Examining the use of STEAM Education in Preschool Education

Constantina Spyropoulou, Manolis Wallace, Costas Vassilakis and Vassilis Poulopoulos

***Abstract*— STEAM (Science, Technology, Engineering, Arts and Mathematics) initiatives are of current interest for both in-school and out-of-school contexts in North America. This is a new concept which is shifting educational paradigms towards art integration in STEM subjects. This article focuses on the need for STEAM education at the early childhood level and investigates the teaching and educational models of STEAM education in the kindergarten and in the first grades of primary school and how pre-school and primary school teachers see these models in the Greek context but also what students eventually learn from these models. The purpose of this chapter is to better understand the educational programs of STEAM education, which are offered by non-profit organizations and both public and private schools. Preschool children have a natural disposition toward science with their sense of curiosity and creativity. More research needs to be done in the area of STEAM implementation in the K-8 classrooms to incorporate engineering education.**

***Index Terms*— Early science education, Greek STEAM implementation, K-8 STEAM, STEM/STEAM education, STEAM educational models.**

I. Introduction

It is important to consider whether or not current STEM educational practices are sufficient in preparing students for the world in which they live and work. This prompts discussions about STEAM (Science, Technology, Engineering, Arts and Mathematics), which Yakman and Lee [41] maintained was a considerably new concept at the time and was shifting educational paradigms towards art integration in STEM subjects.

The recent years there has been a tendency to integrate the Arts into STEM education and finally make it STEAM. STEAM is important because it helps teachers incorporate multiple disciplines at the same time and promotes learning experiences that allow children to explore, question, research, discover, and exercise innovative building skills [9]. One of STEAM education's main goals is to provide students with an authentic learning experience which includes tasks with a real-world context, ill- defined problems, complex or multistep questions, multiple ways to approach a problem, integrate across the disciplines and have failure and iterations built into the assignment itself.

Adding the Arts provides more options for the teachers to present STEM concepts to children, especially at the elementary and early childhood levels. Research has shown that providing meaningful hands-on STEAM experiences for early childhood and elementary age children positively impacts their perceptions and dispositions towards STEAM [3], [6] (DeJarnette, 2012).

STEAM concepts are not too difficult for preschoolers (Kropp, 2014) who are persistent and determined when building designs. The preschool age is a great age in which to introduce science literacy (Koester, 2013). Early learning librarians can utilize children's literature to design STEAM activities in the library and begin building a foundation for STEM concepts (Kropp, 2014) [33]. There are many benefits for young children from early exposure to STEAM. Integrated and exciting learning experiences improve students' interests and learning in STEM and helps prepare them for the 21st Century. However, little research exists regarding the impact of STEAM initiatives at the early childhood level [30].

When faced with this new emphasis on STEAM education in the primary grades, teachers are often intimidated, lack self-efficacy, and reveal negative dispositions as a result of their lack of training [23]. When they feel inadequate with certain content areas, they tend to spend less time teaching that particular content with their students. Nugent et al. [35] research revealed that teachers significantly increased their knowledge of engineering and developed more positive attitudes towards STEM, increasing their self-efficacy and confidence in teaching STEM lessons, after receiving effective professional development. This lack of STEM or STEAM training for elementary and early childhood teachers brings new urgency for quality professional development in light of the newly released Next Generation Science Standards (NGSS) [34], which emphasize K-12 engineering and technology education.

The objective of this article is to examine the current state of the art regarding the use of STEAM in pre-school education and to point out that cohesive STEAM lessons within the curriculum will provide a positive impact on students' achievement with students on the preschool level. When children are introduced to STEAM at an earlier age, there tends to be less gender-based stereotypes and fewer obstacles regarding STEAM. In addition, this article notes that there is a lack of STEAM training for elementary and early childhood teachers which brings new urgency for quality professional development.

Published on December 19, 2020.
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II. State Of The Art

According to the OECD (Organisation for Economic Co-operation and Development) there is a common need in Europe to produce higher student achievements in basic maths, science and literacy skills and although this situation is particularly problematic in some countries such as Greece, there is still significant under performance, particularly in maths skills in all OECD countries (Stefan Haesen, Erwin Van de Put, 2018, copyright by EuroSTEAM). If a country wants to support growing technological innovation, then it is important to increase the amount of positive exposures and experiences to STEM fields for K-8 students [2].

The STEM to STEAM movement grew out of educators 'dissatisfaction with students 'lack of success academically and their inability to make meaningful connections to the material [41]. According to the Council of Canadian Academies [11], "STEM skills are necessary, but they are not sufficient on their own, other skills such as leadership, creativity, adaptability, and entrepreneurial ability may be required to maximize the impact of STEM skills". Many scholars have found that some of these skills can be obtained by integrating the arts with STEM. Proponents of STEAM suggest that integrating the arts with STEM "bring new energy and language to the table" and can encourage student's curiosity, experimentation and discovery of the unknown through creative and innovative solutions [8]. Taylor [39] explains that STEAM "is not just another curriculum fad but an important response to the pressing need to prepare young people with higher- order abilities to deal positively and productively with 21st century global challenges that are impacting the economy, the natural environment and our diverse cultural heritage".

Nations would like their students to be able to compete globally and be able to create innovative solutions to current global issues [29]. Countries, such as Canada and Australia, see the benefits in STEAM education, recognizing that the "design and creativity of the arts are crucial underpinnings of the successful mathematician, scientist and engineer" [19], as well as an essential component of student engagement and motivation. The United States and Korea want to increase student interest, engagement, motivation, and value in STEM education through STEAM education [24], [38]. The overall goal is the same: to train students to be world leaders in science and technology by fostering an interest and deeper understanding through the integration of arts, "experiential and inquiry-based approaches" [38] to develop creativity, innovation, critical-thinking and problem- solving skills [24], [26].

STEAM practices can be described as "thinking through the materials", which helps students have a deeper understanding of the material and make connections between the other disciplines (Guyotte, Sochacka, Constantino, Walther & Kellam, 2014). According to Dobson and Burke (2013), "a balance of critical thinking, analytical skills and creativity is key for innovation. STEM, arts and humanities can be integrated to engage students in pursuing a balanced education —an education that will create more employment opportunities and

options in the future". STEAM education can also encourage "effective communication and collaboration that is more student-centric," these skills are needed in both post-secondary education and the workforce (Connor, Karmokar & Whittington, 2015; [19]. STEAM has the potential to provide all students with academic success and a more meaningful learning experience by solving a problem creatively or connecting it to a real-world context [26]. Harris and de Bruin [17] maintain that, as educators, we want to meet the child's individual needs by building their self-confidence, self-esteem and creating a safe learning environment for them to make mistakes and excel, which is a major component of STEAM education.

The literature lacks research on STEAM education in Greece. The STEAM movement in Greece is very recent and has occurred over the last seven years. Review of existing studies and exploratory research needs to be done on STEAM-based institutions or programs in a Greek context. This is to better understand the curriculum and instruction models, student learning and assessment of STEAM in a Greek context.

A. Art integration in STEM

In the literature there are several areas of teaching STEAM, ranging from schools [5]; Drake & Reid, 2010; Wynn & Harris, 2012; [16], [19] ; Mote, Strelecki & Johnson, 2014), community agencies [7], [12], [18], [22] to university initiatives [29], [16], faculties of education [10], museums, other organizations [7], such as non- profit laboratories or centers and collaborations among these partners [7]. STEAM education is being implemented at every level of education, through art integration in STEM, designed-based, project-based learning and problem solving. There are multiple instructional models in the literature for implementing STEAM education.

School-Based STEAM models: The STEAM approach varying from school to school some fully integrate the arts into STEM subjects; others develop and implement a STEAM curriculum (STEAM schools and STEAM-related classes, and STEAM programs in an in-school or out-of-school context); others create "makerspaces" where students go to work on STEAM projects; some host STEAM workshops and others have STEAM competitions or challenges [19]; littleBits Education, n.d.).

Higher Education STEAM Models: Madden et al., [29] and Ghanbari [16] report on higher education STEAM models. Industry leaders, such as Lockheed Martin, are calling for, as well as rallying behind, the STEM/STEAM movement with the objective of supporting students to be creative, innovative, collaborative, and "approach problems both divergently and convergently" [29]. In response to this call from industry, certain colleges and universities are beginning to integrate the arts with STEM subjects at the post-secondary level with multidisciplinary programs and integrated courses [29].

Community-Based STEAM Models: Aside from approaching STEAM education from a higher education, secondary or elementary point of view, some STEAM initiatives focus more on a community approach to learning by creating partnerships with museums and other organizations. Clark and Button [7] studied a higher education STEAM initiative, the Sustainability Transdisciplinary Education project. In the Sustainability Transdisciplinary Education project, students, museum personnel (from, New Britain Museum of American Art, NBMAA), several other non-governmental organizations personnel, state and federal elected officials, and community members were involved [7]. The main goal of this project was for K-12 students, university students and the community to have a shared learning experience [7].

Faculties of Education STEAM Initiatives: The study presented in [10], conducted in Spain, focused on how STEAM facilitated pre-service teachers integrate mathematics and art into the curriculum. The researchers partnered with the Columbus Museum of Art to integrate the "learning-thinking model to observe, describe, interpret, and prove (ODIP)" [10]. ODIP was used as a pedagogical tool to promote the Standards for Mathematical Practice.

After School STEAM Programs by Non-Profit Community Organizations: Besides STEAM schools, there are many after-school programs and non-profit organizations that promote STEAM education. DiMaggio & Anheier [12] observed that non-profit organizations in the education sector are "more conducive than for-profit because they empower professionals with access to private donors or funding agencies," and they have more creative autonomy.

STEAM Education and Makerspaces in Canada: Canada has taken a vested interest in STEAM and its potential benefits. Elizabeth Buckley School, located in Victoria, BC, claims to be the first STEAM school in Canada which is incorporating STEAM and the arts into everyday living [13]. Similarly, Ian Brodie, an elementary school teacher affiliated with both Western University and York University, taught mathematical concepts through music, dance, drama and visual arts in his classroom and at the Math Performance Festival at Western University [5]. Several school boards in Ontario have created makerspaces in the school library and other spaces such as the Library Learning Commons to provide a learning space that facilitates STEM and STEAM initiatives [32].

B. Collaboration and Capacity Building in Schools

Fullan [14] affirms that teachers in schools are important change agents when it comes to reform and integrating new approaches to teaching and learning. Directors, instructors, museum staff, university and government partners are in charge of the STEAM programs in the community settings. According to Allina [1], a productive STEAM education program includes a co-teaching models, co-planning with other teachers, and collaborations with local artists, scientists, non-profit organizations and other experts. Collaboration and capacity building are an integral part of STEAM programs 'growth and sustainability.

Collaboration and capacity building can "grow out of common interests and commitment" to student learning [20]. Such a Professional Learning Community (PLC), nurtures "positive school culture", encourages "a group of teachers sharing and critically interrogating their practice in an ongoing, reflective, collaborative, inclusive, learning-oriented, growth promoting way" thus empowering teachers [20]. The same can be said about instructors in community after-school programs for children and teens, in which the instructors can be agents of change for the learning and interactions of the students in these out-of- school contexts. Directors, instructors, museum staff, university and government partners are in charge of the STEAM programs in the community settings.

C. Components of a Productive Pedagogy in STEAM

The number of students participating in after-school programs has significantly increased in recent years. This means that it is important to consider what components contribute to the productivity of a STEAM program whether it is offered during the regular school day or as an after-school or out-of-school program. When speaking of after-school programs, Huang and Dietel [22] note that an effective STEAM program has the following five components:

1) specific program goals and objectives,
2) experienced leadership,
3) highly qualified or trained staff members,
4) a program that aligns with the school curriculum, and
5) some sort of program assessment or evaluation.

The type of projects made at the STEAM program is also a key component and can affect the students 'learning experience. All of these components in a well-structured in-school, after-school, or out-of-school program work together to create a conducive learning environment that promotes several learning skills, such as the development of 21st century skills, which develop high order thinking skills, such as critical thinking, communication, innovation, creativity, and collaboration.

D. Curriculum Models and the Transdisciplinary Approach

STEAM is not only interdisciplinary but can be described as transdisciplinary because it "goes beyond, or transcends, the boundaries of particular discipline" (Costantino, 2018; [19], [25].

In a transdisciplinary space, students are able to transfer their knowledge across a discipline and solve creative problems in another context, both in the classroom and out of school [15], [27]. STEAM teaches students skills, such as "critical thinking and problem solving; collaboration and communication; and creativity and innovation" that can be transferred to another context [28].

E. Assessment in STEAM

Assessment and documentation are important in STEAM education to observe, record, interpret and share the learning experience (Krechevsky et al., 2010). The Ontario Ministry of Education [36], [37] suggest three stages for pedagogical documentation:

1) first of all, observing and recording student experiences;
2) secondly, interpreting the learning in the service of pedagogy;
3) finally, responding, sharing and building a culture of inquiry and collaboration [32].

According to Harste (2001) "learning does not end with presentation (product) but rather with reflection, reflexivity, and action".

F. Rationale for an Integrative Curriculum

Research suggests several enablers and constraints of an integrative curriculum. Although the planning of an integrative curriculum may require more time and preparation by teachers and school leaders —proponents of STEAM and

STEM argue— the benefits, outweigh the costs. A major component of the arts and integrative curriculum is inquiry based because students are given the opportunity to question and use critical-thinking skills to approach a problem that has multiple solutions [16].

The integration of the arts promotes communication and critical-thinking skills, and helps students to develop a global perspective [10]. Bequette and Bequette [5] caution educators that STEAM as an integrative curriculum may "weaken each discipline and confuse the boundaries between different approaches", so it is necessary that teachers get proper training prior to and during implementation.

G. Next Generation Science Standards (NGSS)

In the spring of 2013, the Next Generation Science Standards (NGSS) were officially released in the United States. States across the nation have slowly been adopting the new standards. Currently in mid-2018, 19 states and the District of Columbia have adopted the standards and have implementation schedules. These standards were developed by 26 lead state partners (Next Generation Science, 2016). The NGSS emphasize scientific inquiry, engineering design, and require K-12 students to have the ability to link broad concepts across scientific fields. The inclusion of K-12 engineering education will bring challenges and anxiety to many teachers who have not been adequately trained on this specific content and skill set, especially at elementary and early childhood levels.

With the adoption of the NGSS by the states, there is a realization that adequate professional development will be required for teachers before they can fully implement the new standards, resulting in slow adoption rates as well as implementation schedules (Next Generation Science, 2016). The inclusion of K-12 engineering education reveals that science educators at the highest levels are in agreement that STEM concepts are not only

appropriate for early childhood, but that young children are also capable of completing simple engineering design challenges and experience success with STEM skills [31].

III. Why should young children learn STEAM subjects?

STEAM become a hot topic in the world of education and in the business community, but what does STEAM have to do with the preschooler? What does STEAM mean and why is it important to plan STEAM activities for preschool?

Children have the ability to learn foundational concepts in these subjects at a young age. Preschools and other childcare providers should nurture STEAM skills and concepts early on the build on them through ongoing opportunities for play and discussion. The skills children learn when engaging with STEAM concepts in preschool are transferable and useful across many aspects of their lives. For example, process skills, which include making observations, hypothesizing and critical thinking, are basic skills for math and science but are also valuable skills for learning any subject. In some ways it is hard to imagine what career options children might have as adults. For early education providers, part of their responsibility to children is preparing them for the realities they'll face later in life.

STEAM activities encourage important learning characteristics and qualities for preschoolers.

- Science requires preschoolers to not only answer but also to ask questions. Science powers curiosity, investigation, and problem solving, often involving experimentation and exploration.
- Technology refers to applying the scientific knowledge a preschooler gains. They do this by using the most basic tools like crayons and rulers, as well as more complex technological inventions like microscopes and computers.
- Engineering activities in preschool are concerned with the design and building. It is testing structures and designs, as well as discovering and testing possible solutions.
- Art encourages creativity and process development, as well as allows children to illustrate concepts they are learning.
- Mathematics isn't limited to just number sense for preschoolers. It also includes the ability to see and create patterns, shapes, as well as organizational skills like graphing and sorting.

IV. Discussion, recommendations and conclusion

The integration of the arts into the STEM subjects needs to be both purposeful and seamless to effectively engage students [5], [40]. Liao [27] suggests that "integrated STEAM education should be focused on transformative learning experiences whereby STEAM subjects are presented together" and "STEAM should create a transdisciplinary space that cannot be defined in reference to any traditional sense of discrete disciplines". For students to transfer their knowledge from one context to another, the learning must go beyond the individual disciplines and seamlessly integrate STEAM [27].

Of course, despite the progress reported in the previous section, a number of questions remain.

What will the result of providing professional development in STEAM (Science, Technology, Engineering, Arts and Math) initiatives in high-needs schools have on the dispositions of early childhood teachers toward STEM as they implement?

What will the result of providing professional development in STEAM in high needs schools have on the self-efficacy of early childhood teachers as they implement?

What will the result of providing professional development in STEAM initiatives in high needs schools have on the rate of implementation of STEAM pedagogy in the early childhood classroom?

Which instructional and educational models are implemented in non-profit educational organizations and in the school context, in the Peloponnese, Greece?

What do students learn from different STEAM educational models?

What kind of assessment is done to students in a STEAM program?

All of these are directions in which further research is required. Still, based on what is already known, the following components can be rather safely identified and recommended as central and important:

- Specific program goals and objectives (inputs)
- Experienced leadership

- Highly qualified or trained staff members with professional development opportunities
- Academic alignment and achievement
- Forms of assessment or evaluation for measuring outcomes
- Articulated measures for program sustainability and growth

Based on these, we expect to see, in the near future, STEAM integrated more in pre-school education and achieving even greater impact on its students and, by extension, on the future of our society in general.

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