STEAM UPGRADE

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STEAM
SCIENCE TECHNOLOGY ENGINEERING DIGITAL ARTS MATHEMATICS
UPGRADE

Upgrading pre- and in-service teachers' digital skills with online STEAM hands-on training modules

Digital Competences in STEAM Education: The STEAM Upgrade Framework

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1. Introduction

Figure 1: STEAM Upgrade Erasmus+ members at the University of Stavanger.

The STEAM Upgrade Framework aims to empower educators and enhance their digital skills in the context of STEAM education. It was developed to support the pedagogical contextualization of the STEAM Upgrade Erasmus+ project (Figure 1) and prepare for its participatory design and local implementation components.

At its core, the framework integrates the European Framework for the Digital Competence of Educators (DigCompEdu) and its self-assessment tool, along with the development of the European Reference Framework of Key Competences for Lifelong Learning. The primary focus of the STEAM Upgrade framework is the development of digital skills among pre- and in-service teachers. The resources provided by STEAM Upgrade play a crucial role in supporting educators' digital competences. Furthermore, the framework contextualizes how these resources can facilitate the teaching of key competencies, knowledge, skills, and attitudes in both transversal and subject-specific areas.

During the development process, various sources were considered, including policy documents from the European Union, OECD's definition and selection of competencies, research literature on assessing and teaching 21st-century skills and competences, as well as lessons learned from the competence-based renewal of Finnish and European education.

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The expected impact of the STEAM Upgrade Framework is significant. It is already used in teacher education programs and professional development program design, ensuring that educators are equipped with the necessary digital skills. The framework also facilitates the development and evaluation of resources to improve educators' digital skills and enable them to support the development of learners' transversal and subject-specific competencies, with a particular emphasis on key competencies. Additionally, the framework supports the design and evaluation of further STEAM educational resources.

The transferability potential of the STEAM Upgrade Framework is substantial. It can be applied broadly and easily adapted to prepare and conduct teacher training and development programs, as well as co-create digital STEAM education modules. The framework is applicable to teacher education at the Early Childhood, Primary, and Secondary levels, incorporating reflections and contributions from six participating countries: Austria, Estonia, Finland, Hungary, Norway, and Spain. It ensures that the generated content aligns with diverse economic, cultural, and educational environments across Europe. Furthermore, the framework can be applied in higher education settings and extended to other fields of education beyond the scope of STEAM.

The methodology applied in developing the Digital Competence Framework in STEAM teaching follows the Key Competence Development outlined by the EU, utilizing the European Framework for the Digital Competence of Educators according to DigCompEdu. The framework focuses on various areas, including fostering the active role and autonomy of learners, providing individual and collaborative learning opportunities enhanced by digital tools, implementing real-world scenarios, promoting experiential learning, encouraging group activities for project-based learning, and facilitating personal skill development.

By embracing this framework, educators can better navigate the digital landscape, foster innovative and engaging learning experiences, and prepare students for the challenges and opportunities of the future.

2. What is STEAM?

STEAM is an acronym for the educational fields of Science, Technology, Engineering, Art and Mathematics. It is an outgrowth of the subject acronym STEM, which did not include Art. STEM used subject titles as found in most curricula. If a subject wasn't included in STEM, it was covered as a topic.

Science refers to various natural and human sciences fields such as chemistry, physics, biology, and physical geography.

Technology refers to the history, present, and future of human-created tools made with the purpose of solving a problem or extending knowledge.

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Engineering entails various fields such as electrical and mechanical, aerospace, naval, civil, and agricultural engineering. Within primary and secondary education, the teaching of engineering is also designed to instill the ethos of the iterative processes, innovation, and sustainability that engineers and designers must adopt in their practices.

Mathematics can be divided into pure and applied mathematics. In schools, mathematics is about numbers and operations, algebra, functions, logic, proof, geometry, and measurement. Increasingly, the applications of mathematics to data processing, mathematical modelling, statistics and probability are receiving attention.

These four were the early foci that comprised **STEM**. The inclusion of the **Arts** into this quadrivium has been a policy shift that has taken place over the past several years.

Art is a wide concept that can refer to all forms and genres of art and artistic contributions, such as visual arts (e.g., painting, drawing, photography, sculpture, media arts/digital media, design), performing arts (e.g., dance, music, theatre, cinema), language arts (poetry, literature), architecture, aesthetics, crafts, and more. However, the role of Art in **STEAM** is much broader than supporting art and science connections in education (Fenyvesi & Lähdesmäki, 2017). Art in STEAM can open the educational process to all forms of social and emotional learning, multiple creativities, non-scientific forms of cognition, self-expression, playfulness, etc. (Fenyvesi et al., 2019)

Design and different design processes are often associated with engineering and art, but design can be seen as part of all STEAM areas (Figure 2).

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Figure 2: STEAM workshop led by Kristof Fenyvesi to build a giant Geodesic Dome at the Nelson Mandela University, South Africa. Photo: Digitally Depicted Photography.

Arguments for including the Arts in STEAM often center on art as an approach, not as a discipline or content area of its own. Often, art is incorporated as a means within the problem-solving / ideation process; sketching, drawings, model building, fabrication, tinkering, marketing of products, and other general design principles all fall within the field of the arts that are integral to STEAM. This framework sees this infusion and seeks to extend it to a pervasive ethos or approach to learning, one that is integrative and holistic (Fenyvesi, 2021) by intent.

Although creativity is particularly associated with art, all STEAM areas should be viewed as being inherently creative, innovative, and sustainable. There are also themes that touch all areas such as ethics, values, societal questions, and culture in general. This framework takes the approach that these processes, along with the teaching and learning of them, are the goals of **STEAM Education.**

Integration between different areas of STEAM can take various forms, including:

1. **Transdisciplinary**: This approach fully merges disciplines without boundaries and includes criticism of disciplinary silos.
2. **Multidisciplinary**: This approach includes collaboration between various disciplines without merging them.
3. **Interdisciplinary**: This approach brings together several disciplines while keeping them separate.

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4. **Cross-disciplinary:** This approach involves observing one discipline from the perspective of another.

The integration of multiple areas is central to the STEAM ethos. However, it is not the position of this framework that learning experiences incorporate all of these areas simultaneously. Instead, by offering resources for teachers, the goal is to promote integrated and holistic approaches to education that inspire creativity, innovation, and sustainability. (Figure 3).

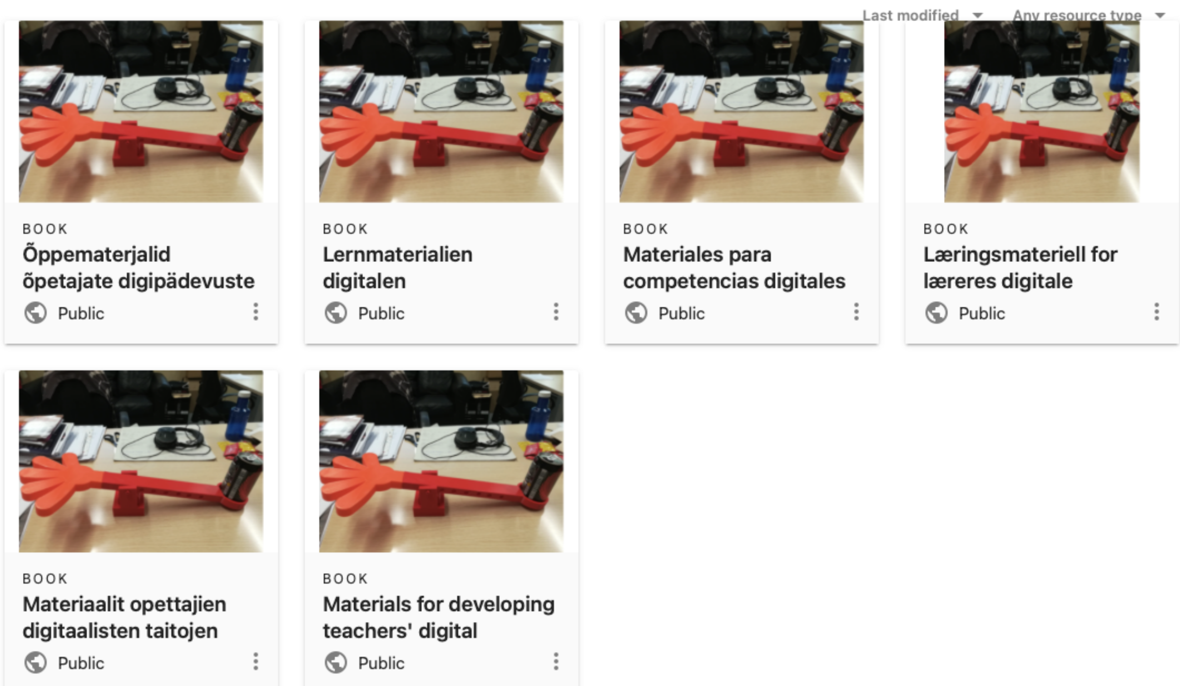

Figure 3: Materials in English, Estonian, Spanish, German, Finnish and Norwegian language for developing teachers' digital competences: https://www.geogebra.org/search/steamupgrade

3. From STEM to STEAM: Integrated and Holistic Approaches to Education

The growing body of evidence supports a holistic, integrated, multi-cross-trans-disciplinary approach to learning in the 21st century. Colucci-Gray & Burnard indicate that STEAM professionals do not work in siloed topics but rather find themselves needing to decompartmentalize disciplines and pull from a wide variety of perspectives to achieve their goals (Colucci-Gray et al., 2017). Evidence also indicates that effective STEM and STEAM education programmes view knowledge as interdisciplinary and present the curriculum in an integrated way (Becker and Park, 2011; Honey et al., 2014; Yildirim, 2016).

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The traditional focus on siloed teaching and learning models in STEM education has made it difficult to embrace the holistic, interdisciplinary approach that characterizes STEAM. Despite the criticism that STEAM is a mere fad, there is growing recognition that STEAM education can support lifelong learning and wellbeing by promoting collaborative and inclusive learning practices. For instance, The Californian's Dedicated to Education Foundation (CDEF), which works with the State of California's Department of Education to implement educational policy, has embraced STEAM education as a means of cultivating integrative and inclusive learning systems. However, there is currently no widely accepted framework for STEAM education. As a result, it is important to view STEAM from a policy perspective as a social practice that can be identified within a variety of learning environments. STEM and STEAM can be thought of as informal approaches to learning within formal contexts, and the STEAM approach can be a useful tool for decompartmentalising disciplines and fostering a more holistic approach to learning.

David Drew in his commentary on STEM learning, “STEM the Tide” concludes, “Ultimately this is a book about power in U.S. society.” (Drew, 2015). David Drew's argument highlights the idea that STEM subjects have become gatekeepers to economic success and power in American society. He suggests that those who have a strong foundation in STEM fields are better positioned to be successful in the modern economy. Drew's analysis also suggests that being skilled in STEM subjects is essential to being able to navigate "Black Swan" events, which are unexpected and disruptive events that can have significant consequences. Drew's argument highlights the need for innovative thinking and flexible mindsets to be able to analyze and respond to these types of events. By emphasizing the importance of STEM education in achieving economic and social success, Drew highlights the potential power dynamics involved in the promotion and development of STEM-focused policies and practices.

When the USA’s National Science Foundation settled on the acronym of STEM in the 1990’s it was primarily as a response to the increasingly strident rhetoric surrounding America’s self-perception of “falling behind” in its desired location in the hierarchy of international prominence (Denning, 1983). To regain that place a new focus was needed, a focus on the technical subjects of Science, and Math, which reside at the center of technological innovation and are required understanding of engineering solutions to human problems. These calls for evermore rigorous standards in these subjects brought about an era of artificial separation and siloing of the subjects, all in the hope of creating excellent scientists, technologists, engineers, or mathematicians.

However, this narrow focus on STEM subjects alone led to a neglect of other areas of study, such as the arts and humanities, which are essential for developing well-rounded individuals with the critical thinking and creativity necessary for innovative problem-solving (Pavlysh et al., 2021). The STEAM movement emerged as a response to this, advocating for the integration of the arts and humanities into STEM education to create a more holistic and interdisciplinary approach to learning. The aim is to equip students with the necessary skills to navigate an

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increasingly complex and rapidly changing world, where cross-disciplinary collaboration and innovative thinking are crucial for success (Figure 4).

Figure 4: International STEAM community at the Johannes Kepler University in Austria. Photo: Henry Segerman.

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4. The STEAM Upgrade Framework

This chapter presents the STEAM Upgrade Framework, which is a guide for cultivating the competencies required for success in STEAM careers and the digital age. It aims to equip individuals with the skills needed to confront future challenges and seize opportunities. In this chapter, we introduce a collection of educational principles central to STEAM education, discuss the characteristics of empowering learners in STEAM education, connect the Framework with the European Council's Framework of Key Competences for Lifelong Learning and the European Council's Digital Competence Framework for Educators (DigCompEdu).

4.1 Key Competences in the STEAM Upgrade Framework

The STEAM Upgrade Framework and associated learning and training modules reflect a growing recognition of the importance of cross-cutting skills and competences in the 21st century. These skills, often referred to as "soft skills," "interpersonal skills," "collaborative skills," or "teamwork skills," are considered essential for lifelong learning and are increasingly recognized as important for success in the workplace. The development of digital technologies has also brought about a need for digital competences.

The creation of awareness of the need for these skills and competences has primarily come from the world of work and industry, rather than the education sector. **The STEAM Upgrade Framework** is designed to align more closely with the methods and ethos of STEAM professionals and provide a learning environment that supports the development of these essential skills and competences. By integrating art and design into STEM education, the framework aims to foster creativity, innovation, and critical thinking in students, preparing them for the challenges of the 21st century.

To begin with, it is important to recognize that STEAM professionals integrate knowledge and skills from across the fields of science, technology, engineering arts and math, rather than compartmentalizing them into individual disciplines. As a result, STEAM pedagogies seek to break down traditional subject silos, which is in line with the demands of STEAM careers (Breiner, 2012; Wang & Wang, 2012). This imperative will require teachers to develop new skills and competencies that emphasize the crossing of subject matter boundaries. **The STEAM Upgrade Framework** serves as a starting point for delineating what these skills and competences look like in practice.

Numerous documents, both research and policy-focused, have emphasized the significance of incorporating the four subjects within STEM. In a study by Diego-Mantecon et al. (2021) it was found that the teachers who designed Project-Based Learning (PBL) scenarios with high cognitive demand did so by creating projects that facilitated formative and generative

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discussions, provided meaningful feedback on an iterative basis, and promoted an inquiry and project-based approach to learning (Figure 5). This approach promotes real-life problem-solving through deep learning experiences (Breiner, 2012).

Figure 5: STEAM Upgrade professional development workshop for teachers at the University of Stavanger. Photo: Kristof Fenyvesi.

The STEAM Upgrade Framework seeks to advance these insights by emphasizing the competencies necessary for working and learning within a STEAM context, along with the digital competences demanded in the digital era. **The STEAM Upgrade Framework underscores key competencies, such as critical thinking, creativity, communication, organizational skills, emotional intelligence, collaboration, digital literacy, adaptability, and lifelong learning**, that are vital for STEAM professionals and can be applied across various fields and settings (Balyk, Barna, Shmyger, & Oleksiuk, 2018).

A critical component of the **STEAM Upgrade Framework** is its focus on a comprehensive approach to learning and development. This approach acknowledges that STEAM professionals require both technical and non-technical competencies to succeed in their careers. For instance,

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a software developer may need not only proficient coding skills but also effective communication and teamwork abilities to collaborate with colleagues and clients. By fostering **critical and creative thinking across diverse domains**, students are better prepared to address intricate problems and devise groundbreaking solutions (Siekmann & Korbel, 2016, p. 17).

The STEAM approach and design thinking play pivotal roles in preparing students for the creative industry by fostering a multidisciplinary and collaborative approach to problem-solving. **Design thinking** is a human-centered approach that prioritizes **empathy, ideation, prototyping, and iteration in problem-solving**. Through design thinking, students can cultivate an iterative and collaborative approach to problem-solving, collaborating with others to understand user needs, generate ideas, and create prototypes that can be tested and refined. The creative industry places great value on these skills, as professionals frequently collaborate across various disciplines to devise creative solutions for intricate problems (Siekmann & Korbel, 2016, p. 18). Furthermore, STEAM and design thinking can facilitate the development of skills highly prized in the creative industry, such as creativity, critical thinking, and communication (ibid.). These skills are fundamental for generating innovative ideas and conveying them effectively to stakeholders, including clients, colleagues, or end-users.

The STEAM Upgrade Framework additionally acknowledges the significance of lifelong learning in the digital era. Swift technological advancements and workforce changes necessitate **continuous skill and knowledge updating** (Siekmann & Korbel, 2016, p. 11). Consequently, the framework highlights the requirement for individuals to be **self-directed learners** who can seek out novel learning opportunities and **adjust to evolving circumstances**.

In conclusion, **the STEAM Upgrade Framework** seeks to furnish a guide for cultivating the **competences necessary for excelling in STEAM careers** and the digital age at large. By promoting a comprehensive approach to learning and development and underscoring the significance of lifelong learning, the Framework strives to equip individuals with the skills needed to confront the challenges and capitalize on the opportunities of the future.

4.2 Upgrading into a STEAM Ecosystem

The integration of STEM in educational and social contexts creates connections between schools, communities, and global enterprises (Wang & Wang, 2012). The objective is to foster a comprehensive learning community that includes students, teachers, and other stakeholders, promoting collaborative, developmental, problem-solving approaches to learning and growth. Therefore, it is crucial to establish **an environment that is abundant in connections** (Mäkelä et al., 2020; Mäkelä et al., 2022). This environment is referred to as the **STEAM Ecosystem**, encompassing numerous resources, missions, problems, and opportunities for engagement.

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The STEAM Ecosystem comprises several components, including:

1. Opportunities for teachers and students to collaborate internally and externally beyond their classroom, school, and traditional learning environment. This requires an extended infrastructure to facilitate such collaborations.
2. Problems, ideas, and projects that demand multi-faceted, multi-phasic, and networked solutions.
3. A classroom, lab, or art studio ethos that promotes exploration driven by learner curiosity, inquiry, innovation, and diverse forms of creativity.
4. Connections between learning environments and experts and creative professionals in relevant fields of inquiry.
5. Access to a diverse range of tools, materials, and technologies, along with the means to invent, redesign, think-with, and make-with such resources.

The STEAM Upgrade Framework serves as both a model for the **STEAM Ecosystem** and a framework for assessment in **STEAM education**. It acknowledges and recognizes that STEAM goes beyond the mere combination of the five subjects represented by the acronym. **STEAM represents an approach to learning**, a defining characteristic of a **conducive learning environment**, **a pedagogical philosophy** for the classroom, and a **descriptor** of the **tangible aspects** of what **students and their teachers aim to achieve**.

4.3 Characteristics of STEAM Education/Teaching/Learning

It is noteworthy that **the STEAM Upgrade Framework** aims to avoid the perception of constructing a rigid STEAM Curriculum. The term "curriculum" originates from Latin, with associations to ruts formed on roads by heavily used chariots. Arguably, these entrenched curricular patterns have contributed to much of the dissatisfaction and tedium prevalent in modern education. Thus, a key driving force behind **the STEAM Upgrade Framework** is to inspire teachers, schools, and stakeholders to break free from these confines and create a broader, more open terrain for learning.

Deep learning has always been an interplay of purposeful, concentrated, and focused effort along familiar paths, while also providing ample opportunities and space for curiosity and inquisitiveness to lead us into uncharted territories. **STEAM, therefore, represents a pedagogy of possibilities, embracing the inherent uncertainties that come with it (Burnard et al., 2022).**

Below, we present a list of some of the key characteristics of STEAM education (Figure 6). While not comprehensive, it offers a glimpse into the ethos we advocate. Consider it akin to essential ingredients in a well-equipped kitchen. These elements are readily available to the chef, who carefully selects which ones to incorporate in order to create a specific dish (the dish, in this metaphor, representing the learning environment and activities that students engage in).

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Without these fundamental components, the chef is unable to create, but with them, they can cultivate a kitchen deserving of a prestigious Michelin Star rating.

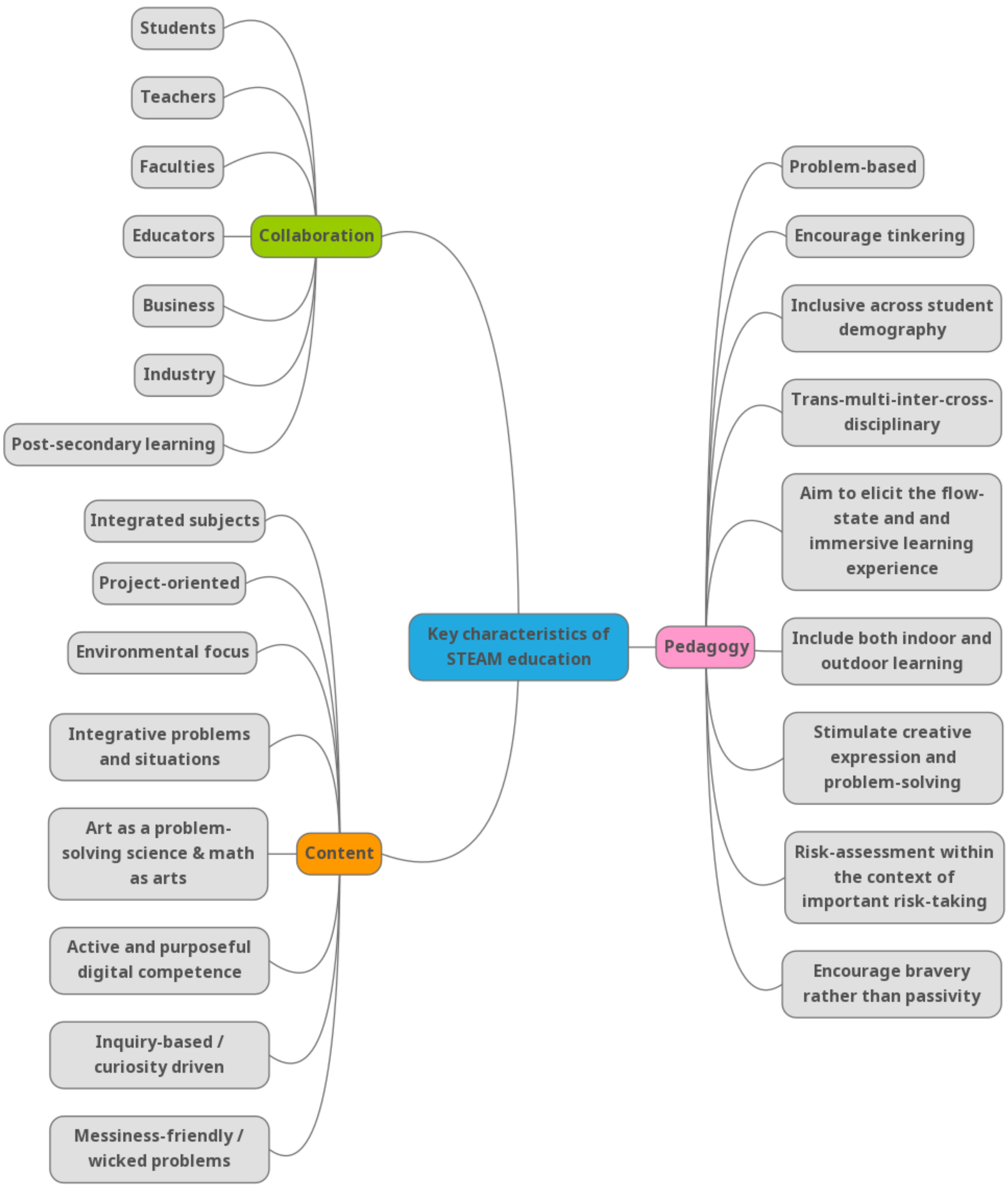

Figure 6: Mapping the didactic characteristics of STEAM approaches, regarding content and pedagogy in the STEAM Upgrade framework.

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Integrated Subjects: This refers to breaking down the artificial divisions between different school subjects. In STEAM education, it goes beyond simply adding a fifth subject to the core academic disciplines. It emphasizes the transcendence of disciplinary boundaries and values the integration of knowledge and skills from multiple fields. This approach encourages collaboration and allows for polymathic approaches, where students can draw on diverse areas of expertise to solve problems and explore new ideas.

Integrative Problems and Situations: STEAM education provides students with opportunities to engage in authentic problems and situations that promote situated learning. Students are challenged with tasks that require the integration of their knowledge and skills across various disciplines. These tasks go beyond rote learning of facts in science or math and instead focus on incorporating the habits, approaches, and skills from all disciplines. This approach redefines the notion of "basics" in these subjects and leads to more dynamic and engaging activities for students to undertake.

Problem-Based: In contrast to approaches that emphasize discrete skills and facts within specific subjects, STEAM education adopts a problem-based approach. Students engage in work that is interconnected and infused with meaning. Rather than focusing solely on individual subject areas, tasks and projects are designed to address larger-scale problems that assume and incorporate skills from various disciplines. For instance, mathematical, scientific, and technological skills are developed through the context of these broader tasks.

Project-Oriented: STEAM education incorporates problems and situations within larger transdisciplinary, multidisciplinary, interdisciplinary, or cross-disciplinary projects. Examples of such projects can be found in recently re-authorized national curricula across Europe, such as the Finnish National Core Curriculum (Vitikka et al., 2012). These projects place a particular emphasis on fostering 21st-century skills, including collaboration, communication, critical thinking, creativity, and other skills that are essential for success in the modern world.

Trans-multi-inter-cross-disciplinary: This aspect is indeed central to the efforts of STEAM education. It empowers learners of all ages to draw from a wide range of knowledge fields and apply them as needed. This aspect serves as both the superstructure and the lifeblood of STEAM education. The multiplex of prefixes - trans, multi, inter, and cross - each brings its own perspective to the process.

- A multi-disciplinary problem involves the use of multiple disciplines that may or may not be in direct conversation with each other.
- Interdisciplinary and cross-disciplinary problems focus on the connections between disciplines.
- Transdisciplinary efforts aim to transcend the boundaries of individual disciplines, seeking holistic understandings of problems.

A comprehensive framework for STEAM education must incorporate each of these perspectives. Curricula that align with the STEAM ethos should develop students' proficiency in the scientific method and foundational facts, incorporate technology as both a tool and a platform for innovation, provide opportunities for students to engage in the engineering and design processes, view the world and problems as opportunities for communication through various

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means, and employ mathematical and statistical methodologies to develop iterative models, rigorous logic, and connections to historical thought. In summary, the trans-multi-inter-cross-disciplinary approach in STEAM education allows for a comprehensive and holistic exploration of problems, drawing from diverse fields of knowledge and promoting a deep understanding of complex issues.

Collaboration Amongst Students: A guiding principle of STEAM is the understanding that most problems cannot be solved by individuals working in isolation. Therefore, it is crucial for STEAM curricular materials to provide students with opportunities to collaborate within their classes, across classes at the same school, and even with students from all over the world, given the ubiquity of technology.

Collaboration amongst Teachers/Faculties: It is now more important than ever for teachers to find partners and collaborators with whom they can plan, co-plan, and enhance their curricula. Despite their subject-specific differences, there are more commonalities among teachers in terms of problem-solving and communication goals. STEAM curricula recognize these commonalities while celebrating the differences. Embracing the polymathic approach of STEAM is critical to understanding the framework and goals of STEAM learning activities.

Collaboration amongst Educators, Business, Industry, and Post-Secondary Learning: To truly nurture well-rounded individuals through education, it is essential to establish productive collaborations with the world of work and adult life that students will enter after completing their basic and secondary education. The STEAM Ecosystem represents a community effort aimed at both solving problems and developing individuals. This ecosystem goes beyond partnerships and fosters relationships in which learners of all ages contribute to the development and solution of global problems. This framework sets high aspirations in terms of equity, access, and inclusion, recognizing that learners of any age can provide valuable insights and creative responses that can be applied to develop global solutions.

Inquiry-based/Curiosity Driven: STEAM learning tasks should differ from traditional skills-oriented and rote memorization exercises. Instead, they should be designed to foster inquiry and questioning. Imagination, curiosity, innovation, and creativity are key aspects of STEAM learning. Learners' imagination plays a significant role in their learning, and encouraging students to remain curious, rather than assuming that everything worth knowing in a field is already known, is a fundamental aspect of STEAM learning.

Inclusive across student demography: As efforts to humanize education gain traction worldwide, there is an increasing demand for equity of opportunity and experience in learning environments. STEAM learning tasks should be designed and implemented for all students, regardless of demographic differences. The ethos of STEAM celebrates diverse approaches to problem-solving and recognizes that diversity is best achieved through an awareness of a variety of perspectives.

Messiness-friendly/Wicked Problems: Real problems that require challenging solutions are not neatly wrapped up within a short 60 or 90-minute lesson. Real problems in all fields constantly undergo refinement processes and improvements in models, allowing for the emergence of new solutions and inventions.

Aim to elicit the Flow-state and an immersive learning experience: Research has shown that the longer learners spend in the "flow state" during an experience, the deeper their

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learning and the richer their experience (Bergström et al., 2021; Conradty et al., 2023; Ellwood & Abrams, 2018; Giasiranis & Sofos, 2017; Gyllenpalm, 2018). STEAM should be characterized by learning activities that seek to elicit this state in learners as often as possible.

Encourage tinkering: Tinkering, often associated with garages or workshops, involves making small shifts or changes to achieve a project goal. It requires proficiency with the available tools, whether physical or intellectual. Within the culture of STEAM education, students are encouraged to take up tools, skills, mindsets, and approaches to "play around" with them, exploring possibilities and seeking solutions.

Include both indoor and outdoor learning: The value of mixing students' physical environments between indoor and outdoor spaces has been well-documented for decades. Providing opportunities for children and all learners to connect with nature and work in both indoor and outdoor settings contributes to their overall health, happiness, and intellectual stimulation.

Environmental focus: The growing environmental crises that humanity has the power to diminish will require the next generation to be aware of them, show concern, and actively participate in plans to solve them.

Actively and purposefully include digital competences: It is an undeniable reality that digital technologies will pervade the lives of our learners in the future. The STEAM Upgrade Framework acknowledges and aims to address the digital competences of all learners.

Stimulate creative expression and creative problem-solving: While the arts have traditionally been associated with creative expression, creativity is also a fundamental aspect of problem-solving. The ability to approach situations from diverse perspectives requires a creative mind and is essential for problem-solving in all fields.

Art as a problem-solving and ideation model: The artistic approach is a problem-solving approach that can be taught, learned, and applied. Seeing the arts as a means to define, represent, and ultimately solve problems is central to this framework. Allowing the mind to freely ideate and create requires discipline and practice. The STEAM framework recognizes the need to create ample opportunities for students to engage in creative play and other activities that can lead to conflict resolution.

Risk assessment within the context of important risk-taking: Life inherently involves risks, and learning to accurately assess and appropriately accept the inherent risks of change is a part of the learning process. Moreover, learning to take appropriate risks enhances courage in the face of problems. Students who possess courage have a greater sense of agency in their lives, enabling them to flourish and thrive.

Encourage bravery rather than passivity: Thriving students embrace the challenges in their lives. Individuals with a strong sense of agency know when and how to act and face problems with boldness. The STEAM Upgrade Framework seeks to foster this proactive attitude among learners of all ages.

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4.4 Connections between the STEAM Upgrade Framework and the European Council's Framework of Key Competences for Lifelong Learning

The European Council's Framework of Key Competences for Lifelong Learning identifies eight key competences for personal fulfillment, a healthy and sustainable lifestyle, employability, active citizenship, and social inclusion (European Commission, 2023a):

- **Literacy**
- **Multilingualism**
- **Numerical, scientific and engineering skills**
- **Digital and technology-based competences**
- **Interpersonal skills, and the ability to adopt new competences**
- **Active citizenship**
- **Entrepreneurship**
- **Cultural awareness and expression**

The Council Recommendation offers a shared framework for European policymakers, educational institutions, employers, and learners to reference key competences. It not only provides guidance on fostering competence development but also highlights effective strategies for implementing innovative learning methods, assessing competences, and supporting educators (European Commission, 2023a).

In order to motivate more young people to engage in science, technology, engineering and mathematics (STEM) related careers, initiatives across Europe started to link science education more closely with the arts and other subjects, using inquiry-based pedagogy, and engaging with a wide range of societal actors and industries (Salmi et al., 2021). While the definition of those competences has not changed much over the years, the support of competence development in STEM becomes increasingly relevant and should be reflected in this Recommendation (Council, 2018). Member states should foster the acquisition of competences in sciences, technology, engineering and mathematics (STEM), taking into account their link to the arts, creativity and innovation and motivating more young people, especially girls and young women, to engage in STEM careers (Council, 2018). Learning methodologies such as inquiry-based, project-based, blended, arts- and games-based learning can increase learning motivation.

The STEAM Upgrade Framework and the European Council's Framework of Key Competences for Lifelong Learning share several connections. Both frameworks emphasize the significance of cultivating a diverse range of competences and skills, including critical thinking, creativity, problem-solving, communication, and collaboration. Additionally, both frameworks recognize the necessity of preparing learners for the challenges presented by a rapidly changing world, where technological advancements and global issues demand new approaches to thinking and working.

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One effective way to implement the European Council's Framework of Key Competences for lifelong learning through STEAM education is by providing learners with opportunities to develop these competences through a multidisciplinary and collaborative learning approach (Morze and Strutynska, 2021). By integrating science, technology, engineering, arts, and mathematics, STEAM education offers learners a comprehensive education that facilitates skill development across multiple domains.

Furthermore, the STEAM Upgrade Framework encourages learners to think critically and creatively, collaborate with others, and develop innovative solutions to complex problems. These skills are essential for cultivating the key competences for lifelong learning outlined in the European Council's framework, such as problem-solving, communication, and social and civic competences (Siekmann & Korbel, 2016, p. 44).

In practical learning scenarios, STEAM education effectively implements the European Council's Framework of Key Competences for lifelong learning by providing learners with hands-on, real-world experiences that allow them to develop these competences in a tangible manner. For instance, by engaging learners in project-based learning activities that necessitate collaborative problem-solving for real-world issues, STEAM education assists learners in developing the critical thinking, creativity, and collaboration skills highlighted in the European Council's framework.

The STEAM approach to education is designed to cultivate a wide range of skills that are crucial for thriving in the contemporary world. These skills encompass critical thinking, problem-solving, teamwork, communication, negotiation, analytical abilities, creativity, and intercultural competence. They are integral components of the key competences within STEAM education, regarded as particularly vital outcomes.

The training modules of the STEAM Upgrade Framework are meticulously developed to align with the European Council's Framework of Key Competences for lifelong learning, which includes eight competences. These eight essential competences are fundamental for achieving success in STEAM learning as well.

1. **How is the Literacy Competence upgraded in STEAM learning?**

STEAM education can significantly boost the development of literacy competence by offering students valuable opportunities to engage in **meaningful communication and collaboration with** their **peers**. Through STEAM activities, **students are motivated to express their ideas and thoughts** using **diverse forms of communication, including writing, speaking, and digital media, including the critical assessment and implementation of information generated with computational language models offered by Artificial Intelligence applications.** They acquire the ability to adapt their communication style to suit **various contexts and audiences**, thereby **fostering critical thinking skills**. Additionally, STEAM learning stimulates students to **explore intricate subjects and employ language creatively to articulate their understanding**, ultimately enhancing their **confidence and proficiency in communication.**

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2. **How is the Multilingual Competence upgraded in STEAM learning?**

Through STEAM learning, students have the opportunity to develop multilingual competence by **collaborating with peers who speak different languages** or by **researching and communicating scientific and technical concepts in multiple languages.** Engaging in **cross-cultural projects and activities**, as well as **utilizing digital tools and resources in multiple languages**, can also foster the development of multilingual competence. These experiences enable students to become **effective communicators in a global and multicultural society.**

3. **How are the Mathematical Competence and the Competences in Science, Technology and Engineering upgraded in STEAM learning?**

Through engaging in STEAM learning, students have immense potential to develop mathematical competence as well as competence in science, technology, and engineering. Mathematical competence entails the development and application of mathematical thinking and insight to **solve real-world problems, with a focus on process, activity, and knowledge.** Competence in science, technology, and engineering involves **understanding the natural world**, **utilizing scientific knowledge and methodology** to **identify questions and draw evidence-based conclusions**, and **applying that knowledge to address human needs and desires**. By acquiring essential knowledge, skills, and attitudes related to these competencies, students can establish a solid comprehension of numbers, measures, structures, and mathematical representations. They can **apply mathematical principles in everyday contexts, understand the characteristics of data and statistics, engage in mathematical and logical reasoning**, and **effectively communicate using mathematical language**. In doing so, students cultivate a **respect for truth and a willingness to evaluate the validity of reasoning**.

4. **How is Digital Competence upgraded in STEAM learning?**

In the digital age, the development of digital competence is crucial for students to thrive in a rapidly evolving technological landscape. Digital competence encompasses a wide range of **skills, knowledge, and attitudes necessary to engage with digital technologies confidently**. It involves **using digital tools, critically evaluating information, understanding digital citizenship, collaborating online, and adapting to technological advancements.** Through STEAM learning, students **acquire and apply these digital competences in authentic and meaningful contexts**. STEAM education prepares students to **navigate the digital landscape with confidence, adapt to technological advancements, and utilize digital technologies effectively** in their personal and professional lives.

5. **How is the personal, social and learning-to-learn competence upgraded by STEAM learning?**

STEAM education provides a **holistic approach that empowers students to cultivate personal growth, interpersonal skills, and effective learning strategies.** Personal competence encompasses **self-awareness, self-confidence, motivation, and a growth mindset. Social competence** involves **effective communication, collaboration, empathy, and cultural**

awareness. Learning-to-learn competence refers to the ability to **manage one's own learning, set goals, adapt to different learning environments, and reflect on one's learning journey.** Through STEAM learning, students develop **personal, social, and learning-to-learn competences** necessary for personal growth and success in the 21st century. By engaging in **self-reflection, collaborative projects, effective communication, critical thinking, empathy-building activities, and self-regulated learning experiences, students cultivate essential skills and attitudes.** STEAM education prepares students to navigate their **personal and social** lives, **collaborate effectively, and become lifelong learners who adapt to new challenges and contribute positively to society.**

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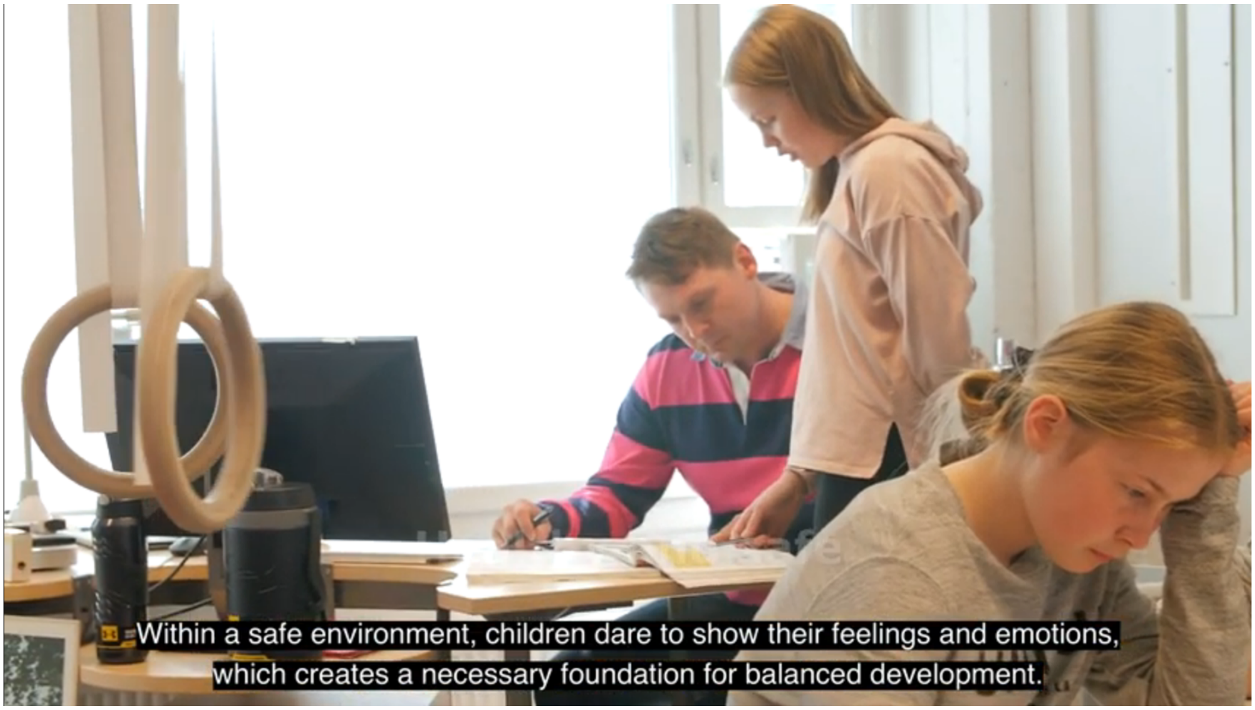

Figure 7a, b: Socially and emotionally responsive (a) learning environment for students' activation in STEAM learning (b) in Jukka Sinnemäki's classroom in Finland. Video: https://youtu.be/R97wBeuQdpg

6. **How does STEAM learning upgrade Citizenship Competence?**

Citizenship competence is crucial for students to become **active, responsible, and engaged members of society**. Citizenship competence encompasses a range of knowledge, skills, and attitudes necessary for **active citizenship**. By exploring **real-world issues, fostering critical thinking, engaging in community service, promoting digital citizenship, embracing cultural diversity, and participating in democratic processes**, students become **informed, engaged, and empathetic citizens.** STEAM education prepares students to become **agents of positive change,** capable of addressing societal challenges and contributing to a more democratic, just, and sustainable world.

7. **How is Entrepreneurship Competence upgraded by STEAM learning?**

Entrepreneurship competence is vital for students to **thrive in an ever-changing global economy**. It involves developing an **entrepreneurial mindset, innovation, creativity, problem-solving, collaboration and communication skills, resilience, and the ability to seize opportunities.** By nurturing these skills, STEAM education prepares students **to identify opportunities, create value, and contribute to economic growth and societal development.** By fostering an entrepreneurial mindset, students are equipped to navigate the complexities of the modern world and become agents of change and innovation.

8. **How does STEAM learning upgrade the Cultural Awareness and Expression Competence?**

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Cultural awareness and expression competence play a vital role in **promoting inclusivity, understanding diversity, and fostering global citizenship.** Cultural awareness and expression competence encompass a range of knowledge, skills, and attitudes necessary for engaging with diverse cultures and expressing oneself creatively. It involves **recognizing and valuing cultural differences, embracing intercultural dialogue, and using artistic and creative mediums** to express ideas and emotions. Through STEAM learning, **students develop cultural awareness and expression competence, enabling them to appreciate and celebrate cultural diversity.** By **exploring cultural heritage, engaging in intercultural dialogue, promoting artistic expression, addressing social justice issues, embracing global perspectives, and fostering empathy and respect, students become culturally competent individuals and global citizens** equipped to thrive in a multicultural world.

These competences serve as **the building blocks for success** in various domains, spanning academia, industry, and public life. Through the integration of STEAM education and the utilization of the eight key competences, students can develop a versatile skill set that empowers them to approach intricate challenges with confidence and creativity. This comprehensive approach ensures a **more holistic education, equipping students with the tools they need to thrive in our rapidly evolving world.**

4.5 Connections between the STEAM Upgrade Framework and the European Council's Digital Competence Framework for Educators (DigCompEdu)

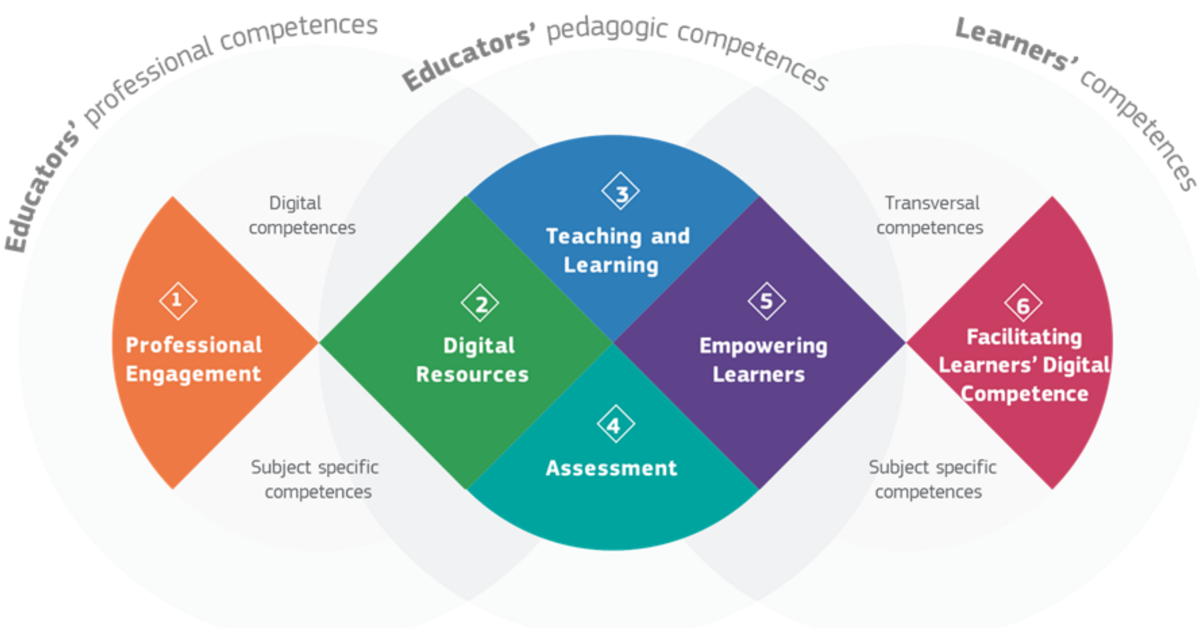

Figure 8: Diagram of the main areas of the Digital Competence Framework for Educators (DigCompEdu). Source: https://joint-research-centre.ec.europa.eu/digcompedu_en (Retrieved: 12.5.2023)

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The **European Framework for the Digital Competence of Educators (DigCompEdu)** is a comprehensive framework that outlines the digital competences educators should possess. It is applicable to teachers at all levels and areas of education, including STEAM education. The framework consists of six areas and a total of **22 competences** that focus on how digital technologies can enhance and innovate education and training (Figure 8).

The areas covered in the framework include:

- **professional engagement,**
- **digital resources**
- **teaching and learning**
- **assessment**
- **empowering learners**
- **facilitating learners' digital competence**

Each area addresses specific competences related to the use of digital technologies in education, such as organizational communication, selecting and creating digital resources, collaborative learning, assessment strategies, and promoting digital problem-solving skills.

DigCompEdu is based on previous work done to define digital competences for citizens and digitally competent education organizations. It aligns with the European Commission's Skills Agenda for Europe and the Europe 2020 flagship initiative Agenda for New Skills for New Jobs (European Commission, 2023b), highlighting the importance of digital competence in the modern workforce.

In summary, the DigCompEdu provides a comprehensive guide for educators, including those in the STEAM Upgrade Framework, to develop the necessary digital competences to enhance teaching, learning, and assessment processes. It covers a wide range of competences related to digital engagement, resource management, teaching methods, learner empowerment, and responsible and innovative use of digital technologies.

Professional Engagement: the DigCompEdu emphasizes teachers' use of **digital technologies for effective communication, collaboration, and professional development.** It includes collaborating with educators, sharing knowledge and experiences, developing educational resources, and utilizing digital platforms for continuous professional development. Reflective practice involves critically assessing and improving digital pedagogical practices individually and collectively. Digital continuous professional development involves using online sources and resources for training, updating subject-specific competences, and engaging in digital professional communities for learning and sharing.

The **Professional Engagement aspect of STEAM** education encompasses various aspects. **Teachers need to provide additional STEAM resources using digital and non-digital methods, effectively communicate STEAM topics through diverse approaches, and inform learners and parents using both digital and non-digital means** (Lavicza et al., 2022). Collaboration with

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colleagues and engagement with external parties necessitate the use of digital and non-digital channels. Moreover, teachers should contribute to organizational communication and participate in the **development of STEAM-related strategies using a combination of digital and non-digital tools** (Ferrari, 2012). According to hee Kim and Kim (2016) characteristics of a STEAM educator include building rapport with students, fostering open-mindedness, promoting teacher cooperation, and engaging in self-improvement through reflection.

In terms of reflective practice, STEAM educators engage in critical self-reflection to identify areas for improvement, seek support and targeted training, and continuously expand their repertoire of pedagogical practices. **Continuous professional development in STEAM** involves identifying opportunities for growth, updating subject-specific competences, acquiring knowledge of new methods and strategies, utilizing digital and non-digital resources for professional growth, actively participating in professional communities, and sharing expertise by providing training to peers.

Digital Resources: the DigCompEdu emphasizes the importance of **teachers being able to select, create, modify, manage, protect, and share digital resources effectively**. This involves **formulating search strategies, evaluating credibility, considering restrictions and copyright, and assessing usefulness.** Teachers should also be capable of **modifying and creating resources based on learning objectives, context, and pedagogical approach. Managing and protecting sensitive content, respecting privacy and copyright rules,** and **understanding open licenses and attribution are crucial skills. Sharing resources through various means** and **appropriately referencing sources** are also essential.

While the DigCompEdu primarily focuses on digital resources, it is important to note that in STEAM education, **a combination of both digital and non-digital resources is required** (Robinson, 2020). STEAM education involves **not only the use of digital tools but also the manipulation of physical objects and materials** (Videla et al., 2021). The **integration of both digital and non-digital resources allows for a holistic and hands-on approach in STEAM teaching and learning** (Santos et al., 2022). Therefore, in addition to the skills outlined in the Digital Resources aspect of the framework, STEAM educators also need to **possess competences related to selecting, manipulating, and integrating non-digital resources into their digital teaching practice** (Lavicza et al., 2022). **STEAM education embraces various teaching and learning approaches that go beyond the digital realm, fostering creativity, hands-on experiences** (Fenyvesi et al., 2016; Thuneberg et al., 2017)**, embodied learning** (Fenyvesi et al., 2019), and **holistic development.** It also recognizes the significance of **self-expression** and **social-emotional learning**.

Based on hee Kim and Kim's (2016) research, teaching competences in STEAM education involve a **deep understanding of the curriculum of STEAM-related subjects.** This includes analyzing, reorganizing, and integrating the content of these subjects to create a cohesive learning experience. Teachers must select important concepts from other subjects to incorporate into STEAM classes. They should suggest clear instructional objectives, connect the content to real-life situations, and provide concrete activities to enhance learning. Using various teaching methods and encouraging active participation from all learners is crucial. Teachers should also help students understand the class assignments and activity processes and guide them in applying their STEAM knowledge to problem-solving.

Teaching and Learning: the DigCompEdu emphasizes **designing, implementing, and reflecting on the use of digital technologies in education.** It encourages **using classroom technologies, structuring lessons to reinforce learning objectives, setting up digital learning environments, managing content and collaboration, and experimenting with new instructional methods.** The framework also highlights the importance of using **digital technologies for guidance,** such as responding to learners' questions, monitoring student behavior, and offering timely support. Additionally, it promotes collaborative learning through digital tools, enabling learners to collaborate, exchange knowledge, and engage in peer assessment. Finally, the framework addresses self-regulated learning, emphasizing the use of digital technologies for planning, monitoring, reflecting, and showcasing learners' progress and work.

Assessment: digital technologies enhance assessment strategies, introducing new methods and enabling targeted feedback. By analyzing the wealth of digital data available on individual student's interactions, teachers can offer more support. The DigCompEdu emphasizes the use of **digital technologies for both formative and summative assessment.** It encourages the use of various **digital assessment tools, such as classroom response systems, quizzes, and games,** to monitor learners' progress. Digital technologies are also utilized in summative assessment through **computer-based tests, audio/video components, simulations, and ePortfolios.** Educators are expected to critically analyze and interpret digital evidence of learner activity and performance to inform teaching and learning. Feedback and planning involve providing targeted and timely feedback using digital technologies, adapting teaching strategies based on evidence, and enabling learners and parents to understand and use digital evidence for decision-making.

Assessment in STEAM education considers the characteristics of STEAM learning, which involve manipulating physical objects, creating artworks, fostering self-expression, and developing social-emotional learning competences (Dubek et al., 2021). It expands beyond the digital tools and data analysis emphasized in the DigCompEdu, integrating both digital and non-digital forms of assessment and feedback. This comprehensive approach acknowledges the diverse needs of learners in the STEAM disciplines, capturing the multi-faceted and dynamic nature of their learning experiences. In STEAM education, assessment embraces a range of concrete forms and methods to evaluate learning outcomes (Herro et al., 2017). According to hee Kim and Kim (2016), assessment in STEAM education involves evaluating learners through a combination of quantitative and qualitative methods. Assessment in STEAM requires the use of diverse evaluation methods to accommodate the varied needs of learners (Bolden & DeLuca, 2016). Assessment in STEAM also considers students' assignment performance process in relation to their academic results, and utilizes convergent evaluation methods to assess various subject knowledge (Douglas et al., 2020).

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Assessment in STEAM can include:

- **Portfolio assessment:** Collecting and curating a body of student work, showcasing their progress and achievements across STEAM disciplines.
- **Project-based assessment:** Evaluating students' ability to plan, execute, and present projects that integrate STEAM concepts and skills.
- **Performance-based assessment:** Assessing students' abilities through live demonstrations, presentations, or exhibitions that highlight their understanding and application of STEAM principles.
- **Observational assessment:** Gathering data through direct observations of students engaging in STEAM activities, capturing their skills, collaboration, and problem-solving approaches (Dubek et al., 2021).
- **Peer assessment:** Involving students in assessing their peers' work and providing constructive feedback, fostering collaboration and critical thinking.
- **Rubrics and scoring guides:** Utilizing assessment criteria and scoring rubrics to provide clear expectations and standards for student performance across STEAM domains (Herro et al., 2017).
- **Self-assessment and reflection:** Encouraging students to reflect on their own learning, progress, and areas for growth in STEAM-related competences.
- **Authentic assessment:** Assessing students' abilities in real-world contexts or simulations that mirror professional or practical applications of STEAM skills.
- **Formative assessment:** Monitoring students' ongoing progress and providing timely feedback to inform instruction and support their learning journey.
- **Interdisciplinary assessment:** Recognizing the interconnectedness of STEAM subjects and assessing students' abilities to integrate knowledge and skills across multiple disciplines.

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Assessment in STEAM

Portfolio Assessment
- Collecting and curating a body of student work, showcasing their progress and achievements across STEAM disciplines.

Project-based assessment
- Evaluating students' ability to plan, execute, and present projects that integrate STEAM concepts and skills.

Performance-based assessment
- Assessing students' abilities through live demonstrations, presentations, or exhibitions that highlight their understanding and application of STEAM principles.

Observational assessment
- Gathering data through direct observations of students engaging in STEAM activities, capturing their skills, collaboration, and problem-solving approaches.

Peer assessment
- Involving students in assessing their peers' work and providing constructive feedback, fostering collaboration and critical thinking.

Rubrics and scoring guides
- Utilizing assessment criteria and scoring rubrics to provide clear expectations and standards for student performance across STEAM domains.

Self-assessment and reflection
- Encouraging students to reflect on their own learning, progress, & areas for growth in STEAM-related competences.

Authentic assessment
- Assessing students' abilities in real-world contexts or simulations that mirror professional or practical applications of STEAM skills.

Formative assessment
- Monitoring students' ongoing progress and providing timely feedback to inform instruction and support their learning journey.

Interdisciplinary assessment

Recognizing the interconnectedness of STEAM subjects and assessing students' abilities to integrate knowledge and skills across multiple disciplines.

Figure 9: Assessment in STEAM.

Empowering learners: the DigCompEdu involves ensuring accessibility and inclusion, differentiation and personalization, and actively engaging learners through the use of digital technologies. The Framework emphasizes providing equitable access to digital resources, employing pedagogical strategies that address learners' diverse needs, and fostering learners' active and creative engagement with the subject matter. The Framework also highlights the importance of **considering learners' digital context, employing assistive technologies for learners with special needs, and continuously monitoring and reflecting on the effectiveness of measures implemented.** Differentiation and personalization are achieved by allowing learners to advance at different levels and speeds and **following individual learning pathways**. Actively engaging learners involves **using digital technologies to visualize concepts, employing motivating and engaging learning environments and activities**, and **encouraging learners' active involvement in complex subject matters.** Educators are expected to select appropriate digital technologies and reflect on their suitability to enhance learners' active learning.

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Figure 10: Empowering teachers as learners through STEAM professional training events during the COVID-19 pandemic in Indonesia. Kristof Fenyvesi's hybrid STEAM workshop at SEAMEO QITEP's Teacher Professional Development program.

In STEAM education, the combination of social and emotional learning (SEL) with the skills, competences, and pedagogical methodologies of STEAM creates a powerful framework for empowering learners (Peterson et al., 2018). Accessibility and inclusion in STEAM education can be enhanced by integrating SEL practices that consider learners' diverse needs and provide equitable access to both digital and non-digital resources (Garner & Gabitova, 2022). Differentiation and personalization can be achieved by incorporating SEL strategies that address individual learners' social and emotional strengths and challenges, allowing them to advance at their own pace and follow personalized learning pathways. Actively engaging learners in STEAM can be enriched by fostering SEL skills such as collaboration, communication, and self-expression, enabling learners to actively participate in hands-on activities, problem-solving, and real-world contexts (Jagers et al., 2019). By integrating SEL competences within STEAM education, educators can create an inclusive, personalized, and engaging learning environment that empowers learners to develop not only their technical skills but also their social, emotional, and interpersonal capabilities (Yada et al., 2023) (Figure 9).

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Characteristics of empowering learners in STEAM education involve:

Project-Based Learning

- Engaging students in real-world projects that require interdisciplinary skills and collaboration, fostering their problem-solving abilities and creativity.

Design Thinking

- Encouraging learners to approach challenges through a human-centered design process, promoting empathy, critical thinking, and innovation.

Inquiry-Based Learning

- Guiding students to ask questions, investigate, and discover knowledge independently, nurturing their curiosity and self-directed learning skills.

Maker Education

- Providing hands-on experiences with tools, materials, and technology, allowing learners to explore, create, and innovate, fostering their confidence and resilience.

Peer Collaboration

- Facilitating collaborative work and peer-to-peer learning opportunities, promoting communication, teamwork, and the development of social skills.

Reflection and Self-Assessment

- Encouraging learners to reflect on their learning process, set goals, and assess their own progress, promoting metacognition and self-regulation skills.

Figure 11: Characteristics of empowering learners in STEAM education.

Characteristics of empowering learners in STEAM education involve:

Holistic Development

- Recognizing and nurturing learners' social, emotional, and interpersonal capabilities alongside their technical skills.

Individualized Support

- Providing personalized learning pathways that address each learner's social and emotional strengths and challenges, ensuring their unique needs are met.

Inclusive Practices

- Creating an inclusive learning environment that values diversity and provides equitable access to resources, both digital and non-digital, for all learners.

Authentic Engagement

- Fostering active participation and ownership of the learning process, enabling learners to actively engage in meaningful, hands-on activities and real-world problem-solving.

Social-Emotional Skills Integration

- Integrating social and emotional learning competences, such as collaboration, communication, empathy, and self-expression, to enhance learners' overall development and well-being.

Figure 12: Characteristics of empowering learners in STEAM education.

By incorporating these concrete forms, methods, and characteristics, STEAM education combined with social and emotional learning empowers learners to develop a broad range of skills, knowledge, and dispositions necessary for success in the modern world (Yada et al., 2023). According to hee Kim and Kim (2016), empowering learners in STEAM education involves gaining a deep understanding of students.

This understanding can be achieved through various strategies, including:

- **Checking level of assignment completion frequently:** Regularly assessing students' progress and level of completion of assignments to gauge their engagement and understanding.
- **Diagnosing students' learning processes:** Asking appropriate questions in class to gain insight into how students are approaching their learning and identifying any misconceptions or difficulties they may have.
- **Discovering students' misconceptions and hard-conceptions:** Actively identifying and addressing students' misconceptions and challenging concepts by providing targeted feedback and engaging them in class activities.

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Additionally, the teaching competences in STEAM education include continuously determining students' degree of class participation, such as their interest and attitudes, and providing them with meaningful feedback. This feedback helps to support and guide students' learning journey, fostering their engagement and motivation in the STEAM subjects

Facilitating Learners' Digital Competence: the Framework for the Digital Competence of Educators highlights the importance of facilitating learners' digital competence. It emphasizes various competences that educators should focus on. One key competence is information and media literacy. Educators are encouraged to incorporate activities that **help learners articulate their information needs, find and evaluate information in digital environments, and effectively organize and process the gathered information**. Another vital competence is digital communication and collaboration. Learners should be taught how to responsibly use digital technologies for communication, collaboration, and civic participation. This involves understanding appropriate digital communication methods, sharing digital content, and being mindful of behavioral norms and cultural diversity in digital environments.

Digital content creation is also emphasized. Educators should provide opportunities for learners to express themselves using digital tools, create and modify digital content in various formats, and gain an understanding of copyright and licensing principles. Promoting responsible use of digital technologies is crucial. Educators should prioritize the physical, psychological, and social well-being of learners in digital environments. This includes teaching them how to protect personal data, understand safety measures, mitigate health risks, and address issues like cyberbullying. Additionally, digital problem-solving skills are highlighted. Learners should engage in activities that require them to identify and solve technical problems, apply technological knowledge creatively, and seek continuous self-development in the digital realm.

By integrating these competences into STEAM education, educators can empower learners to effectively navigate digital technologies, develop critical thinking and communication skills, and become responsible and creative digital citizens. As stated by hee Kim and Kim (2016), facilitating learners' competence in STEAM education involves inducing learners to actively participate in the learning process. This can be achieved by creating an open learning atmosphere that fosters creative problem-solving. Educators should strive to stimulate learning activities that encourage learners to take initiative in solving problems. By providing an environment that promotes active engagement and independent thinking, educators can empower learners to develop their skills and competences in STEAM education.

In STEAM education, facilitating learners' competence can be greatly supported through the creation of multi-purposeful and diverse learning environments (Yada et al., 2023). By incorporating both digital and non-digital technologies, educators can provide learners with a wide range of tools and resources to explore and engage with (Robinson, 2020). These diverse learning environments offer opportunities for hands-on experimentation, problem-solving, and critical thinking across various disciplines. Learners can explore scientific concepts through interactive simulations, create artistic expressions using digital media, collaborate on

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engineering projects, and much more. By **offering multi purposeful learning environments**, educators encourage learners to apply their knowledge and skills in different contexts, fostering adaptability and creativity (Dubek et al., 2021). Additionally, the **inclusion of diverse learning environments** ensures that learners with different strengths, interests, and learning styles can thrive and excel (Colucci-Gray et al., 2017). It promotes inclusivity and allows learners to discover their passions and strengths while developing a well-rounded set of competences.

5. Competencies and Didactics promoted by the STEAM Upgrade Activities

This chapter presents a collection of competencies and didactics promoted by the STEAM Upgrade Framework. The activities are illustrated utilizing the GeoGebra online platform. Each activity describes its content, who the activity is optimized for, the STEAM competences promoted by it, and the pedagogical and didactic methods available for its implementation.

Activity 1: Archimedes' Lever

GeoGebra link: https://www.geogebra.org/m/mpznnga7#material/xwzawuyn

For preschoolers, the activity of exploring Archimedes' lever can contribute to the development of several STEAM competences. These competences include:

- *Science Competence:* Through the lever activity, preschoolers can begin to understand basic scientific concepts such as forces and simple machines. They can observe cause and effect relationships, explore the concept of balance, and learn about the amplification of force through leverage.
- *Mathematical Competence:* The lever activity provides opportunities for preschoolers to engage in simple mathematical concepts. They can compare and measure the lengths of different lever arms, explore the relationship between force and distance, and observe how changing these variables affects the outcome.
- *Engineering and Design Competence:* Preschoolers can engage in basic engineering and design thinking by building and manipulating lever models. They can experiment with different materials, sizes, and positions of the fulcrum to optimize the lever's performance and achieve desired outcomes.
- *Creativity and Imagination:* The lever activity allows preschoolers to use their creativity and imagination as they explore and interact with the lever mechanism. They can come up with new ways to use the lever, create their own lever designs, or imagine scenarios where levers are used in their daily lives.

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To deliver this activity, the preschool teacher can employ various pedagogical and didactic STEAM methods, such as:

- *Hands-on Exploration:* Preschoolers learn best through hands-on experiences. The teacher can provide lever models or construction materials for students to build their own levers. They can manipulate the levers, observe the cause-effect relationships, and make discoveries through their own exploration.
- *Play-Based Learning:* Lever-related activities can be incorporated into play-based learning, where preschoolers engage in imaginative play scenarios that involve levers. This allows them to explore the concept in a fun and interactive way, fostering their creativity and problem-solving skills.
- *Storytelling and Visualization:* The teacher can use age-appropriate stories, visual aids, or videos to introduce the concept of levers and Archimedes' discoveries. This helps preschoolers understand the historical and scientific context and provides a foundation for their exploration of levers.
- *Collaborative Learning:* The lever activity can be conducted in small groups, encouraging preschoolers to collaborate, share ideas, and learn from each other. This promotes social interaction, communication skills, and teamwork.
- *Integration of Arts:* The lever activity can be combined with art activities, such as drawing or painting lever designs, creating lever-themed crafts, or incorporating lever concepts into dramatic play or performances. This allows preschoolers to express their understanding of levers through various artistic mediums.

Activity 2: Robot dancing - IO2

GeoGebra link: https://www.geogebra.org/m/mpznnga7#material/guk37gtf

The activity described aims to develop the following STEAM competencies with preschoolers:

- *Science:* The activity introduces the concept of programming and mapping skills through the use of the Bee-Bot robot. Children learn to give directions and commands to the robot to move in specific ways.
- *Technology:* The use of the Bee-Bot robot and the music player or computer involves technology in the activity. Children learn to interact with and manipulate technology tools (Leoste et al., 2022).
- *Engineering:* The activity encourages problem-solving and critical thinking as children plan and program their own choreography for the Bee-Bot robot. They have to consider the robot's movements and navigate it in space.
- *Arts:* The activity incorporates dance, movement, and choreography, allowing children to express themselves creatively. They learn about body awareness, coordination, and rhythm through dance.
- *Mathematics:* The Bee-Bot robot moves in specific increments (15 centimeters) and turns at 90-degree angles. Children learn basic spatial concepts and develop a sense of distance and direction.

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Pedagogical/didactic methods that can be used by the kindergarten teacher to deliver this activity include:

- *Demonstration and imitation:* The teacher can demonstrate the choreography and movements for the children to imitate. This helps them understand the desired movements and develop their motor skills.
- *Hands-on learning:* Children actively participate in programming the Bee-Bot robot using the provided commands. They get hands-on experience of controlling and directing the robot's movements.
- *Collaborative learning:* The activity can be done in groups or pairs, promoting collaboration and teamwork. Children can work together to program the robot and create choreographies.
- *Differentiation:* The teacher can adapt the activity for students with special educational needs, ensuring that all students can participate and feel comfortable. Movements and choreographies can be adjusted based on individual abilities.
- *Integration of music and movement:* The use of music enhances the activity by creating a rhythmic and engaging atmosphere. Children can move and dance to the music while programming and controlling the robot's movements.

Activity 3: An astronomy game: Introducing the Solar System and outer space based on the Bee-bot/Code and Go robots (or similar)

GeoGebra link: https://www.geogebra.org/m/mpznnga7#material/fnuuaynb

Preschoolers can develop several STEAM (Science, Technology, Engineering, Arts, Mathematics) competences with this activity.

Some of the competences include:

- *Scientific knowledge:* Preschoolers can learn about the Solar System, planets, celestial bodies, and space exploration. They can gain knowledge about the characteristics of different planets, moons, asteroids, comets, and their relationships within the Solar System.
- *Computational thinking:* By programming the educational robot to navigate through the game board or mat, preschoolers can develop computational thinking skills. They learn to plan, sequence, and execute commands to achieve specific goals.
- *Problem-solving:* Preschoolers can encounter challenges or obstacles within the game and learn to solve them using critical thinking skills. They may need to find alternative paths or strategies to reach their desired destinations on the game board.
- *Creativity:* Through the activity, preschoolers can engage in creative tasks such as designing their own game boards, creating game pieces, or adapting the activity based on their imagination and interests.
- *Spatial awareness:* By interacting with the game board and programming the robot's movements, preschoolers can develop spatial awareness skills. They learn about directions, distances, and spatial relationships as they navigate through the game.

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The pedagogical approaches and didactic methods to deliver these activities may include:

- *Play-based learning:* The activity can be designed as a game or play-based learning experience. Preschoolers can engage in hands-on exploration and experimentation, which enhances their learning and motivation.
- *Inquiry-based learning:* Encourage preschoolers to ask questions, make observations, and explore the concepts related to the Solar System. This approach promotes their curiosity and active engagement in the learning process.
- *Collaborative learning:* Preschoolers can work in teams or pairs to solve challenges and navigate through the game board. Collaboration fosters communication, cooperation, and the sharing of ideas among peers.
- *Storytelling:* Introduce narratives or stories related to space and the Solar System to make the learning experience more engaging and memorable for preschoolers. Storytelling can help contextualize the concepts and stimulate their imagination.
- *Hands-on activities:* Provide hands-on activities alongside the use of the educational robot, such as creating models of planets, moons, or asteroids using art and craft materials. These activities reinforce the concepts and provide a tangible experience for preschoolers.
- *Integration of technology:* The use of educational robots and augmented reality (AR) enhances the learning experience. Preschoolers can program the robots and use prepared cards to visualize AR..

Activity 4: Creating semi-immersive environments for activity design with coordinated commodity projectors

Geogebra link: https://www.geogebra.org/m/mpznnga7#material/w3pchx8j

The preschoolers can gain several STEAM competences from this activity, including:

- *Science:* They can learn about prehistoric life, including the Paleolithic and Neolithic periods, and explore scientific concepts such as climate changes and the fauna of that time.
- *Technology:* They can engage in activities related to technology, such as creating multimedia content using software, selecting and operating projectors, and using digital tools for drawing and illustration.
- *Engineering:* They can design and construct props and objects related to the Stone Age, such as primitive tools, artwork, and cave-like environments.
- *Arts:* They can participate in various artistic activities, such as painting, clay modeling, theater, dance, and music, which are centered around the theme of the Stone Age.
- *Mathematics:* While not explicitly mentioned in the activity description, mathematical concepts can be integrated into activities such as measuring and proportioning artwork or designing the floorplan of the projection area.

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Teachers can use various STEAM methods and didactics when introducing this activity, such as:

- *Inquiry-based learning:* Encouraging students to ask questions, explore the provided materials, and discover knowledge through their own investigations and observations.
- *Project-based learning:* Organizing the activity as a project where students collaborate and work on a specific goal, such as decorating the cave and preparing a welcome party. This approach allows for hands-on experiences and interdisciplinary learning.
- *Multimodal learning:* Using a combination of visual, auditory, and kinesthetic elements to engage different senses and learning styles. This can include projecting images and videos, playing music, and involving physical movements in activities like dancing or role-playing.
- *Collaborative learning:* Promoting teamwork, communication, and cooperation among students as they work together on different tasks and activities within the overall theme of the Stone Age.
- *Integrating technology:* Incorporating digital media, such as multimedia content creation and projection, to enhance the learning experience and immerse children in the selected environments.
- *Authentic assessment:* Assessing students' learning and progress through their active participation in the activities, their creativity, problem-solving skills, and their ability to apply knowledge in different contexts.

Activity 5: Building a sustainable city in Augmented Reality (AR)

GeoGebra link: https://www.geogebra.org/m/mpznnga7#material/qzhjjana

The STEAM competences that elementary school students can gain from this activity are:

- *Science:* Students can explore and understand sustainability concepts related to energy supply, sustainable solutions, and environmental challenges.
- *Technology:* They learn to use augmented reality (AR) technology, specifically Ludenso Create, to create 3D objects and simulate environments.
- *Engineering:* Students engage in the design process by envisioning and building a sustainable future city, considering smart energy use and other sustainable solutions.
- *Arts:* Through the creation of 3D objects and the design of their future homes and city, students can express their creativity and artistic ideas.
- *Mathematics:* Students can apply mathematical concepts when designing and building the city, such as measuring and scaling the objects and spaces.

When introducing this activity, teachers can use various STEAM methods and didactics, such as:

- *Project-based learning:* Students work on a real-world project, the sustainability challenge, where they investigate, design, and create a sustainable city using AR technology.

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- *Collaborative learning:* Teachers can set up a virtual classroom or gallery in Ludenso Create, where students can collaborate, share ideas, and view each other's creations in real-time.
- *Experiential learning:* Students have the opportunity to experience their creations in AR glasses or on a tablet, immersing themselves in the augmented reality environment and gaining a deeper understanding of their designs.
- *Inquiry-based learning:* Students are encouraged to explore and investigate different aspects of sustainability, making informed decisions and designing solutions based on their research and understanding.
- *Integration of subjects:* Teachers can integrate multiple subjects like science, technology, art, and mathematics into the activity, providing a holistic learning experience.

Activity 6: Designing and building a hovercraft. Make it swiftly drift away!

GeoGebra: https://www.geogebra.org/m/mpznnga7#material/vcfycusg

The elementary school students can gain the following STEAM competences from this activity:

- *Science:* They can learn about the principles of physics and engineering involved in the design and operation of a hovercraft. They can explore concepts such as air pressure, forces, motion, and friction.
- *Technology:* By using the micro:bit, a pocket-sized computer, students can gain hands-on experience with coding and programming. They can learn how to program the micro:bit to control the hovercraft and make it move in different directions.
- *Engineering:* Students engage in the design and construction of a hovercraft using the provided template and materials. They can explore different design choices, make modifications, and troubleshoot any issues that arise during the building process.
- *Arts:* The activity encourages creativity and artistic expression through the design of the hovercraft. Students can personalize their hovercrafts by adding colors, patterns, and decorations. They can also engage in sketching or drawing their ideas before constructing the hovercraft.
- *Mathematics:* Students can apply mathematical concepts such as measurement, geometry, and calculations to ensure the hovercraft is built accurately and functions properly. They may need to calculate dimensions, angles, and distances for the design and assembly.

When introducing this activity, classroom teachers can use various STEAM methods and didactics, such as:

- *Project-Based Learning (PBL):* This activity lends itself well to a project-based approach. Students can work collaboratively in groups, engaging in the entire process of designing, building, coding, and testing their hovercrafts. PBL promotes hands-on learning, problem-solving, critical thinking, and teamwork.

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- *Inquiry-Based Learning:* Teachers can encourage students to ask questions and explore the scientific and technological principles behind hovercrafts. Students can conduct investigations, make observations, and draw conclusions based on their findings. This approach fosters curiosity, investigation, and discovery.
- *Hands-on Experiments:* Teachers can provide opportunities for students to experiment with different materials, designs, and coding sequences to observe the effects on the hovercraft's performance. This hands-on approach allows students to learn through direct manipulation and experimentation.
- *Integration of Technology:* The use of the micro:bit and block coding provides a technological component to the activity. Teachers can introduce coding concepts and guide students in programming the micro:bit to control the hovercraft's movements. This integration of technology enhances students' computational thinking skills.
- *Reflection and Documentation:* Teachers can encourage students to reflect on their design choices, problem-solving strategies, and outcomes. Students can document their process, challenges faced, and lessons learned through various means, such as journals, videos, or presentations. Reflection promotes metacognition and fosters a deeper understanding of the STEAM concepts involved.

Activity 7: Timing gates - loop de loop

GeoGebra link: https://www.geogebra.org/m/mpznnga7#material/w3yjtxv5

From the given activity, elementary school students can gain several STEAM competences. Here are some of the competences they can develop:

- *Science:* Students can learn about concepts such as energy, speed, momentum, potential energy, and kinetic energy. They can explore how these concepts are applied in the construction of the raceway and the movement of the marble and car.
- *Technology:* Students get hands-on experience with microcontrollers, specifically the Micro:bit, and learn how to program it to measure the speed of the car. They also gain exposure to simple coding and algorithmic thinking.
- *Engineering:* Through constructing the raceway, designing the car, and making adjustments to maximize the marble's speed, students engage in engineering design processes. They learn about problem-solving, iteration, and optimization
- *Arts:* While not explicitly mentioned in the activity description, students may have the opportunity to use their creativity and artistic skills when constructing the raceway, designing the car, and making the project visually appealing.
- *Mathematics:* Students can apply mathematical concepts such as measurement, calculations of speed and distance, and data analysis to interpret the results obtained from the microcontroller.

Regarding the STEAM methods and didactics that teachers can use when introducing this activity, here are some possible approaches:

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- *Inquiry-Based Learning:* Encourage students to explore and discover solutions to the challenge on their own. Provide guidance and ask open-ended questions to promote critical thinking and problem-solving skills.
- *Hands-on Learning:* Allow students to actively engage in constructing the raceway, designing the car, and making adjustments. Provide them with the necessary materials and tools to build their prototypes.
- *Collaboration:* Promote teamwork and collaboration among students. Encourage them to work in groups, share ideas, and collaborate on constructing the raceway and solving problems.
- *Integration of Subjects:* Highlight the interdisciplinary nature of the activity by connecting concepts from science, technology, engineering, arts, and mathematics. Help students see how these subjects are interconnected and how they can apply knowledge from multiple disciplines to solve real-world challenges.
- *Reflective Practice:* Facilitate discussions and reflections after the asctivity. Ask students to share their experiences, challenges faced, and lessons learned. Encourage them to think critically about their design choices, problem-solving strategies, and the effectiveness of their solutions.

Activity 8: Code to keep it alive

GeoGebra link: https://www.geogebra.org/m/mpznnga7#material/fcevz7uq

The activity described involves using a greenhouse with codable digital sensors and outputs to maintain optimal living conditions for a plant. Elementary school students can gain several STEAM (Science, Technology, Engineering, Arts, and Mathematics) competences from this activity:

- *Science:* Students will learn about plant biology, including the environmental factors that affect plant growth such as light, temperature, and moisture. They will gain knowledge about how these factors can be measured and manipulated using sensors and outputs.
- *Technology:* Students will learn to use and program microcontrollers, specifically the Arduino microcontroller, to sense and react to the environment. They will develop coding skills and learn how to manipulate code to achieve desired outcomes.
- *Engineering:* Students will engage in hands-on construction by setting up the greenhouse and connecting sensors, outputs, and the microcontroller. They will learn about the engineering principles behind building a system to maintain optimal conditions for plant growth.
- *Mathematics:* Students will use mathematical concepts such as thresholds, variables, and calculations to determine optimal conditions for the plant. They may also collect and analyze data from the sensors to make informed decisions about adjusting the environmental variables.

In terms of STEAM methods and didactics, teachers can use the following approaches when introducing this activity:

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- *Inquiry-based learning:* Encourage students to ask questions and explore the greenhouse setup. Allow them to make observations, manipulate the sensors, and observe the outputs to understand how the system works. This fosters curiosity and engages students in the learning process.
- *Project-based learning:* Frame the activity as a real-life multidisciplinary challenge. Students can work in groups with specific responsibilities, such as coding, engineering, and biology, to maintain and expand the greenhouse system. This promotes collaboration, problem-solving, and integration of knowledge from different disciplines.
- *Hands-on experimentation:* Provide opportunities for students to interact directly with the greenhouse, sensors, and outputs. Allow them to adjust the threshold values and observe how the system responds. This hands-on approach helps students develop a deeper understanding of the concepts and strengthens their problem-solving skills.
- *Reflective practice:* Encourage students to reflect on their observations and make informed decisions about adjusting the environmental variables. Engage them in discussions about the impact of their choices on the plant's growth and overall system performance. This cultivates critical thinking and decision-making skills.

Activity 9: A prototype of the self-driving bus

Based on the LEGO Mindstorms EV3 robot
Geogebra link: https://www.geogebra.org/m/mpznnga7#material/w89qczrv

The activity described in the provided text can help secondary school students develop various STEAM (Science, Technology, Engineering, Arts, and Mathematics) competences. Some of the STEAM competences that can be gained from this activity include:

- *Science:* Students can learn about the principles and technologies behind self-driving buses, such as computer vision, artificial intelligence, and machine learning. They can also explore the use of sensors to detect pedestrians and other objects.
- *Technology:* By using the LEGO Mindstorms EV3 robot and the LEGO EV3 Classroom app, students gain hands-on experience with robotics technology and learn how to program and control a robot. They become familiar with the hardware and software components of the robot.
- *Engineering:* Students engage in the engineering design process by building a self-driving bus prototype using the LEGO Mindstorms EV3 robot. They learn about the structure and mechanisms of the robot and how to design and modify its behavior to mimic a self-driving bus.
- *Arts:* Although the text does not explicitly mention artistic aspects, students can incorporate creativity and aesthetics into their designs by customizing the appearance and behavior of the robot. For example, they can change the color of the robot's LED lights or make it play different sounds.
- *Mathematics:* Students can apply mathematical concepts and measurements in programming the robot's movements and calculating distances. They can use mathematical calculations to determine how far the robot needs to drive or turn.

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In terms of STEAM methods and didactics, teachers can employ the following approaches when introducing this activity:

- *Problem-Based Learning (PBL):* Present the challenge of building a self-driving bus prototype and allow students to explore and find solutions collaboratively. Encourage them to apply critical thinking, problem-solving skills, and creativity throughout the process.
- *Project-Based Learning (PBL):* Frame the activity as a project where students engage in an extended, in-depth investigation of self-driving buses. They can work in teams, conduct research, plan and execute their designs, and present their solutions to the class.
- *Inquiry-Based Learning:* Encourage students to ask questions, make observations, and investigate the principles behind self-driving technology. Provide opportunities for them to explore and discover concepts related to robotics, programming, and autonomous systems.
- *Hands-On Learning:* Provide students with the LEGO Mindstorms EV3 robot and allow them to physically build and program the self-driving bus prototype. This hands-on approach promotes experiential learning and enhances students' understanding of the concepts.
- *Collaborative Learning:* Encourage teamwork and collaboration among students as they work together in teams to design and program the self-driving bus prototype. This fosters communication skills, cooperation, and the ability to work effectively in a group setting.
- *Integrating Subjects:* Emphasize the interdisciplinary nature of the activity by highlighting connections to various subjects. For example, discuss the mathematics involved in programming the robot's movements, the science behind its sensors, and the technological aspects of self-driving technology.

Activity 10: Virtual presence

GeoGebra link: https://www.geogebra.org/m/mpznnga7#material/ef8dffmr

From this activity, secondary school students can gain several STEAM (Science, Technology, Engineering, Arts, and Mathematics) competences. **Here are some STEAM competences that can be developed through this activity:**

- *Technology Skills:* Students will use video conferencing software like Zoom and learn how to use various tools and settings to improve video quality. They will also use laptops or tablets and web cameras to record videos, gaining technical skills in using these devices and software.
- *Engineering and Design:* Students will experiment with different physical environments, lighting setups, and camera angles to create the best setup for video recording. They will build their own studio setups using available tools and materials, demonstrating engineering and design thinking.

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- *Media Production:* Students will learn about the factors that affect video quality, such as composition, lighting, and sound. They will apply this knowledge to create high-quality educational videos, developing skills in media production and editing.
- *Critical Thinking:* Students will analyze various screenshots and videos to identify common mistakes in video production and find solutions to avoid them. They will critically evaluate their own work and make improvements based on their observations and reflections.
- *Creativity:* Students will explore different creative techniques to improve video quality, such as using fabrics of different colors and patterns as backgrounds or adjusting lighting setups. They will apply their creativity to enhance the visual appeal and impact of their videos.
- *Communication Skills:* Students will present and analyze their group work, sharing the experience gained during the video recording process. They will develop effective communication skills by explaining their choices, providing feedback, and discussing their findings with their peers.

When introducing this activity, teachers can use various STEAM methods and didactics to engage students and facilitate learning. **Some possible STEAM methods and didactics that can be used include:**

- *Project-Based Learning:* Students can work on a hands-on project where they plan, create, and analyze their own educational videos. This approach promotes active learning, problem-solving, and collaboration.
- *Inquiry-Based Learning:* Teachers can encourage students to ask questions, explore different video production techniques, and conduct experiments to find solutions. This approach fosters curiosity, critical thinking, and independent learning.
- *Collaborative Learning:* Students can work in small groups to discuss common mistakes in video production, share their ideas and solutions, and provide feedback to each other. This promotes teamwork, communication, and peer learning.
- *Visual Thinking Strategies:* Teachers can use visual aids, such as screenshots and videos, to stimulate students' visual thinking and analysis. Students can observe, describe, interpret, and make connections to understand the principles of video production.
- *Reflection and Self-Assessment:* Students can reflect on their own video recordings, analyze the strengths and areas for improvement, and set goals for future improvement. They can also assess their peers' work and provide constructive feedback, promoting self-reflection and evaluation skills.

Activity 11: Virtual mazes - for practicing problem-solving and mindful decision

GeoGebra Link: https://www.geogebra.org/m/mpznnga7#material/ef8dffmr

The activity of solving virtual mazes using augmented reality (AR) involves several STEAM competences that secondary school students can gain:

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- *Science:* Students can explore the principles of augmented reality technology and understand how it overlays virtual elements onto the real world. They can also learn about the principles of geometry and spatial orientation while solving the mazes.
- *Technology:* By using the GeoGebra AR application, students gain experience in using technology for problem-solving and decision-making. They learn to navigate and interact with virtual environments using mobile phones or tablets.
- *Engineering:* Students can engage in the process of 3D modeling and printing of virtual mazes. They learn about the steps involved in converting a paper maze into a virtual representation and then into a physical 3D object.
- *Arts:* The activity offers opportunities for students to express their creativity through designing and customizing their own mazes in the virtual environment. They can experiment with different shapes, sizes, and layouts to create visually appealing and challenging mazes.
- *Mathematics:* Solving mazes involves critical thinking, logical reasoning, and spatial orientation skills. Students apply mathematical concepts such as directions (north, east, west, south) and turning angles to navigate through the maze. They can also explore geometric properties and patterns within the mazes.

When introducing this activity, teachers can use various STEAM methods and didactics, such as:

- *Inquiry-Based Learning:* Encourage students to explore the maze-solving process independently or in small groups. Provide guiding questions to stimulate their thinking and problem-solving skills.
- *Project-Based Learning:* Frame the activity as a project where students have the opportunity to design and create their own mazes using both physical and virtual tools. This approach promotes creativity, collaboration, and critical thinking.
- *Collaborative Learning:* Encourage students to work together in pairs or small groups to solve the mazes. This fosters teamwork, communication, and the exchange of ideas and strategies.
- *Problem-Based Learning:* Pose open-ended challenges or variations of the maze-solving task to promote critical thinking and problem-solving skills. Encourage students to think creatively and explore different approaches to find solutions.
- *Integration of Technology:* Introduce students to the GeoGebra AR application and guide them in using it effectively to solve mazes. Teach them how to navigate through the virtual environment, track their positions, and make decisions based on the augmented reality overlays.

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Activity 12: GeoGebra interactive books – creative material developing and sharing

Geogebra link: https://www.geogebra.org/m/mpznnga7#material/zb3tbenc

The STEAM competences that secondary school students and teachers can gain from the activity of developing GeoGebra interactive books include:

- *Science:* Students can explore scientific concepts through interactive simulations and models embedded in the GeoGebra books. They can conduct experiments, analyze data, and make scientific predictions.
- *Technology:* Students and teachers will develop digital skills by using the GeoGebra application and integrating various digital materials such as text, video, audio, and animations into the books.
- *Engineering:* Through the process of designing and creating interactive books, students can apply engineering principles such as problem-solving, logical thinking, and iterative design.
- *Arts:* Students can express their creativity by designing visually appealing and engaging interactive books. They can incorporate multimedia elements, illustrations, and graphics to enhance the learning experience.
- *Mathematics:* GeoGebra is a powerful mathematical tool, and students can deepen their understanding of mathematical concepts by using interactive graphs, equations, and geometric constructions in the books.

Teachers can use various STEAM methods and didactics when introducing this activity. Some examples include:

- *Inquiry-based learning:* Encourage students to explore and discover mathematical and scientific concepts on their own by using the interactive tools in GeoGebra. Teachers can guide them through questioning and investigations.
- *Project-based learning:* Assign students to develop their own GeoGebra interactive books on specific topics, allowing them to engage in a hands-on project that integrates multiple disciplines.
- *Collaborative learning:* Encourage students to work in groups to develop and share their GeoGebra books. This fosters teamwork, communication, and the exchange of ideas.
- *Problem-solving:* Present students with real-world problems that require the application of mathematical and scientific principles. They can use GeoGebra to model and solve these problems.
- *Differentiated instruction:* Teachers can tailor the content and complexity of the GeoGebra books to meet the diverse needs and abilities of their students. They can provide additional resources or challenges based on individual students' interests and learning styles.

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6. Conclusions

The STEAM Upgrade Framework represents a transformative approach that presents a collection of didactic and pedagogical approaches to STEAM education, while connecting them with the development of European key competences for lifelong learning and the European Framework for the Digital Competence of Educators (DigCompEdu). The linkages between the STEAM Upgrade Framework and the Framework of Key Competences for Lifelong Learning of the European Council were investigated. We emphasized the link between the STEAM Upgrade Framework's approach to competencies and those defined by the European Council as critical for lifelong learning. This link reinforces the case for incorporating arts into STEAM education as a means of developing well-rounded individuals with a diverse skill set. The framework is already implemented in the STEAM Upgrade project partner countries by participating in EduLabs and other STEAM programs, supporting the development and evaluation of resources that improve educators' digital skills and facilitate the development of learners' transversal and subject-specific competencies, particularly key competencies.

In summary, the STEAMupdgrade Framework, as a Digital Competences Framework in STEAM teaching, is designed to equip educators with the necessary digital competences to navigate the modern educational landscape. By leveraging this framework, educators will be empowered to incorporate innovative digital solutions, foster learner autonomy, and cultivate a rich and inclusive learning environment. The findings presented above lay the groundwork for further research into the benefits and strategies for implementing DigiCompEdu in STEAM education. The framework's transferability potential ensures its adaptability across various educational contexts throughout Europe.

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