the efficacy of these practices in addressing authentic challenges. Central to this inquiry was an emphasis on three key dimensions: firstly, the imperative of directly tackling real-world challenges, thereby underscoring the practical relevance and societal impact of STEAM education. Secondly, a concerted focus on the requisite skills and competencies demanded of teacher-facilitators, acknowledging their pivotal role in guiding and nurturing student learning experiences. Lastly, an examination of the diverse skill sets cultivated among students through engagement with STEAM practices, spanning from domain-specific expertise to broader competencies such as critical thinking, collaboration, and problem-solving.

By grounding theoretical insights in tangible examples and practical considerations, the workshop sought to deepen participants' understanding of the transformative potential inherent in STEAM education and its capacity to prepare students for active participation in an ever-evolving global landscape. Finally, participants pointed out that STEAM practices that incorporate an Outdoor Education Element have an advantage in relation to addressing local challenges and therefore increasing motivation and ownership among students.

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5.4. Workshop 3: Learning science through theatre as a real-life use-case practice

5.4.1. The context

The third workshop took place in the context of the “Learning Science through Theatre” initiative in Greece and its final event, in March 2024. The 2-day event included a variety of activities, as well as the staging of a number of science plays created by local schools. The Road-STEAMer workshop was delivered online with 20 teachers, school advisors, science theatre experts and STEAM researchers.

In the Learning Science Through Theatre (LSTT) approach, students engage in an innovative blend of scientific exploration and theatrical expression. LSTT serves as a STEAM practice, seamlessly integrating science education with creative performance to foster communication and learning. Through this method, schools forge connections with both their local community and the broader research community, employing a fresh and imaginative approach to scientific concepts. In LSTT sessions, students across primary and secondary grades are encouraged to bring scientific ideas to life through dramatic interpretation, drawing from their curriculum to inspire and engage. Furthermore, LSTT descends from the STEAM IDEAS' Square (SIS) method, utilising a Design Thinking approach to facilitate collaboration between science, art, and society. This collaborative space serves as a hub for generating and implementing innovative ideas aimed at addressing societal needs and envisioning a better future. By embracing an interdisciplinary approach, LSTT contributes to the broader goal of fostering creativity and innovation within schools, ultimately transforming classrooms into dynamic and inspiring learning environments.

A number of other relevant STEAM practices which were presented at the event, and these were also used as examples of RLUC for the purposes of this research during the workshop. These were:

- The **Global Science Opera in Real-time** (GSOrt) initiative, which aims to integrate remote rural schools from Greece and the rest of Europe into the annual effort of the Global Science Opera practice. Its main aim is to encourage collaborations between multiple remote schools (more than two) using teleconference and similar online collaboration platforms to arrange and perform a joint-stage performance within a

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synchronous or asynchronous digital environment. The final outcome becomes part of one or more scenes in the Global Science Opera. The name "real-time" in its title is related to the use of videoconference designed in such a way so that any task of performance (e.g. stage action, music, movement, etc) is distributed in more than two places at asynchronous or, more preferably, synchronous manner (at the same time). Global Science Opera Real Time is a community of European remote and rural schools working together in creating a distributed online-performance event.

LeDS, which strives to deliver a holistic learning journey for students by blending students' artistic abilities with crucial technological, social and emotional skills. Through tasks such as programming suits, mastering video mapping, and orchestrating special effects, students unintentionally delve into various concepts and disciplines, spanning from mathematics and physics to computational thinking and more.

- **iMuSciCA**, which creates and investigates innovative and enabling technologies aimed at facilitating open co-creation tools integrated into musical activities to bolster STEM education. The "iMuSciCA workbench" provides learners with opportunities to explore principles of physics, geometry, mathematics, and technology through virtually constructing musical instrument and by simulating their acoustic properties in a multimodal engaging environment.

5.4.2. The workshop

During the workshop, participants were presented with the Road-STEAMer criteria and were invited to reflect upon their own practices (namely, their work with the activities presented above) by paying particular attention to societal challenges, skills needed and addressed as well as delivery settings.

Three major items emerged in the subsequent discussions:

- Teachers often conflate the meaningful addressing of societal challenges with simple stakeholder engagement. In particular, there is an obvious difference between working on STEAM projects that address challenges, such as climate change, biodiversity, food systems, etc. in living labs and/or open schooling formats in which the expertise of particular stakeholders (parents, museums, research

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institutions, industry) is exploited in co-creation activities, and working on STEAM projects that add an engagement activity at the end (a presentation to parents or local communities).

- There is also a misunderstanding relating to teacher motivation and skills. Innovative teachers who engage in interesting STEAM projects, often going beyond prescribed curricula and directives, are not acting upon a desire to stand out or exercise skills and expert knowledge that they have acquired. Rather, it is the fact that innovation, creativity, sensitivity to societal challenges, etc. are part of their professional identity. They are intrinsic to their role.

- Finally, on the matter of the integration of the arts in STEAM, lack of skills and resources, especially in educational contexts in which the arts are persistently underfunded, results in the false impression and practice that by adding a small artistic activity at the end of a STEM project, one has transformed this into a STEAM one. The arts is a fundamental aspect of proper STEAM and it defines the way the science is taught, learned and reflected upon. It has to be present in the design of the practice from the very beginning and for this the relevant skills are crucial.

5.5. Workshop 4: STEAM practices in Poland

5.5.1. The context

The fourth online workshop took place on April 2024. The event was conducted with Polish STEAM practitioners, researchers and teachers, gathered through the network provided by the Copernicus Science Centre (one of the two affiliated entities of ECSITE in the Road-STEAMer project). The workshop's goal was again to evoke a discussion and reflection on STEAM practices, using the Road-STEAMer criteria identified by the project as a trigger. The specific focus was on gaining feedback on the application of such criteria on the ground. The workshop was structured as a participative discussion where attendees could share their opinions and personal experiences, provide feedback and follow-ups on the discussions, and learn from one another.

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5.5.2. The workshop

Following a brief introduction to the project details, participants took the floor and immediately recognised that some of the identified STEAM criteria perfectly matched their activities on the ground. Several practitioners agreed on the personalisation feature of their activities, especially in the aftermath of the COVID-19 epidemic. This facilitated settings where learners felt actively involved in the activities and fostered a sense of responsibility and individuality in relation to the conducted STEAM practices. The post-COVID-19 scenario also promoted an increased willingness to socialise and participate in STEAM activities in groups, thus further raising a sense of collaboration. Examples showcasing this re-appreciation of personalisation and collaboration within STEAM included science competitions inviting groups of participants to design satellite prototypes or rovers. These competitions also played a significant role in connecting theoretical knowledge to real-world scenarios and challenges.

Discussions also covered the necessary skills that teachers and STEAM practitioners need in order to deliver high-quality activities that exhibit the Road-STEAMer criteria/characteristics. Participants agreed on the need to become skilled facilitators, capable of guiding pupils' discussions and providing a safe space for students to express their creativity. Other soft skills required for this goal included increased open-mindedness. Teachers should be open to discovering new emerging topics such as Artificial Intelligence (AI) together with students. Follow-up discussions led to another extremely interesting topic revolving around teacher vulnerability when undertaking innovative ideas and methodologies to teach science or developing further open-mindedness towards new topics. This stems from two risks:

- Conceptual risk: the possibility that students might undermine a teacher's authority while exploring new technologies that they (the students) are more familiar with.

- Material risk: teachers from public institutions might need to overuse the school's expensive equipment to carry out these innovative activities with their students. This is a greater issue in regions where schools have limited resources.

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5.6. Workshop 5: The ultimate test. STEAM delivered in emergency settings (the Ukraine context)

5.6.1. The Context

The fifth and final online workshop on RLUC took place shortly after the fourth, in early May, 2024. Aiming at inquiring STEAM practitioners and researchers in Ukraine, the event was co-organised by the Junior Academy of Science in Ukraine (also an affiliated entity of ECSITE within the Road-STEAMer project) which mobilised their network and gathered 20 participants interested in this opportunity. Participants included professionals in a wide range of roles, including chief, senior and fellow researchers, professors of science education, directors and deputy directors of science centres, practitioners and teachers. Other than obtaining feedback on the application of the identified STEAM criteria on the Ukrainian ground, a major focus of the last workshop was to analyse how STEAM practice was delivered in emergency settings such as the current context of Ukraine.

5.6.2. The workshop

After an explanation of the project core objectives and the identified criteria, the workshop facilitator invited to ponder ways the European Union can continue to fund and support STEAM practices in emergency settings such as that of Ukraine. Upon this input, participants listed a series of activities in Ukraine related to the STEAM methodologies. Some activities included projects building on the integration between formal and informal education and fostering problem-solving activities linked to real-world problems (e.g., sustainable solutions for water usage). While the majority of the participants agreed to generally accept the 6+1 criteria identified by Road-STEAMer, some suggested further elements to potentially consider in the future when thinking of STEAM features. For instance, attendees discussed the possible of a ‘Task-Commitment’ within the criteria, e.g., the idea that STEAM activities should encompass logical and natural ending, and encourage learners to execute the said activities until their logical conclusion. Additionally, participants rightly noted that, while STEAM activities might encompass some of the STEAM criteria, a specific STEAM activity might also not encompass all of them. This could be the case for some practices carried out in relation to Mathematics, which usually implies abstract concepts and might relate to puzzle-based learning (e.g., creativity). However, such activities sometimes are difficult to associate with the criterion of ‘Real-world connection’.

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During the workshop, participants also provided preliminary contributions regarding one of the main focuses of the event, i.e., how practitioners carry out STEAM practices in an emergency setting. During the first period of war, some activities on puzzles and gamified learning with respect to Maths were implemented to distract pupils from that situation. Other practices undertaken during the current scenario included the use of AI tools to improve the mood and motivation of pupils under enormous pressure due to war. For instance, AI were used to take pictures of plants and analyse them based on their characteristics.

Some further activities implied the use of digital tools and platform that would promote interdisciplinary by merging arts and science. The example of students who were invited to make drawings based on specific science-based learning outcomes via ad-hoc digital apps was explored. The discussions also covered more general types of activities like Space Living Labs - connected to thinking-making-doing, real-world connection, and inclusion-empowerment-personalisation.

Overall, there was an obvious willingness from the participants to focus on achievements, on innovative practices and future plans for STEAM rather than the challenges due to war.

6. Taking stock

A number of crucial items have emerged from the five workshops conducted by Road-STEAMer:

- The criteria identified by the project offer an accurate picture of the various STEAM activities addressed. It is almost impossible for all of these criteria/characteristics to be all equally present in an activity. The specific approaches and methodologies adopted in each of the activities determine which of them is "stronger".[1]

- Proper STEAM activities require resources. In countries in which education is underfunded, especially arts education, the difficulty is increasing.

[1] This is expected, and indeed, described in the Road-STEAMer conceptual framework (D2.2), when it is explained that each educational approach tends to manifest the criteria in different configurations (see for instance p. 23)

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- There are many STEAM activities in which the arts are an additional element rather than carry an equal value from the start. These activities are better described as STEM+A. This is an issue that requires further exploration and should be addressed in future STEAM funding and research. The instrumental view of the arts undermines STEAM and its potential for engaging science teaching and learning.

- The criterion of real-world connection greatly determines the delivery and the success of a STEAM practice. The majority of the participants agreed that connecting STEAM practices with societal challenges offers an interesting context and increases motivation for both teachers and students, who may feel passionately about a local issue (the quality of the air, the state of local resources, biodiversity, etc.). However, as mentioned in section 5.6.2 above, this does not automatically disqualify STEAM activities with a more abstract nature.

- STEAM has a rather crucial role to play in an emergency setting such as education delivered in Ukraine, as it could be a way to increase resilience in the face of harsh developments, it could incorporate expressive means to address trauma and could addressed skills that will be needed to rebuild the country.

7. Concluding note on further research

The workshops conducted in the context of this work reached nearly 100 participants. The consortium will continue to engage with the participants and it will also incorporate aspects of this work into further implementation, dissemination and exploitation events. Upon the completion of the last four workshops, participants were sent a questionnaire designed by the University of Exeter, designed to assess the extent to which participants' understand and agree with the Road-STEAMer "6+1" criteria. Its findings will be part of a forthcoming publication. Further exploration of the Ukraine context will also be conducted in order to draw meaningful recommendations for the role of STEAM in emergency settings.

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