STEAMComp Edu: STEAM Competence Framework for Educators

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STEAM (science, technology, engineering, arts, and mathematics) education is gaining increasing attention worldwide, with many initiatives being implemented to promote its adoption and effectiveness; thus, its successful integration into educational systems has become increasingly critical. Educators will play a central role in this integration; that is why it is critical to assess their needs, map the necessary roles and competences, and provide the means to guide their professional development in a systematic way. To address these requirements, our study introduces the STEAM Competence Framework for Educators (STEAMComp Edu), as a culmination of literature reviews, expert consultations, and empirical validation by 302 educational professionals, policymakers, and scholars.

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1. Introduction

STEAM (science, technology, engineering, arts, and mathematics) education, an evolution of the established STEM (science, technology, engineering, and mathematics) model, has recently gained significant scholarly attention. By incorporating arts into the foundational STEM disciplines, STEAM education expands the curriculum beyond technical skills, incorporating creativity and a deeper understanding of cultural and societal contexts, thereby fostering a more rounded and enriched learning experience [1][2][3][4]. The meaning attributed to the ‘A’ in STEAM is subject to interpretation across scholarly literature, frequently encompassing a range of subjects such as visual arts, music, drama, dance, literature, and history [3]. Nonetheless, a unifying theme is evident: the ‘A’ effectively broadens the scope to include disciplines not conventionally covered by the STEM framework. These disciplines, whether artistic, humanistic, or social, emphasize creativity, expression, and human-centric design, playing a pivotal role in fostering holistic thinking and innovation [5]. Unlike traditional education methods that teach these subjects separately, STEAM integrates them into a cohesive curriculum based on real-world applications. This approach fosters creativity and innovation and equips learners with a holistic understanding, preparing them for the multifaceted challenges of the 21st century [6]. Thus, STEAM education constitutes an approach to learning that integrates a broader spectrum of subjects alongside the “traditional” STEM disciplines. This evolution from STEM to STEAM acknowledges that comprehensive education is not just about scientific and technological advancements but also about understanding and expressing the human experience [3].

Moreover, the integration of diverse disciplines in STEAM education highlights the significance of interdisciplinary and experiential learning. This shift aligns with the current imperative for a workforce proficient in adapting to swift

technological advancements while also demonstrating creative and critical thinking skills; qualities frequently nurtured by the arts [7]. To achieve this, STEAM education brings together different subjects in a single curriculum, linking them to real-life situations. This integrated approach not only encourages creativity and new ideas but also gives students a broader understanding, helping them get ready for the varied challenges of today's world [8][9][10][11].

Central to the implementation of this approach are educators who specialize in STEAM education. Their role is pivotal in this educational context because they can facilitate the paradigmatic shift toward integrated learning, by effectively translating the theoretical framework into impactful educational practice. However, to achieve this, they face the challenging responsibility of designing teaching plans that would integrate the various disciplines of STEAM. To do so effectively, they must continually update their skills and adopt new teaching methods [12]. Furthermore, the diverse scope of STEAM subjects necessitates specific materials, targeted teacher training, and innovative strategies for classroom management and student engagement [6][13]. These requirements present considerable challenges for schools. Additionally, evaluating students and grading multidisciplinary projects, while ensuring equal emphasis on each STEAM subject and the development of relevant competences, poses a significant challenge.

In terms of research, several studies have confirmed the advantages of STEAM education, highlighting its role in promoting creativity, critical thinking, and problem-solving in students [1][11][14][15][16]. Some research focuses on the importance of technology and engineering in this multidisciplinary approach [8][17][18], while other work emphasizes the vital role of arts, arguing that they add a well-rounded quality to the existing STEM model [19][20]. Interestingly, the role of educators in the success of STEAM education has been a focal point in research, and studies have also brought attention to the difficulties they face in managing this complex field of study [13][21][22][23]. Despite widespread acknowledgment of STEAM education's importance, there remains a gap in scholarly literature concerning the specific skills and competences that educators need to effectively put this approach into practice.

Competence frameworks that outline the essential competences for specific occupations have been proposed, offering to professionals of specific sectors a structured template for self-improvement [24][25]. These frameworks, grounded in academic and pedagogical research, delineate the intricate matrix of competences essential for achieving proficiency within the specific sector. Moreover, competence frameworks facilitate standardized assessments, peer reviews, and self-evaluations, all of which contribute to holistic professional development [26]. In the European context, a constantly expanding array of competence frameworks exists to direct educators across diverse fields. Whether they focus on pedagogical strategies, subject-specific expertise, or broader educational philosophies, these frameworks serve as foundational pillars for educators to benchmark and enhance their skills. The European Framework for the Digital Competence of Educators (DigCompEdu) [27] stands out, offering a detailed competence set for educators to navigate the digital age. UNESCO's competence profile for educators [28] outlines key knowledge, skills, and attitudes for effectively integrating digital technologies in education, focusing on mobile computing systems, smart boards, and Web 2.0 applications. Similarly, the European e-Competence Framework (e-CF) by the European Committee for Standardisation (CEN) serves as a standard for ICT competences in Europe, catering to ICT practitioners, companies, and educational institutions [29].

Regarding STEAM education, certain studies, such as Wang et al. [30], have stressed the necessity for educators to have a cohesive understanding of the various STEAM disciplines, going beyond merely isolated expertise in individual subjects. The importance of specialized pedagogical skills tailored to STEAM education's interdisciplinary nature has also been highlighted [7]. While these findings serve as a starting point, there is a widely acknowledged need for an all-encompassing framework that would fully outline the skills and knowledge needed by STEAM educators. In addition to setting common competence standards, such a framework could also point to best practices that could be adopted across European educational settings. This would help ensure that STEAM educators are adequately equipped to encourage interdisciplinary learning and serve as a valuable resource for professional development programs, supporting educators in their pursuit of excellence in STEAM education, as indicated by Conradty and Bogner [31].

2. The STEAMComp Edu Framework

Acknowledging the multifaceted roles of STEAM educators, the STEAMComp Edu framework[32] groups the competences into areas and the areas into perspectives. The framework features 41 core competences, organized in 14 distinct areas, and grouped under five perspectives. The framework notably highlights the crucial role of educator collaboration and community involvement, reflecting insights and needs directly expressed by educators. Organized hierarchically, it provides clear and comprehensive coverage, addressing educators' varied roles, including instructional design, mentorship, and community engagement. Table 1 provides the structure of the framework, including the perspectives, areas, and examples of competences. The STEAM educators' roles represented by the five perspectives incorporated in STEAMComp Edu include:

- The educator's role as a teacher-trainer-tutor encompasses the educator's ability to facilitate effective student learning through mastery of pedagogical techniques, deep content knowledge, adeptness in instruction, proficient use of educational tools, and the capability to provide constructive feedback and assessment. Furthermore, it emphasizes the importance of empowering learners, fostering their autonomy, and guiding them toward academic success.

- The educator's role as a learning designer and creator focuses on the design and development phase of the educational process. It requires competences related to planning, preparing, and developing educational procedures, learning activities tailored for diverse STEAM learning environments. In addition, competences that focus on the educator's ability to create a supportive environment that bolsters learners' growth in STEAM domains are included in this role.

- The educator's role as an orchestrator and manager involves competences related to managing and orchestrating educational procedures, content, digital technologies, lab equipment, and group learning activities among students and other educators.

- The educator's role as a community member underscores the educator's position within broader institutional and STEAM-related communities. It involves competences in networking, collaborating with peers, and actively

participating in community initiatives. Additionally, it emphasizes the application of policies that champion STEAM education and sharing experiences and best practices within the community.

- The educator's role as a professional provides competences related to educators' own professional growth. It necessitates competences in continuous learning, staying updated with the latest in STEAM education, and refining transferable and digital skills essential for STEAM activities.

Table 1. STEAM Educators' Competence Framework Perspectives, Areas, and competences.

Perspectives	Areas	N of Statements (Competences)	Examples of Competences
1. Educator as teacher-trainer-tutor/implementing the educational procedure	1.1 Pedagogy	5	1.1.1 Apply teaching and learning techniques that promote STEAM education (e.g., inquiry-based learning, problem-based, game-based learning techniques)
	1.2 STEAM education foundations	2	1.2.2 Understand the contribution of arts (A) to STEAM
	1.3 Use content and tools	2	1.3.1 Identify and select appropriate content and tools for STEAM education
	1.4 Feedback and Assessment	3	1.4.1 Use diversity and suitable assessment formats and approaches for both formative and summative assessment
	1.5 Learner empowerment	3	1.5.1 Ensure accessibility and inclusion in STEAM-related educational procedures
2. **Educator as learning designer and creator/designing and creating learning opportunities**	2.1 Educational design	3	2.1.1 Understand and develop STEAM-related curriculum
	2.2 Learner development	2	2.2.1 Facilitate learners' STEAM competences
3. Educator as orchestrator and manager/coordinating procedures and outputs	3.1 **Educational procedure and resource coordination**	3	3.1.1 Apply teaching and learning organization and management methods for STEAM education

Perspectives	Areas	N of Statements (Competences)	Examples of Competences
	3.2 **Stakeholders' coordination and leadership skills**	2	3.2.1 Coordinate learners and group of learners during STEAM-related activities
4. Educator as community member/interacting with the environment	4.1 Community building	3	4.1.1 Engage in STEAM communities of educators
	4.2 **Application and awareness of STEAM education policies**	2	4.2.1 Collaborate in the Implementation of STEAM Education Policies
5. Educator as professional/developing and applying competences	5.1 Transferable skills	3	5.1.2 Develop presentation and communication skills
	5.2 Digital skills	5	5.2.2 Use and manage digital tools for communication and collaboration in STEAM education
	5.3 Professional development	3	5.3.1 Adapt self-reflective practices for STEAM education

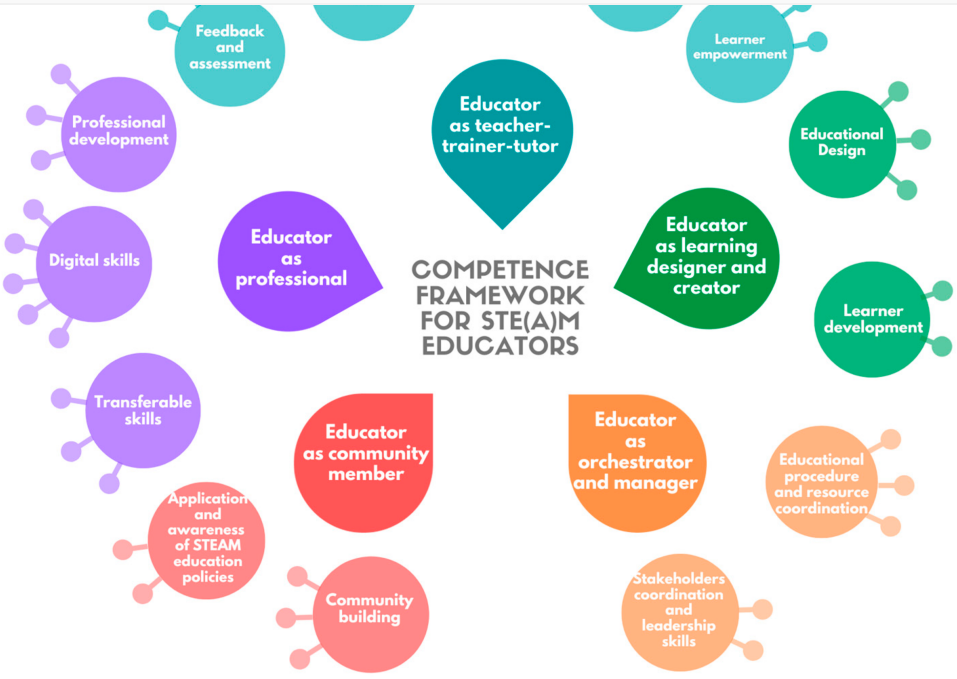

Figure 1. STEAM Educators' Competence Framework Perspectives and Areas.

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