STEAM FRAMEWORK FOR EARLY CHILDHOOD EDUCATION

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PR1 - " STEAM FRAMEWORK FOR EARLY CHILDHOOD EDUCATION "

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Executive Summary

This document corresponds to Project Result 1 and it was necessary so as the consortium could proceed with designing learning activities appropriately. For that reason, a systematic literature review was conducted, along with a desk research to examine existing STEAM approaches and identify the key competences that need to be treated through the SEGA project learning proposal. Additionally, a questionnaire was designed and addressed to educators across Europe in order to grasp their understanding of the field, so as to be able to design the training activities accordingly.

The document is divided into 4 sections. Section 1 presents the methodology and the results of the literature review. Section 2 presents the methodology and the results of the quantitative survey (questionnaire). Section 3 presents the results from the desk research. Section 4 presents the conclusions and the theoretical framework which was constructed for the needs of the project

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Introduction

Early Childhood Education (ECE) plays a critical role in shaping a child's development. ECE positively affects learning (Barnett & Frede, 2010) and gives to children the opportunity to obtain knowledge. In Early Years children are curious, ask questions, make observations and want to know more about the world around them (Abanoz & Yabaş, 2022). In ECE different kinds of skills must be integrated into the learning process (Wahyuningsih et al., 2020). Aldemir and Kermani (2017), state that early years have a strong influence on many of the skills that children are going to develop and learn in later life such as those related to education (Aldemir, Kermani, 2017).

Stem is the acronym for Science, Technology, Engineering, and Mathematics. Scientific administrators in the U.S National Science Foundation (NSF) introduced the STEM acronym. According to the National Science Teachers Association (NSTA), "*A common definition of STEM education […] is an interdisciplinary approach to learning where rigorous academic concepts are coupled with real-world lessons as students apply science, technology, engineering, and mathematics in contexts that make connections between school, community, work, and the global enterprise enabling the development of STEM literacy and with it the ability to compete in the new economy.*".

According to Bybee (2013), STEM education had a significant purpose, to develop a STEM literate society (Kennedy & Odell, 2014). Bybee (2013) stresses that STEM literacy refers to an individual's competence (as set of Knowledge, Skills and Attitudes) to identify questions and problems in real-life situations, explain the natural and designed world, and draw evidence-based conclusions about STEM related-issues (Ardianto et. al., 2019). As an interdisciplinary subject, STEM requires that pedagogical approaches should be different from the traditional ones to support students' learning (Kennedy & Odell, 2014). One of Moore's (2008), conclusions state that students through STEM integration gain a deeper understanding of each discipline contextualizing concepts (Martín Páez, et. al., 2019).

The attempts to integrate STEM to the existing curriculum is increasing globally. Nowadays, many researchers have focused on the significance and the utilization of early introduction to STEM education. However, the initiatives for curriculum development, teacher's preparation and standardization in the ECE setting are still limited in many countries (Hassan et. al., 2018).

Tippett and Milford, (2017) claimed that STEM Education can be an appropriate component of ECE. Aldemir and Kermani (2017) found that when children in ECE are supported through organized and developmentally appropriate activities, they can accomplish higher levels of understanding in STEM. A focus on integrating activities into the curriculum through an authentic problem was recommended in STEM education (Corlu, 2017).

STEM activities can be effective means for providing rich learning experiences to students of all backgrounds (Brenneman et. al, 2019), while encouraging them to research, as well as find and create alternative solutions to problems (Abanoz & Yabaş, 2022). In ECE children can explore the real world surrounding them through playful STEM challenges (Zdybel et al., 2020). Research has shown that investing in ECE on the fields of Science, Technology, Engineering and Mathematics yields the best results in 21st century skills (Abanoz & Yabaş, 2022).

Lavi et al. (2021) stress that the 21st century skills framework include:

- domain general skills such as Problem-solving, (Hollenstein, 2022; Şahin, 2021; Akcay Malcok & Ceylan, 2021; Sangngam, 2021; Iwuanyanwu, 2020) and Critical thinking (Milford & Tippett, 2017)
- soft skills such as Creativity (Üret &Ceylan, 2021) and Collaboration (Greca Dufranc et al., 2020)
- STEM specific skills such as Logical-mathematical skills (He et al., 2021; Uhlenberg & Geiken, 2022; Wang et al., 2022) and Engineering-design skills (Pantoya et al., 2015; Malone et al., 2018; Tank et. al, 2018; Başaran, 2018; Türk & Akcanca, 2021; Ültay & Aktaş, 2020).

STEM activities when implemented as part of the educational process children are able to benefit from their creativity and interact with innovative problem solving processes during childhood (Soylu, 2016).

Holmlund et al. (2018) note that there are still varying conceptions of what a STEM program entails. Early childhood educators hold a central and important role in implementing STEM activities or projects in the educational process by assisting young children learn and understand STEM concepts (Haney et al., 2002; Keys & Bryan, 2001; Wan et al., 2020). Teachers have to look for signs from children and adjust the learning experiences to support their curiosity, learning, and understanding (National Association for the Education of Young Children, 2013).

The multidisciplinary nature of STEM education allows Early childhood educators to offer children more meaningful learning experiences. Moreover, a STEM framework in ECE may provide to teachers the opportunity to reflect on their teaching practices and to the students to think about STEM-related ideas outside the school environment (Tippett & Milford, 2017). McClure et. al. (2017) showed that sufficient training and professional development are required for teachers in ECE settings to effectively engage young children with an appropriate level of STEM education.

Early childhood educators' perceptions of STEM education and impacts on professional training can be categorized into four areas (Wan et al., 2020): 1) Concept and features of STEM, 2) Value and appropriateness of STEM education, 3) Challenges of Early Childhood STEM education, and 4) Impacts on professional training.

Hachey (2020) concluded that today, both research and interventions aim at fixing the "leaking STEM pipeline" and theory/research on STEM identity development focus on children in middle school and above. Yet, children's attitudes about STEM and themselves as STEM learners are formed early enough, and identity development is a task of early childhood. This suggests a need to focus on young children's engagement with STEM education as means of nurturing their early STEM identity development. There is still a need to assess current and developing Early childhood STEM efforts, particularly ones aiming to empower role-taking, new forms of social interactions and new means of personal expression during meaningful and engaging STEM instruction.

The aim of this deliverable is to create a framework for STEAM education in ECE. For this purpose, initially a literature review was conducted. Then a questionnaire was addressed to ECE educators in order to gain insights on their perspectives. Furthermore several training programs and STEM Education programs addressed to Early childhood were examined. By combining all the corresponding information, a framework regarding the core competencies for STEAM education in ECE was developed.

Literature review

The literature review was chosen as a methodological tool to synthesize research findings and to uncover areas in which more research is needed (Snyder, 2019). The literature was based on online and printed sources, including books and journal articles. This deliverable aims to present a literature review that provides a comprehensive summary and evaluation of existing research, to highlight the areas where further investigation is needed and to establish the current state of knowledge around the STEM in ECE topic.

There were two main phases in the research approach. In the first phase, several databases were accessed for relevant literature fin order to identify studies related to STEM education, 21st century skills in ECE and early childhood educators' beliefs on STEM Education. The search was carried out in Scopus, Eric, Google Scholar and Mendeley, by using various combinations of keywords such as STEM education, learning, early childhood education, skills. Articles published between 2015 and 2023 were selected.

In the second phase the records were reviewed to ascertain, whether the studies were suitable for the current study by examining the abstract, according to a number of criteria. These criteria were:

- relation with STEM education
- including children between the age of four to six, or early childhood educators as participants
- peer-reviewed articles

The study included .37 research studies, as a result of this search.

Out of a list of 37 articles, we categorized 4 of them as very philosophical, as erasmus projects and/or as not very scientific, 10 of them as skills/competencies relevant, 7 of them as reviews of STEM, 4 of them as STEM framework and 12 of them as having to do with teachers.

In the following sections, the selected articles are examined based on the competencies they refer to.

Cultivating 21st century Skills in Early Childhood through STEM education

Learning in the 21st century requires an instructional approach that offers learning opportunities, within the authentic world context (Iwuanyanwu, 2020). Abanoz and Yabaz (2022), argue that quality STEM education experiences had an impact on the improvement of children's twenty-first-century skills (Choi & Hong, 2013; Lindeman, Jabot & Berkley, 2014).

Based on the predefined categories, sources have been assessed as being eligible and relevant to STEM, early childhood education and skills. Related references in the sources were also analyzed, and relevant ones were included. In accordance with the specified categories, 17 studies were selected for the review process and summarized based on the categories (Lavi, et all., 2021) in table 2.

Table 2. *Results of Review on 21st Century skills in ECE through the framework of STEM education*

Category	Focus Area	Article
Domain - general skills	Critical Thinking	Milford & Tippett, 2017
	Problem Solving	Hollenstein, 2022 Şahin, 2021 Akcay Malçok, Ceylan, 2021 Sangngam, 2021 Iwuanyanwu, 2020
Soft Skills	Creativity	Üret, Ceylan, 2021
	Collaboration	Greca Dufranc et al, 2020
STEM - Specific Skills	Logical-mathematical and spatial skills	He, et al., 2021; Uhlenberg & Geiken, 2022; Wang, et al, 2022
	Engineering-design skills	Pantoya, et al., 2015; Malone et al., 2018; Tank et. al, 2018; Başaran, 2018; Türk & Akcanca, 2021 Ültay & Aktaş, 2020

Domain - general Skills in Early Childhood

Critical Thinking

The definition of Critical thinking according to Dewey, (1933), is "*Active, persistent, and careful consideration of any belief or supposed form of knowledge in the light of the grounds that support it and the further conclusion to which it tends*". Edward Glaser (1941) defines critical thinking as follows "*The ability to think critically involves three things: (1) an attitude of being disposed to consider in a thoughtful way the problems and subjects that come within the range of one's experiences, (2) knowledge of the methods of logical inquiry and reasoning, and (3) some skill in applying those methods*".

Hognestad (2010) states that "*Critical thinking can therefore be seen as an important goal in education by virtue of children's ability to engage in discussions, learning to think independently, make good arguments and act upon them*". Other researchers point out that students in ECE can cultivate their critical thinking skills of analysis and interpretation (Daniel, 2017; Sundararajan et al., 2018).

Ismail et al. (2018) stress that critical thinking is the cognitive strategy used to help solve problems in a more effective way. Researchers state that implementing STEM activities within the educational process, affects students' critical thinking skills, developed as part of the curriculum (Ismail et al. 2018; Smith et al, 2018) while Ghazali and Yusof (2022) highlight that STEM education enables children to develop critical thinking and upper thinking skills.

Critical thinking abilities can be developed through questioning. Students are urged to think carefully and evaluate data before drawing conclusions, by asking questions (Padmanabha, 2018). Milford & Tippett (2017) in their research, in order to organize their in-class observations, used a protocol consisting of a list of potential characteristics of an effective and appropriate STEM curriculum for young children. They also used semi-structured interviews, focus groups, and a questionnaire to collect data from multiple stakeholders (teachers, students, and parents) to investigate how STEM-related activities were included in ECE, to ascertain whether they were interested in STEM subjects. Furthermore, they intended to examine parents' opinions on the general topic of STEM and examined what their children had learned about it. According to their findings, students seemed eager to take part in the STEM activities, asking questions and designing solutions to problems.

Problem Solving

Problem solving is connected to the thinking process. It involves critical thinking, decision-making, creativity, and information processing. It is the ability to solve problems in a worthy goal of education (Martinez, 1998). It is considered the most complex mental function and is defined as a high-level cognitive process, which requires control of more fundamental abilities. Effective problem solvers use a systematic approach that allows them to break down problems into smaller parts (Goldstein & Levin, 1987). In the framework of STEM education, children obtain 21st-century skills, such as systematic thinking and problem-solving (Sahin, 2021).

Hollenstein et al. (2022) stated that one of the crucial 21st-century digital skills, in the context of digital transformation, is problem solving—equally so in the fields of science, technology, engineering, and mathematics (STEM). In the context of kindergarten, learning through play is central; therefore, pretend play, and particularly guided pretend play, is suggested as an innovative way to foster skills for digital problem solving. As yet, the potential of pretend play for children's learning about digital transformation and digital problem-solving processes has hardly been researched. Moreover, the kindergarten teacher's participation in the pretend play is important for enabling longer and more complex problem-solving processes, thus teacher training to foster problem-solving skills during guided pretend play must be discussed.

In his research, Sangngam (2021) studied the changes in early childhood students' creative problem solving skills comparing before and after the intervention with STEM education learning activities. Sangngam (2021) states that activities which were organized according to STEM Education's theoretical concepts developed more creative problem solving skills. The training of students to become competent problem solvers because of the dynamic nature of professional environments where they are likely to find themselves in the future is an important aspect of teaching STEM (Iwuanyanwu, 2020).

Sahin (2021) implies that educational programs with STEM-based activities significantly affect children's problem-solving skills, as a result of his research where he examined the effect of a STEM-Based Education Program on the problem-solving skills of children aged five years old. Malcok and Ceylan (2021) state that educational programmes have to contribute to the problem-solving skills of the children and may have important characteristics related to STEM education to support problem-solving skills. According to their findings, the practices aiming to improve the specific skills of the children are more effective than the practices lacking a focus. STEM-based programs and activities that have a great role in gaining 21st century skills, such as problem-solving skills in early childhood education.

Soft Skills in Early Childhood

Creativity

Creativity can be defined as the ability to produce original and unique thoughts, ideas, and possibilities, to help solve problems, is an ongoing act, regardless of when it leads to creation. Moreover, creativity creates original ideas, gives rise to possibilities, is also flexible within the context to identify even emotional or mental constructs as outcomes (Walia, 2019). According to Gardner, (1995), creativity gives children the ability to connect with other areas of learning to improve their understanding.

A major factor has been the cultivation of creativity in education on an international level. Students can cultivate their creativity skills by being curious, inventing, making use of previous knowledge, crafting, delivering and presenting solutions (Collard, 2016). Researchers highlight that there is a great demand for creative and innovative thinkers in STEM. STEM education motivates students to really engage in STEM activities and gives the opportunity to "*think outside the box*" (Larkin, 2015), can develop students' creativity as it helps them to apply their knowledge from different disciplinary areas due to the interdisciplinary nature of STEM (Bozkurt Altan & Tan, 2021), while the students who implemented STEM project-based learning cultivated their creativity skills in the dimension of resolution, elaboration, and novelty (Hanif et al., 2019).

Sirajudin et al. (2021) in their study described the effectiveness of the STEM learning model in improving the creative thinking skills of students. According to their research findings "*The STEM education learning approach and the student's initial ability level in this study affect the students' creative thinking abilities, while the creative thinking of students who have been trained in class can be developed in the real world*" (Sirajudin, et al., 2021).

Uret and Ceylan, (2021), in their study examine the effect of STEM education on the creativity of 5-year-old children. The semi-experimental method with pretest-posttest-control group, was used for observing the difference of creativity scores between the study and the control group. Research findings revealed the relationship between creativity and the educational environment created with STEM education.

Collaboration

Collaboration "*is the mutual engagement of participants in a coordinated effort to solve a problem together. Collaborative interactions are characterized by shared goals, symmetry of structure, and a high degree of negotiation, interactivity, and interdependence*" (Phan et al., 2011). Through social interaction and imitating one another, children acquire new skills and learn to collaborate with others (Campos et al., 2011).

According to Child and Stuart (2016), collaboration is one of the essential skills of the 21st century while collaborative learning contributes by equipping students with the necessary skills in order to improve the way that they work together and solve problems as teams. Team members can help each other and reach their goals through listening and learning together (Kuhn, 2015; Lai, 2011). Implementing new technologies in the curriculum of ECE can cultivate collaborative skills by fostering peer-to-peer interactions and social development (Lee et al., 2013).

Moreover through STEM education, students' collaboration skills can be improved (Ata-Aktürk et al., 2017), while as Ong et al. (2016) highlight, children who have the opportunity to be exposed to STEM opportunities from their early ages, can collaborate with their peers in a more effective way and have the opportunity to solve real-life problems. Moreover, STEM education helps in achieving goals and shaping learners to be open-minded toward others' ideas (Dani et al., 2020).

As part of an innovative and methodological approach to learning, the adoption of robotics in STEM education has been encouraged (Bargagna et al., 2019; Ferreira et al., 2018). According to Darmawansah et al. (2023), "*When robots and educational robotics are considered a core part of STEM education, it offers the possibility to promote STEM disciplines such as engineering concepts or even interdisciplinary practices*.". Robotics gives students the opportunity to examine how technologies are working in everyday life, and how to find new ways to cultivate their collaboration skills (Greca Dufranc et al., 2020).

STEM - Specific Skills in Early Childhood

Logical-mathematical and spatial skills

Logico-mathematical skills are described as including classification, seriation, numerical relationships, spatial relationships, and temporal relationships (Kamii, 2003), while spatial skills include orienting, visualizing, reflecting, composing, designing (Newcombe & Frick, 2010; Fessakis et al., 2016). Piaget described that "*logical-mathematical knowledge is developed from a child's active thought and interpretation process of the world around him/her*" (Lee & Kim, 2018). Gardner's theory includes logico-mathematical intelligence, defined as the ability to identify patterns, use numbers effectively, evaluate situations and problems in a rational way, find solutions through scientific research, and perform logical mathematics operations easily (Gardner & Hatch, 1989; Cavas & Cavas, 2020). Researchers observed a correlation between mathematical and spatial skills, especially those that included children as participants (Newcombe & Frick, 2010; Young et al., 2018, Xie et al, 2020).

Arum et al. (2018) found that teachers have to design learning methods and use learning strategies to cultivate student's logical and mathematical skills. Based on the results of their study, Kirkland et al. (2015) state that the implementation of a higher order of thinking activities might lead to the improvement of the logico-mathematical thinking in ECE.

Lee and Kim (2018) examined the effects of the S-Block curriculum on 5 year old children's logical mathematical and spatial ability. "*S-Block is a smart toy system that integrates IOT technology with a traditional block toy*". Moreover, they included storytelling in order to encourage children to solve the problems. Their findings revealed that children's logical mathematical performance and spatial ability can be improved, necessitating the use of developmentally appropriate technology in early childhood education.

He et al. (2021) explored the relationship between STEM education and the development of children's mathematical ability, as manifested in spatial ability. The findings also show that STEM training mainly affects children's mathematical ability through building block skills. Moreover researchers outline Computational Thinking as an essential part of STEM disciplines in K-12 (Kanaki & Kalogiannakis, 2022), while incorporating Computational Thinking into STEM education will also enhance students' learning of STEM contents and cultivate STEM skills such as Logical-mathematical skills, science process skills and engineering - design skills (Wang et al., 2022).

Newcombe, (2017) noted "*that a crucial element in STEM success is spatial intelligence… Recognition of spatial skills enriches the traditional educational focus on developing literacy skills and numerical skills, and the implicit concentration on verbal and mathematical intelligence*". Uhlenberg and Geiken (2022) outline that through STEM in ECE, a sensory rich environment can be provided in order to cultivate STEM skills such as Logical-mathematical and spatial skills (Mix et al., 2016; Newcomb, 2017).

Engineering-design skills

Engineering as Isabelle et al. (2021) state "*is a critical part of the Next Generation Science Standards (NGSS Lead States, 2013). Accordingly, not* *only do children need to think and act like scientists, but they also need to think and act like engineers*". According to Bustamante (2018), "*Early engineering may provide a learning context that is uniquely conducive to building these core components, as engineering activities typically involve observing physical phenomena, and identifying and manipulating causal connections to build a tool or structure that solves a problem*".

The design context provides children with opportunities for planning, making, and evaluating a tool, product or process, while reflecting of their own original ideas.

Malone et al. (2018) report that STEM education is also related to designing and engineering (Ültay and Aktaş, 2020). The best way to provide STEM experiences to young children is to use the design context. When students use computers to program or create structural designs, they need to use their engineering-design skills in order to find out the mathematics and science of designs. Çil (2019) argues that through this design context children have the opportunity to imagine, create, evaluate, process while reflecting on their own ideas.

Moreover their research outlines that the utilization of integrated STEM improved 4 to 8 year old students' conceptual understanding of engineering and technology. Başaran (2018), based on the model of action research, conducted a study with the participation of 3 early childhood educators and 57 students. The study found that the implementation of STEM activities in the classroom had a positive and permanent effect on students' engineering design skills in early childhood education.

Tank et al. (2018) examined how an engineering design-based STEM integration unit works in three kindergarten classrooms. Data were collected by classroom observation and videos. According to their findings they state that "*engineering design provides a space and context for kindergarten students to make connections across disciplines*". Furthermore, students through the cultivation of their engineering-design skills achieved high levels of understanding and engagement, as they were able to meaningfully engage in and with multiple stages of an engineering design process.

Türk and Akcanca (2021) conducted an action research study to examine "*whether the designed intervention program based on STEM can be beneficial for 5-6 year old children to learn more about the specific features of the magnets*''. During the program several STEM activities were implemented. Data were collected through observation notes containing the statements of the children in the process of product designing and product presentation and the expressions of the pictures they made before and after the program, emphasizing in the engineering design skills. Results underline the importance of STEM activities, as an interdisciplinary approach, while during the product development stage of intervention programmes, children acquired their engineering design skills.

Pantoya et al. (2015) intended to promote STEM learning in Pre-K – 2nd grade, through engineering-centered literacy practices. Findings show that through STEM practices children were more creative while instilling a concrete sense for what engineers can do. Furthermore, they reported that the children "*appeared to have initiated the development of an engineering* *identity that could shape a students' propensity to continue to seek engineering-based activities*".

Ültay and Aktaş (2020) gave children different kinds of materials. Students had a mission to design a product to carry eggs without breaking them. In accordance with the results, it was stated that during ECE it is very important to cultivate children's engineering design skills, while at the same time "*the material richness will be beneficial in terms of richness of knowledge and experience*".

Teachers

Burton et al. (2022) stressed the fact that although the literature highlights the importance of engaging young children in STEM, on the other hand early childhood and elementary teachers lack adequate preparation for teaching, integrating STEM pedagogies. Many of them lack confidence or even face anxiety and fear when required to teach STEM content. In turn, these negative feelings affect the experiences of their learners. Burton et al. (2022) referred to attitudes, beliefs, and values that pre-service teacher hold about teaching through integrated STEM. Ideas, perceptions, and values influence dispositions, because these can "*be thought of as lenses that affect one's view of some aspect of the world" and are "psychologically held understandings, premises, or propositions about the world that are thought to be true*" (Phillip, 2007).

Hachey (2020) reviewed several studies US public schools for ages up to 3rd grade and states that "STEM education (and a related focus on early STEM identity development) is missing, and further research shows that STEM education is not well understood by early childhood teachers (who receive greater training in early literacy pedagogy)". Tao (2019) reported that early childhood teachers have low self-efficacy for teaching STEM and are not very familiarized with STEM education overall. Also, DeJarnette (2018) commented upon the training lack of early childhood teachers and their low self-confidence for teaching STEM, which results in minimal teaching time spent on the area. Pantoya et al. (2015) that the corresponding teaching time from early childhood to grade two is less than 10%.

Li et al. (2021) state that the role of the teachers is of high significance for fostering preschool children's learning in STEM domains. They need to hold the necessary content knowledge and also the corresponding pedagogy to facilitate high-quality STEM experiences for children (Early Childhood STEM Working Group, 2017). Furthermore, Li et al. (2021) state that early STEM educational experiences (e.g. in home environments) significantly affect young children's learning and development. After studying 10 articles covering topics about curriculum and pedagogy, teacher education and professional development, family environment, and inclusive education for enhancing young children's STEM learning experiences, they came up with the following important main points:

- The potential of using personification storytelling as an effective strategy to introduce abstract scientific concepts to young children is high
- Young children's understanding of abstract concepts and development of advanced process skills are higher when teachers are able to create

learning opportunities by providing explicit instructions and scaffolding, but also the corresponding STEM- related resources

- An inclusive education program involving engineering play may support the development of children's domain-general social-cognitive functioning and the implementation of STEM curricula for all children
- Early STEM experiences in early childhood settings may be promoted by transforming traditional learning centers to be more multifunctional and inclusive (e.g. by accessing multiple resources as in the case of a library).
- Early STEM teachers should be better prepared for the task in their study period.
- Professional development of early STEM teachers should be enhanced through corresponding training programmes.

Nikolopoulou (2022) focused on teachers' perceptions on the importance of STEM education for young children with the STEM activities used in class. The teachers perceived challenges and problems in the implementation of STEM activities and more specifically teachers reported various skills and, in particular, children's social skills. Children's interest/motivation, their cognitive level or age, and the learning outcomes are the primary factors considered when preparing STEM activities. Teachers perceive challenges regarding experiential learning and children's interest-participation, while major problems include limited time, infrastructure and support.

Çiftçi & Topçu (2022) discussed the challenges faced by the pre-service early childhood teachers in the planning process of STEM education–based activities. The analysis revealed eight (8) themes regarding the pre-service teachers' solutions about successful planning and implementation of STEM education–based activities: materials to be used, group works conducted by the pre-service teachers, classroom arrangement and management, time management, appropriateness to children's level, identifying and expressing the problem, activity planning and implementation, and implementing STEM education.

Abanoz & Yabaş (2022) focused on two research questions: How do early childhood teachers define their expectations before implementing the integrated STEM curriculum? How do early childhood teachers define the teaching-learning process of the integrated STEM curriculum? The implementation of the curriculum allowed children to practice both cognitive process and social product skills. Teachers directly observed children demonstrate those skills as they worked on the problem collaboratively. Quality STEM education experiences had an impact on improvement in children's twenty-first-century skills (Choi & Hong 2013; Lindeman et al., 2014).

MacDonald et al. (2020) report findings from a two-year independent evaluation of the Little Scientists program, a STEM professional development program for early childhood educators across Australia. Educators have noticed children's STEM capabilities and have described how the children have shown high levels of motivation and interest, as well as a growing confidence in STEM related learning experiences. It would appear that participants are more aware of children's existing, but also growing, skills and knowledge in STEM, including creative thinking, problem-solving, hypothesizing, and self-investigating.

MacDonald, et al., (2021) later conducted another survey of Australian early childhood educators in order to ascertain their beliefs and confidence regarding STEM education. Although respondents indicated positive dispositions toward STEM and believe they have sufficient capabilities in mathematics, they lack confidence in the disciplines of science, technology and engineering. Inquiry-based learning appears to provide a comfortable entry point for STEM for early childhood educators, so it would seem that inquiry-based STEM programs are potentially well-positioned to have a positive impact upon early childhood STEM education practices.

Ndijuye & Tandika, (2020) employed a qualitative research approach with a phenomenological design. This is a design within the interpretivist paradigm that investigates different ways in which people experience something or think about something (Bowden, 2005). This design allowed the researchers to locate commonalities of lived experiences (Patton, 2009) of pre-primary stakeholders related to STEM education in Tanzania. Tanzanians have limited exposure to STEM learning. In other words, they struggle to understand why it matters and how it works. At pre-primary level, even important stakeholders of this sub sector such as teachers and school principals do not have a clear understanding of the importance and processes involved in equipping children with STEM foundations. Providing a clear illustration of a STEM learning program—what participants learn and how they learn it, with what goals and outcomes—sketches a memorable picture that can fill in cognitive gaps.

Ceylan & Malçok, (2020) examined a case study in Turkey in a preschool education institution at a state university in Istanbul, and it came up that teachers were satisfied with the training in STEM education and they observed positive changes in children as a result of this education. Teachers support that STEM education can be appropriately incorporated in early childhood education.

Sibuma et al. (2018) state that children attending preschool can attain higher levels of understanding in STEM when they are provided with well-planned, stimulating and developmentally appropriate activities. These activities will be prepared and/or presented by their educators. Thys, there are effects of implementing an integrated STEM curriculum on Pre-K teacher content knowledge, pedagogical content knowledge, and self-efficacy in STEM and engineering.

Conclusions

Reviewing the literature, one concrete conclusion is that not much work has been done in ECE. It is evident that researchers and educators consider ECE a crucial educational level and believe that STEAM education should hold a significant space within its settings.

The reviewed papers can be divided based on the competencies they highlight. In the area of domain-general skills, Critical Thinking was often mentioned. Being also one of the 21st century skills, researchers believe that STEAM education fosters critical thinking cultivation (e.g. Ismail et al., 2018). Questioning, data evaluation, concluding are ways of developing critical thinking

(Padmanabha, 2018). Other researchers connect critical thinking with problem solving, highlighting the latter as a significant category of competencies which is directly connected to STEAM education, as it relies significantly on solving real-life problems. As Martinez (1998) stated, problem solving is the ability to solve problems in a worthy goal of education.

Regarding soft skills, creativity has been highlighted by pedagogists as a fundamental element of children's development in early years. According to Larkin (2015), STEM education gives children the opportunity to "think outside the box". Another important skill is that of Collaboration, which research data indicate that it can be cultivated through STEM education (e.g. Ata-Aktürk et al., 2017; Ong et al., 2016).

Other skills revealed through the literature review were logical-mathematical and spatial skills and engineering-design skills. Thus, one could conclude that STEM education seems to provide an ideal space for the cultivation of the 21st century skills, along with mathematical reasoning and spatial skills, through the engineering design process.

Finally, regarding teachers the need for STEM oriented training has been highlighted, along with the increasingly positive perception that educators have about STEM education in the early years.

All these elements (competencies and needs) should be considered for the needs of the SEGA Framework.

Questionnaire analysis

A was addressed to teachers in order to investigate their perception regarding STEAM education and to record their expressed self-efficacy on integrating STEAM activities in their practice. The questionnaire consisted of three parts. Part one included demographic information (gender, age, level of education, teaching experience incountry). Part two consisted of 8 multiple choice and open ended questions that aimed to inquire the understanding of the STEAM approach. Questions included examples of common activities conducted in classrooms K-2 and why or why not they can be classified as STEAM activities.

Part three included 14 questions that addressed teacher attitudes towards STEAM approach. 5-point likert scale questions from strongly disagree to strongly agee were included in order to record attitudes or predispositions on STEAM practices applied in their classes.

Results

Demographic information

Overall, 80 teachers responded to the questionnaire, 33 from Greece, 1 Turkey, 1 Italy , 2 UK,1 Germay , 16 from Netherlands , 15 from Poland , 10 from Portugal, 1 from Romania (Figure 1).

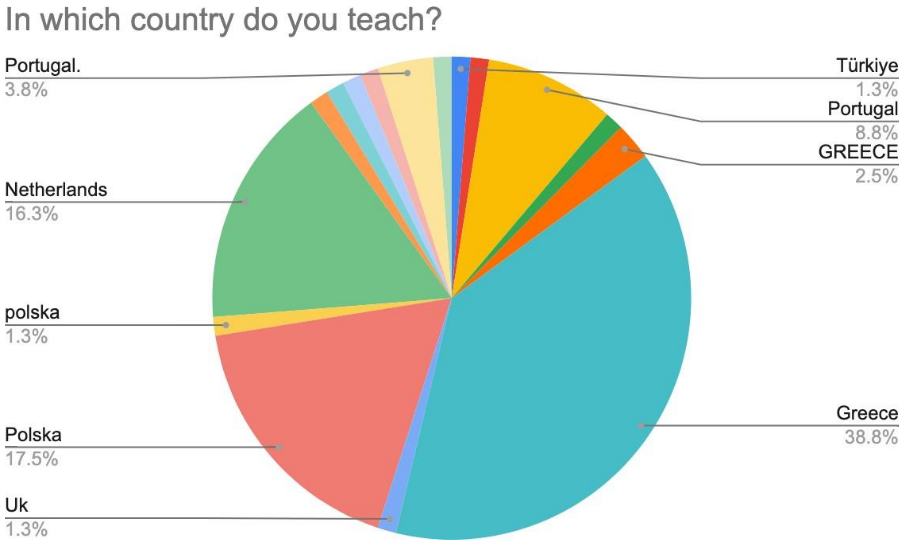

***Figure 1**. Countries of participating teachers*

Regarding the ages of the respondents, the distribution is rather representative of the current status in education, with the majority being distributed mainly among the two middle age groups and the 1st and 4th age group rather closely more or less equal in the available ages and thus the teachers can be considered as a representative sample population (Figure 2).

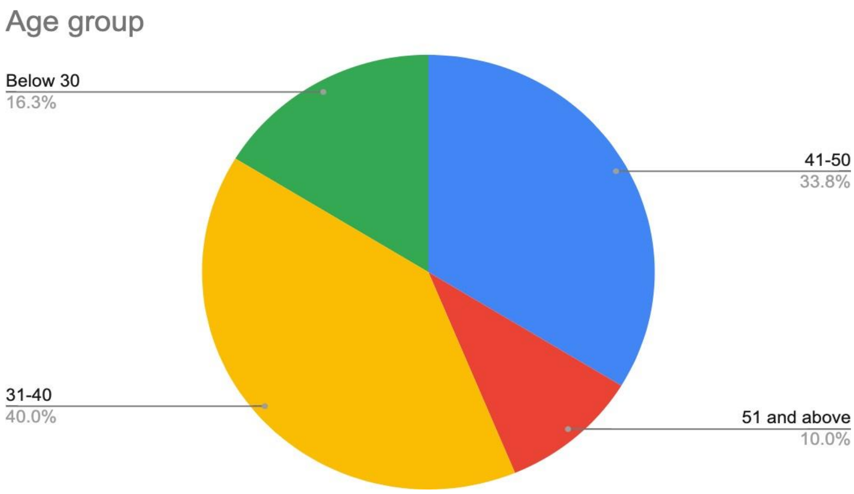

Figure 2 *. Teachers age distribution*

Regarding gender, the majority of the respondents were women, as expected considering the age group of the students (Figure 3).

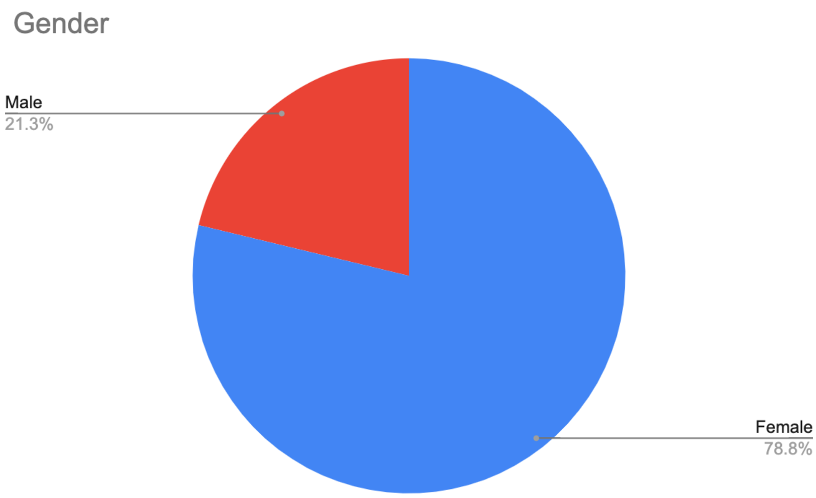

Figure 3 *. Gender distribution*

As for the level of education, it is interesting that only 22.6% holds just a bachelor's degree, as the rest have studied in a higher level. About 1/5 hold a docorate degree (Figure 4).

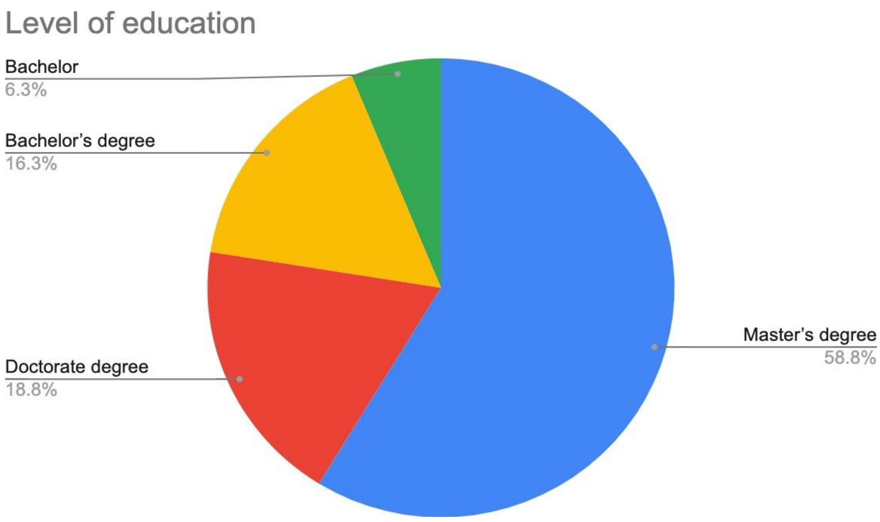

***Figure 4**. Gender distribution*

Regarding their experience in STEAM teaching, about 1/4 provided a definite answer (23.8% - yes). About half of the respondents provided a negative answer and 30% reported having some experience of this kind (Figure 5)

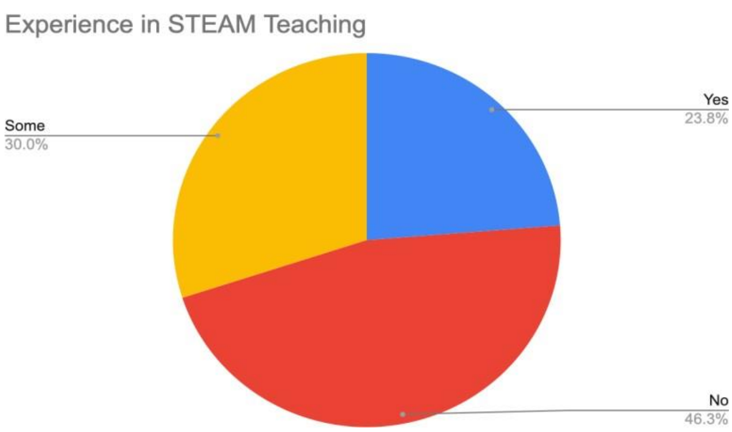

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***Figure 5**. Teachers' experience in STEAM teaching*

Overall, the participants appear to be a rather representative sample of the teacher population, appearing to have a good distribution among E.U. countries, also outside the ones of the consortium members.

Part II – Section A

The second part of the questionnaire included a set of open ended questions along with examples of activities asking teachers to identify if they are STEAM activities.

The first open ended question was "**Can you give a definition of the STEAM approach? If not, please answer "NO"**

Out of the 80 participants, 28 answered No. 12 teachers defined STEAM as an acronym - Science, Technology, Engineering, Arts, Mathematics. 19 teachers defined STEAM as an **integrated, interdisciplinary approach** to learning that connects Science, Technology, Engineering, Arts, Mathematics.

17 teachers mentioned **21 century skills and specifically critical thinking, collaboration, inquiry, problem solving.** Two teachers referred to solving real life problems. One teacher answered "learning by doing" and one teacher referred to the engineering cycle.

Overall the teachers were unable to provide a concrete definition about STEAM. Only 1/4 mentioned the interdisciplinary nature of the approach, but almost all of those you provided a non-negative answer referred to the constituent disciplinary areas of the term. Only 1 teacher mentioned realistic problems and 1 referred to the engineering design process. Thus, it is safe to conclude that teachers were not really aware of what the STEAM approach entails, which highlights the need to train them starting from the very basics.

The next question- **What is the purpose of STEAM Education?** - was a multiple choice question with the following possible answers: To provide students knowledge about science, math and technology subjects, To cultivate competences (competences = knowledge +skills+ attitudes + values), To teach students about the engineering design process, To cultivate skills, other

58.8% of teachers answered "to cultivate competences (competences = knowledge +skills+ attitudes + values)", followed by 18.8% that answered "to provide students knowledge about science, math and technology subjects". One teacher answered, other, elaborating with "all of them and develop creativity". 8 of the teachers answered to teach students about the engineering design process and 6 to cultivate skills (Figure 6). The answers reveal the vast majority of the teachers provided generic answers related to competence cultivation in the

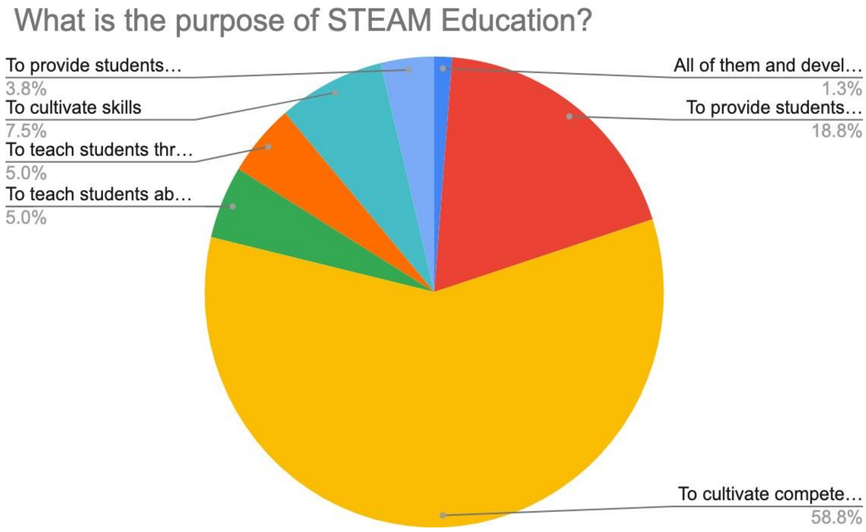


***Figure 6**. Teachers' perception of the STEAM Education purpose*

The following question was also a multiple-choice question asking teachers which type of teachers should teach STEAM. 60 out of 80 teachers answered all teachers and 17 teachers answered Science teachers. Two teachers answered elementary teachers. One teacher answered not sure (Figure 7). Thus, teachers mainly perceive STEAM teaching as part of their practice and consider that there in no need for specialists.

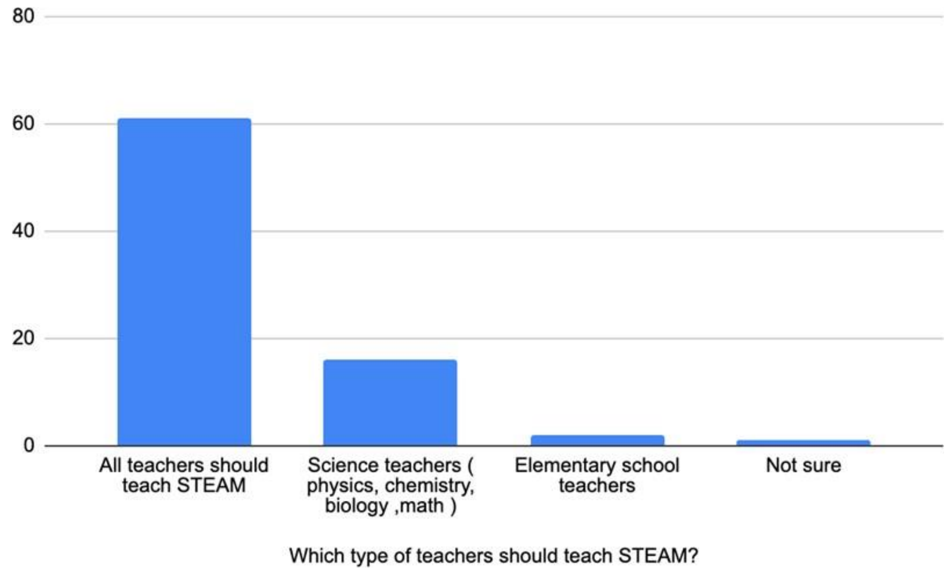


Figure 7. *Teachers' perception STEAM teaching background*

In the questions when should STEAM teaching start, 48/80 teachers answered from Kindergarten while 24 considered Elementary school as an initiation point and only 8 answered in Middle year school (Figure 8). It is obvious that the respondents agree with the research evidence that STEAM Education should start for the early years.

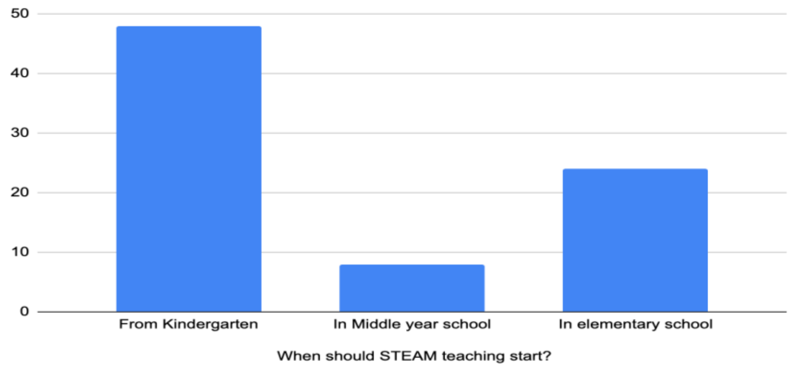


Figure 8. *Teachers' perception regarding STEAM teaching timeframe.*

Part II – Section B

In section B of this part of the questionnaire, three activity examples were presented to the respondents, asking them to state if the fall under the STEAM activity category.

The first example was titled "Counting up to 10"; in order to learn how to count up to 10, students make numbers using play dough.

29 teachers answered Yes. Out of them, 7 provided the explanation that it is related to mathematics and that is why it is a STEAM activity. Others noted that "the activity has STEAM methodology because it uses different materials and dynamics" or referred to the fact that as the students are required to create something (playdoh number) it involves construction, creativity or art and that is why it is a STEAM activity. Overall, in all cases it seemed that the respondents who provided an affirmative answer justified it with the common misconception that an activity is STEAM if it combines some of the areas included in the acronym.

25 teachers answered maybe, with one of them explaining that "If the strategies intrinsic to the activity involve moments of experimentation with the material to represent quantity, yes. If this is necessary to represent a digit, no." In this case also, the misconception of STEAM being an activity which involves some kind of construction or tangible representation emerges. All 26 teachers that answered that it is not a STEAM activity mostly explained that it only has to do with math or that it is an artful approach of teaching in general.

The second example was named Growing Plants. Students plant lentils in a jar. Some students place their jar in a sunny area and some in the dark. Students make day by day observations. Students also create drawings with lentils.

43 teachers considered this as a STEAM activity. Some of the justifications were that: it is a qualitative activity, it engages students in inquiry, it is related to science and that "The methodology is interdisciplinary and didactically integrates the application of concepts through practical strategies". Overall they stressed out the fact that it involves Science (2 of the respondents stated that it is about Biology) and thus it is a STEAM activity. In this case too, the dominant perception that any activity related to Science that involves also some kind of experimentation and/or counting (mathematics) is a STEAM activity.

25 teachers answered maybe explaining that the activity could be transformed into a STEAM activity if there was a connection with a real world problem. One teachers noted that "It is something that has been going on for years in the classrooms so I guess it doesn't involve pioneering methods as STEAM does". 12 teachers answered no stating that it does not combine Science Technology Engineering Art and Mathematics.

The third activity was titled Building a house. Inspired by the story of the three little piglets, students are asked to build a house for the class mascot, a stuffed animal. The students are separated into teams and are asked to build the house so it could stand up best to a "wolf blowing". The blowing wolf could be a hair dryer. The students are provided with different materials. Each team creaates their house, tests it and makes changes and adjustments. Finally, each team presents their house to the whole class.

69 teachers answered that this is a STEAM activity and 11 maybe. No teacher answered no. Out of them, 21 explained that it is a STEAM activity because it is related to engineering. 6 teachers noted that it is a STEAM activity as it is interdisciplinary. 6 teachers stated that it is a STEAM activity as in cultivates critical thinking. 9 teachers explained that it is a STEAM activity as it cultivates skills (in general) and problem solving. 7 teachers noted that it is a hands-on activity and other 2 that it is connected to a story. In this case, the design of the house is referred to as engineering and it is the dominant justification. In fact, 10 of the teachers used the term "cycle", referring to the engineering design process. All teachers that answered maybe stated as a reason that they were not sure.

Overall, although the majority of the teachers provided the correct answer (the two activities were not STEAM and the last was STEAM), their justification mainly relied on the misconceptions stated in the corresponding literature. Intuitionally they seem to have an understanding of why an activity is STEAM or not, but overall they fail to precisely justify their perception. This indicates that still teachers need to be trained, starting from the very basics of the STEAM terminology with additional practical examples. All of them, except just a few (2-3 in each question) didn't refer to the need of having a problem of a problematic state which needs to be examined and addressed by combining knowledge, applying a problem solving approach (engineering design process) in a recurring manner.

Part III

The third part of the questionnaire aimed to evaluate teacher attitudes towards the STEAM approach. It included 14 statements to be graded using a 5-point likert (strongly disagree to strongly agree).

The first statement was "I am willing to collaborate with other subject teachers". As in their previous answers many of the teachers highlighted the interdisciplinary nature of STEAM activities, although the majority stated that such activities should be implemented by a non-specialized educator, this statement examined the possibility of them being insecure that other disciplines might take part of their professional space. This is a not so uncommon anxiety source for teachers. The responses (Figure 9) indicate that they hold no such fear or anxiety.

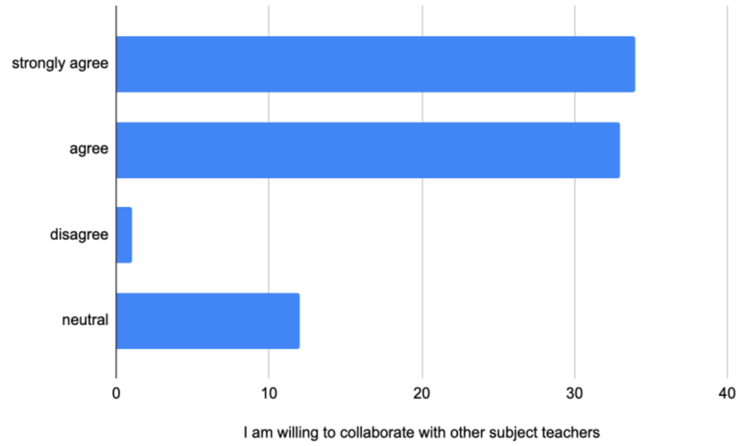


Figure 9*. Teachers' will to collaborate with others for interdisciplinary STEAM activities.*

The next statement required them to grade the significance of STEAM approach in education. As seen in Figure 10, the majority of the respondents agree or strongly agree. Also, there are no negative grades for the statement. This indicates a strong interest for STEAM education, providing added value to the training initiatives such as the one proposed by this project. Combining it with the misconceptions which emerge through the previous questions, a proper training approach seems to be a necessity.

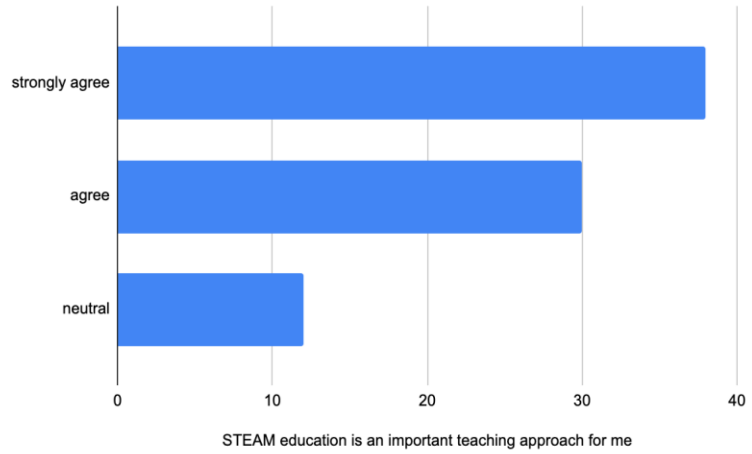


Figure 10*. Teachers' perception of STEAM education as part of their practice.*

In the statement "I am confident that I can implement STEAM education in my classroom", about half (41/80) selected "I agree" or "I strongly agree". The teachers seem to have self-confidence, despite the fact that fewer provided a fully justified answer in the 3 questions about the presented activities. This could indicate an "illusion of competence" effect, which could be addressed via proper training. It is noteworthy that 26/80 (about 1/3) appear not confident enough to implement STEAM education, further enhancing the need for training.

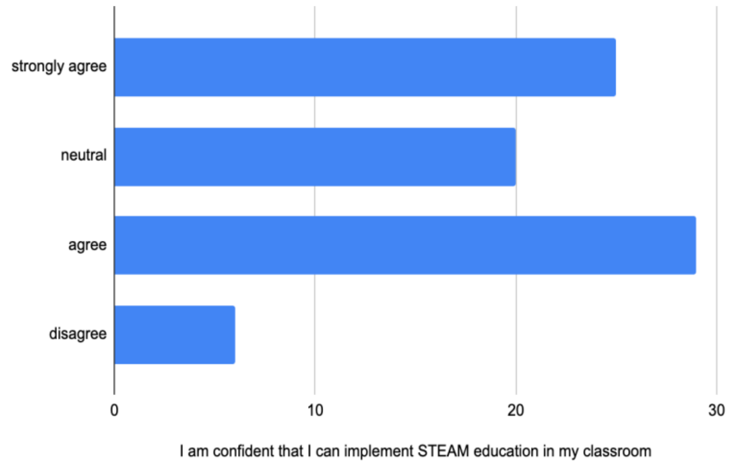


Figure 11. *Teachers' confidence regarding STEAM teaching.*

Examining their perception of STEAM education as a motivating approach for the students, the majority (65/80) agree or strongly agree with the statement (Figure 12).

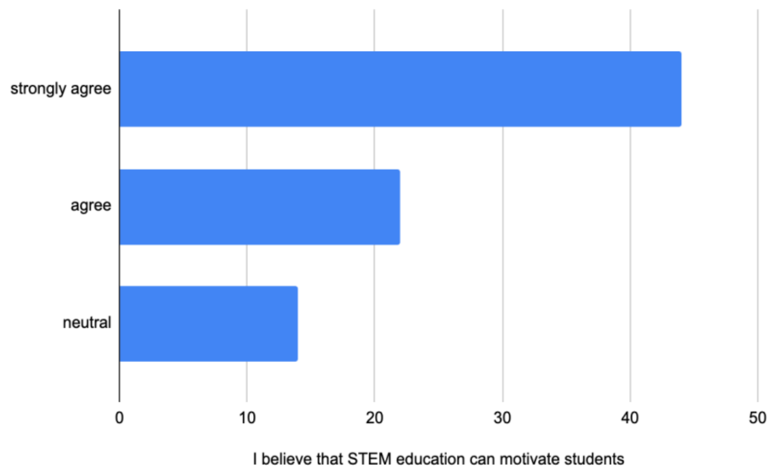


Figure 12. *Teachers' perception of students' motivation in STEAM activities.*

Even more respondents agreed that STEAM approach may enhance the quality of education overall (Figure 13). This further strengthens the conclusion that teachers have a positive attitude towards STEAM education and they are willing to know more about it.

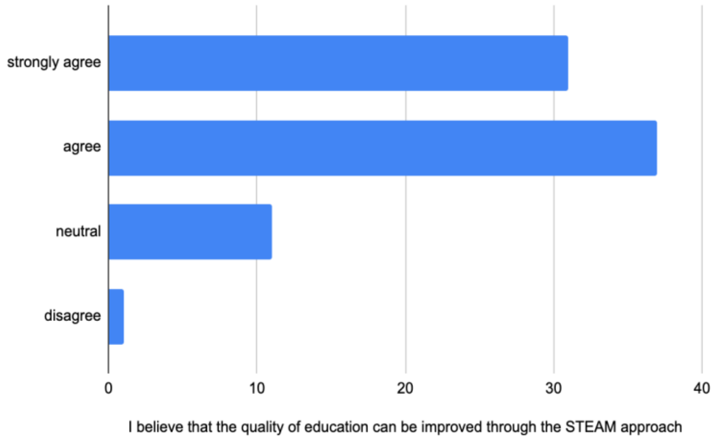


Figure 13*. Teachers' perception STEAM impact on education overall.*

It was considered also important wo examine whether the teachers perceive STEAM activities as enjoyable for them too and not only a necessity or significant for their students. This thought as an indicator of intimidation towards the implementation of such activities (for any reason, e.g. anxiety or lack of knowledge) in the classroom. The majority agreed, although in this case the neutral grades were more than in other statements (Figure 14). The neutral responses are more than in the previous 3 statements which appears as slightly contradictory, since the teachers state that they consider themselves confident and STEAM activities important and motivating for their students, but at the same time they are not that enthusiastic about implementing such activities themselves.

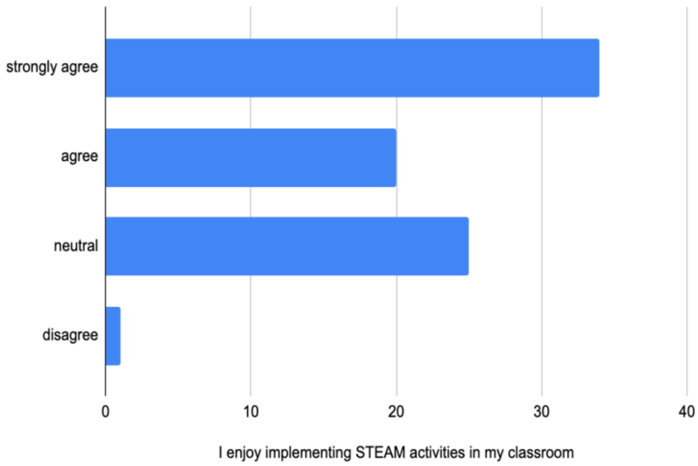


Figure 14*. Teachers' statement on pleasure drawing from implementing STEAM activities.*

Figure 15 presents their answers for the statement "I do not find it difficult to implement STEAM Education". In this case also, the neutral and disagree grades are more than in the question about self-confidence. This indicates also a contradiction, as they claim to be confident to implement STEAM Education but are not that positive in their grading of how difficult it is for them.

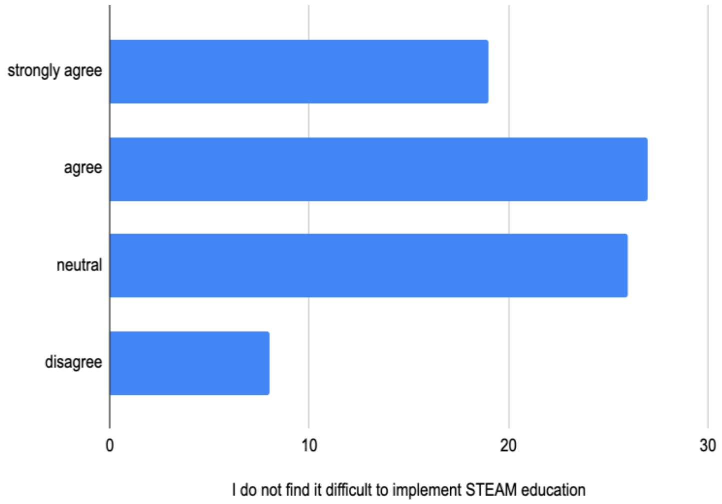


Figure 15. *Teachers' self-declaration of STEAM activities ease of implementation.*

The next statement, "I can accept failure during teaching sessions" was considered significant although it has a twofold interpretation. On one hand students may the ones who fail to fulfill the requirements of a STEAM activity and on the other, teachers may be the ones to fail in successfully implementing or facilitating a STEAM activity in their classroom (especially in their first attempts). In the case of problem-solving approaches, such as STEAM, failure is mainly considered as a new opportunity of learning. Although the two interpretations were not provided to the respondents, most of them agreed that failure is accepted, which is a positive observation (Figure 16).

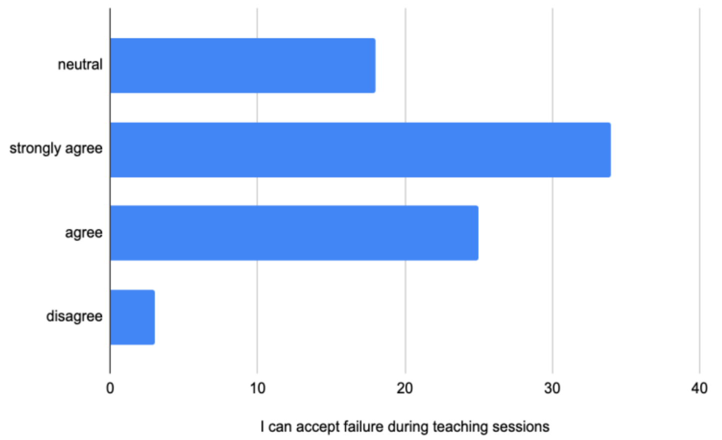


Figure 16. *Teachers' acceptance of failure in STEAM sessions.*

As Technology is an integral part of STEAM education and considering the vast rate of technological advancement, the next statement referred to the teachers' readiness to face such challenges that emerge constantly (e.g. new technologies and availability of products). Their grading was more positive than in the previous statements (Figure 17), indicating that the consideration of technology as an intimidating factor is no longer an issue in education. Possibly the past years in which the demand to adapt technology (during the Covid-19 pandemic) affected the teachers perception of technology use and their self-efficacy in a positive manner.

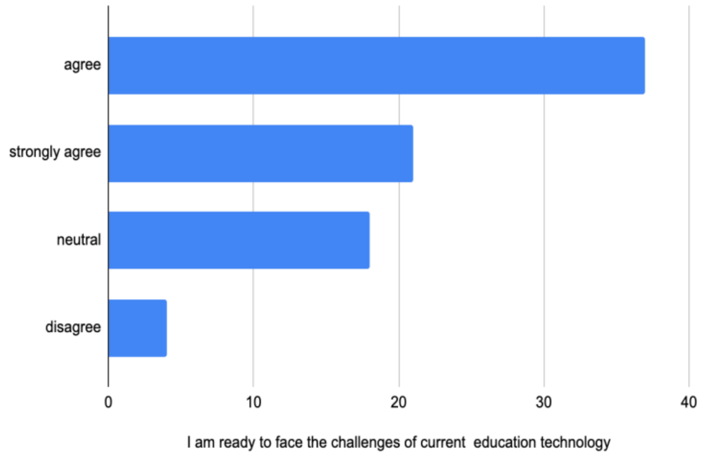


Figure 17. *Teachers' readiness to face technological challenges.*

Apart from technological advances, new methodologies have emerged recently in order to support innovative teaching approaches such as STEAM education. Problem solving, project-based learning, problem-based learning, computational thinking, game-based learning, gamification are some of the emerging approaches in teaching and learning. Thus, it was considered important to examine the teachers perception on new methodologies, as the STEAM approach is actually a rather new approach in educational design which involves novelties (e.g. selecting a realistic problem and applying the engineering design process). Most of them agree with the statement (Figure 18).

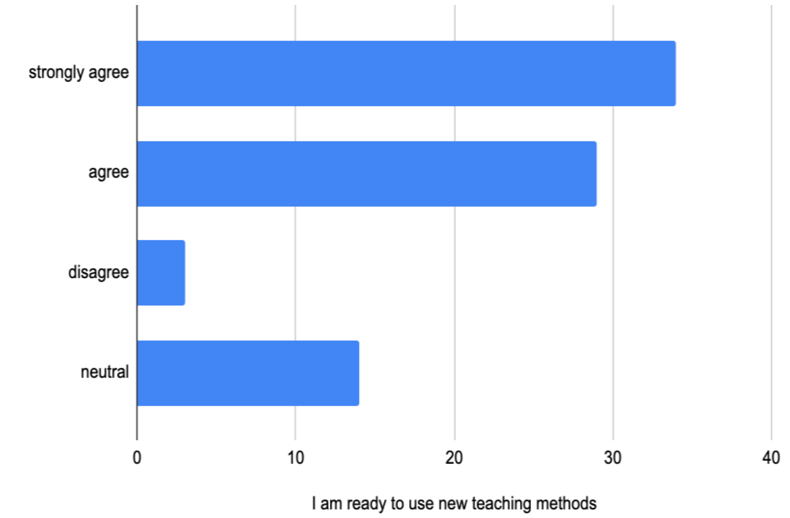


Figure 18. *Teachers' openness to adopt new teaching methodologies.*

Figure 19 reveals that the participants in the survey state that they are willing to enhance their knowledge in STEAM education. This complies with the conclusions drawn from previous statements of the questionnaire which indicate a need for further training.

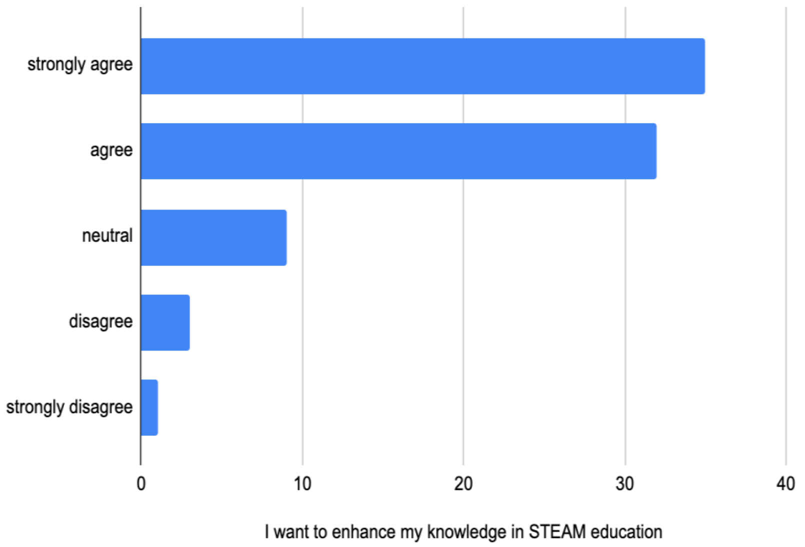


Figure 19. *Teachers' will to enhance their knowledge in STEAM education*

The last three statements of the questionnaire intended to further examine qualitative aspects of the teachers' readiness to implement STEAM education. Figure 20 shows that about 6/10 of the respondents feel comfortable enough to set their own goals in STEAM education, indicating that they consider themselves able to design educational activities of this kind. The number is slightly higher than that in the statements about their readiness to implement STEAM Education (see the previous 4 questions). This indicates that they feel more confident when facing a challenge of educational design and this could be further enhanced through proper training which would address all the misconceptions.

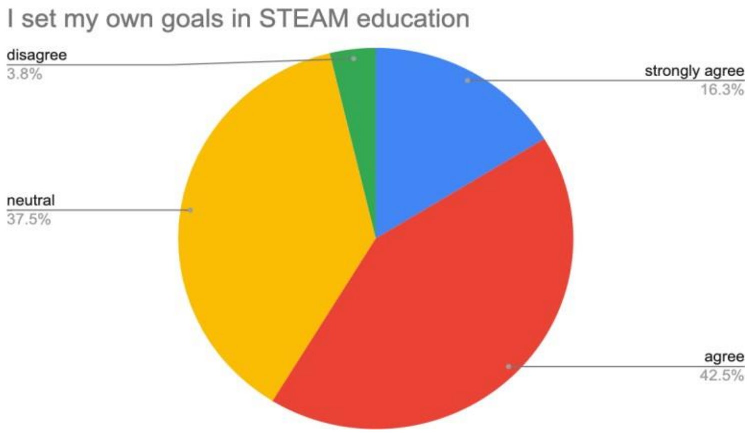


Figure 20. *Teachers' ability on goal setting in STEAM education.*

Furthermore, regarding educational design itself the majority of the teachers agree with the statement that in their teaching they adapt their methods to meet the needs of their students (Figure 21). Considering that the STEAM approach is by nature a student-centered one, this statement is important as it reveals that teachers are aware of the need to design approaches in that manner overall and additionally they claim that they act likewise already.

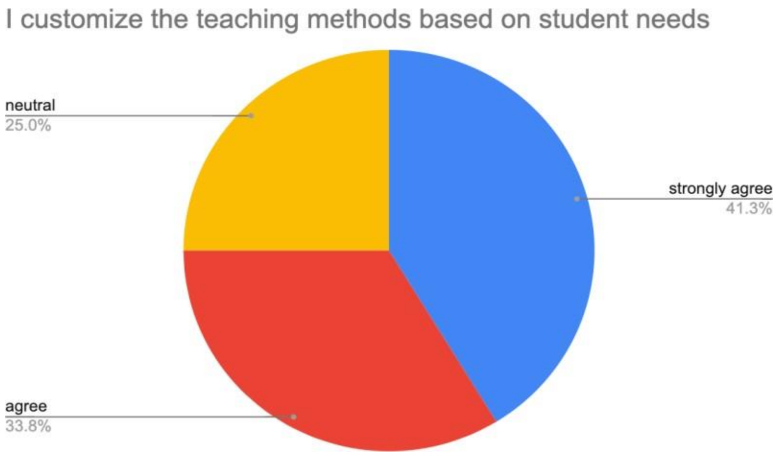


Figure 21. *Teachers' adaptation to students' needs.*

Regarding the technicalities of implementing STEAM Education, the last statement was "I need to have special equipment to implement a STEAM activity in my classroom". The goal was to examine the teachers' perspective on the matter, as there are many examples of unplugged activities in the literature and activities which utilize common material, easily accessible or already available in a common classroom. More than half of the respondents (Figure 22) consider that special equipment is needed. A significant portion (37.5%) grade the statement neutrally, revealing an uncertainty in their grading. It is interesting that this is the only statement in this section of the questionnaire in which “disagree” and “strongly disagree” were selected. The answers reveal that still teachers do not have a clear view on how to implement STEAM education.

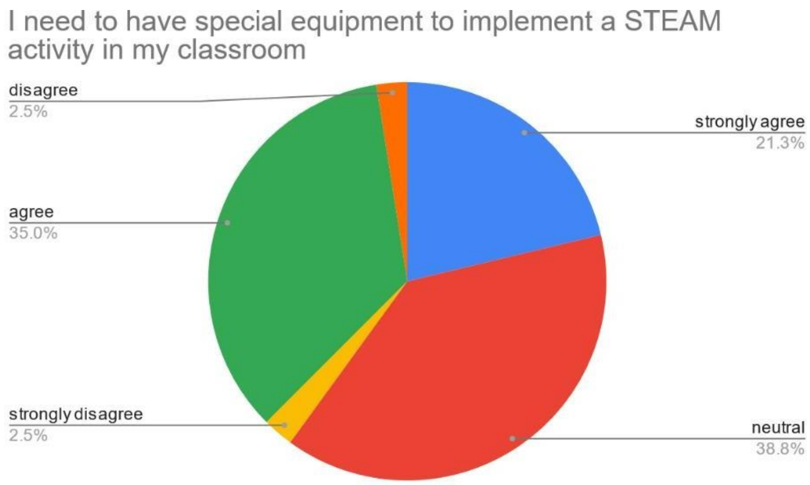


Figure 22. *Teachers’ perception STEAM impact on education overall.*

Conclusions

The participants of the survey constituted a representative sample of the teaching community in the partner countries. A concrete conclusion is that teachers still lack a good understanding of what characterizes a complete STEAM activity. The misconceptions identified in the literature still seem to be evidently present. Thus, in any kind of training approach for teachers one should start with the fundamentals and the basic terminology.

Teachers were not able to clearly identify if a proposed activity is a STEAM activity or not. On the other hand they all agree that STEAM education should be implemented from the early years. They are confident regarding their educational design skills and think that non-specialized teachers should be the ones implementing STEAM education in early years. They are willing to further receive training and improve their skills, but still they hold several misconceptions. For example they mainly think that special equipment is require for implementing STEAM education.

All these issues should be carefully considered when designing a training programme for supporting teachers implement STEAM education in the early years.

STEAM FRAMEWORK FOR EARLY CHILDHOOD EDUCATION

Desk research

As a final step towards the design of the STEAM Framework for the needs of the SEGA project, a desk research was conducted by the partners in order to identify STE(A)M programmes which are offered to educators and/or children, in order to examine the types of activities integrated in them. Additionally, of interest was the equipment usually suggested within such programs and their applicability in educational settings.

Overall the partnership identified6 STEAM programs as a representative sample:

Academi@ STEM Mangualde (Portugal) offers both workshops for students and professional development workshops for teachers. Their workshops span from Pre-School to 7th grade and they focus on the cultivation of competences as sets of knowledge, skills and attitudes. The integrated activities treat all STEM areas, including the engineering design process and problem solving via inquiry and research. The sessions start from the theoretical basics and end up with assessment methods.

KUBO - Programming Initiation Solution (Portugal) is a program mainly focusing on Computational Thinking which is a neighboring disciplinary area with STEAM and Mathematics. The program utilizes the KUBO robot and treats the 21st century skills (4C model), incorporating the engineering design process.

Artist Residencies in STEAM (Portugal) which pays particular attention to the A (art) in STEAM by bringing together artists, teachers and students in custom designed projects. It is addressed to slightly higher ages (10-15 years old).

Young engineers (Greece) is a program offered by a private company to elementary school children, based on the Kids First Coding robot and a Simple machines robotic kit. The program focuses on programming, but also on collaboration and reflection on realistic problems

Lilliputian Scientists (Greece) is another program offered by a private company to preschool children. The program describes activities related to constuction and activities related to science experiments. Through robotic kits, it focuses more on Science concepts

Bee Adventurers (Greece) is another program offered by a private company to preschool children. The goal is to connect Science with algorithmic thinking. It utilizes the Beebot device and it indirectly contextualizes the activities with the STEAM approach

Overall, regarding programs offered to young children it is very common to make use of some kind of robotic devices. This seems to make the programs more attractive and motivating, but on the other hand shifts more focus on programming. All programs claim to treat Science concepts and representations of real-life problems which are examined through the engineering design process.

Conclusions

The SEGA project aims to enhance STEAM education for young children through gaming. In order to achieve this goal, the initial step was to create a Framework for the key competencies regarding STEAM Education in early years, taking into account the teachers, as their role is more enhanced when addressing these age groups. For this reason, the SEGA consortium implemented a trifold research approach including: a literature review, a survey and a desk research.

The literature review revealed that there is not much work done for the age group that the SEGA project is targeting. Regarding the identified resources, mainly the following elements and/or competencies are highlighted:

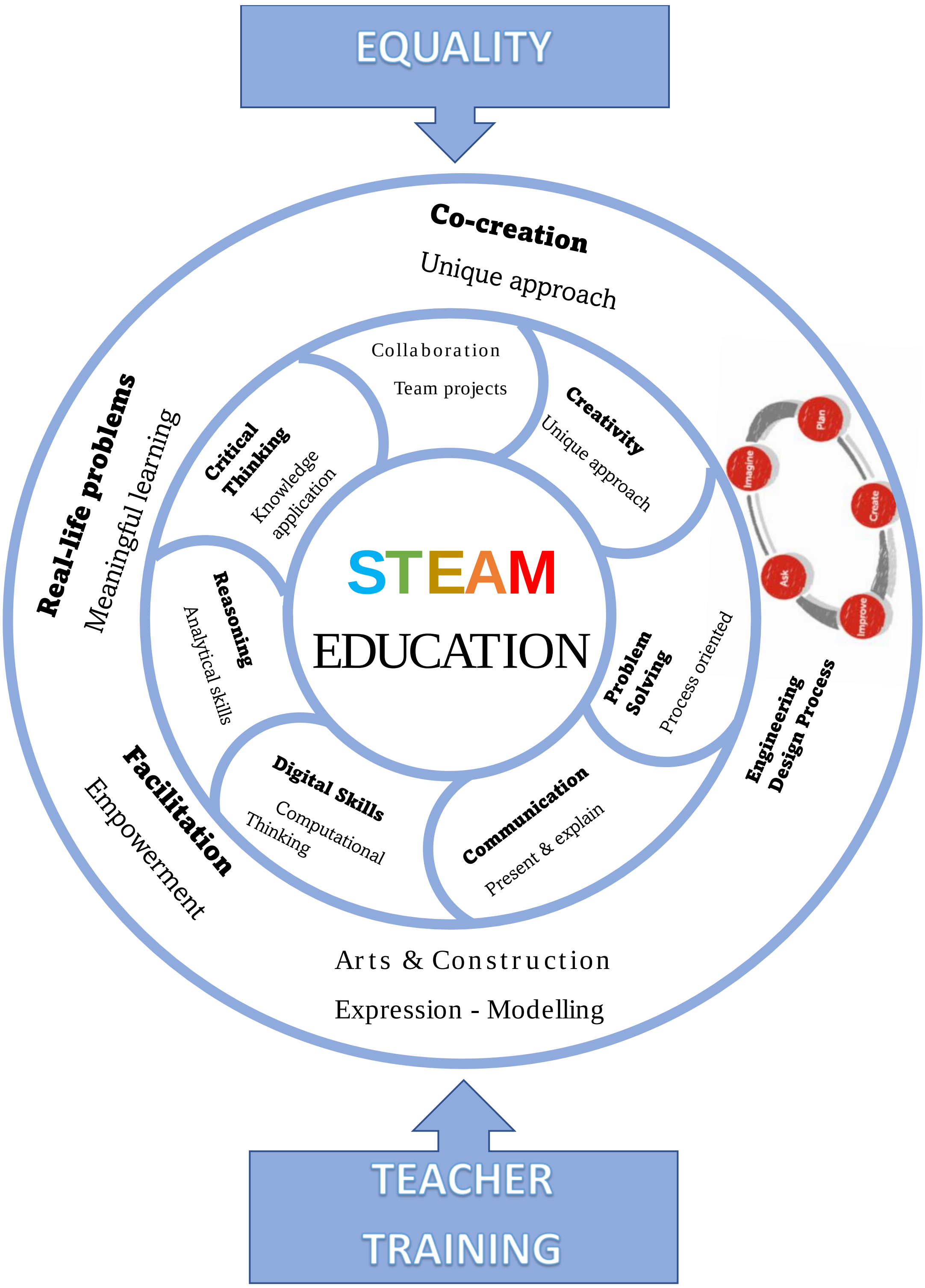
- 21st century skills (Communication, Collaboration, Critical Thinking, Creativity)
- Problem solving
- Real-life problems
- Engineering design
- Logical-mathematical skills
- Spatial skills

The survey was addressed to teachers. It reveals that teachers generally recognize the significance of STEAM education in the early years and value its contribution to a child's development. On the other hand, examining their readiness to support children when implementing STEAM education, several issues emerged. They are confident about their educational design skills, but seem to not fully grasp what STEAM is. The misconceptions described in the literature were verified through the survey. Thus, the framework should consider them.

Lastly, the desk research revealed that engineering design for solving problems is a core constituent of training programs for children. More programs are available and some are offered to teachers, having a similar structure. Also, many of them incorporate various robotic kits, possibly enhancing the perception that special equipment is usually needed to implement STEAM education. Thus, it is also important to highlight the significance of unplugged activities which utilize common material.

Considering all the aforementioned issues, the following framework is proposed, considering also the Engineering Design Model proposed by

STEAM FRAMEWORK FOR EARLY CHILDHOOD EDUCATION



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