UNIVERSITY OF THESSALY

SCHOOL OF ENGINEERING

DEPARTMENT OF ELECTRICAL AND COMPUTER ENGINEERING

EDUCATIONAL ROBOTICS WITH STEAM APPLICATIONS FOR CHILDREN AND ADULTS

Diploma Thesis

Koukosia Evangelia

Supervisor: Tsalapata Hariklia

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ΠΑΝΕΠΙΣΤΗΜΙΟ ΘΕΣΣΑΛΙΑΣ

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Approved by the Examination Committee:

Supervisor **Tsalapata Hariklia**
Laboratory Teaching Staff, Department of Electrical and Computer Engineering, University of Thessaly

Member **Stamoulis Georgios**
Professor, Department of Electrical and Computer Engineering, University of Thessaly

Member **Daskalopoulou Aspasia**
Assistant Professor, Department of Electrical and Computer Engineering, University of Thessaly

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ABSTRACT

Educational Robotics (ER) is without a doubt a great learning tool. In recent years, as part of its development and expansion, both worldwide and in Greece, STEM concepts (Science, Technology, Engineering, and Mathematics) are beginning to be incorporated into its teaching. In addition to its contribution to the development of skills required for the digital age of the 21st century, ways and good practices that have been implemented and/or can be implemented in the future are analyzed so that educational robotics can become for both children and adults an accessible form of learning new technologies without social, economic or any other form of restrictions. In this paper, an introduction is also made to STEM concepts and how they can find application, despite the existence of several obstacles, in modern basic education of citizens, utilizing appropriate teaching methods. Particular emphasis is also placed on the introduction of art within STEM education and on the approach of a more integrated STEAM educational program (Science, Technology, Engineering, Arts, and Mathematics) that could be an incentive, without excluding older or low technological experienced people, to engage creatively with programming. Finally, the implementation of a photography project with the use of raspberry pi and the python programming language is chosen as a simple example that aims to encourage children and adults to come one step closer to robotics and STEAM concepts.

Keywords: Educational robotics, STEAM education, lifelong learning, 21st century skills, teaching methods, computational thinking, raspberry pi

ΠΕΡΙΛΗΨΗ

Η εκπαιδευτική ρομποτική αποτελεί αναμφισβήτητα ένα σπουδαίο εργαλείο μάθησης. Τα τελευταία χρόνια, στα πλαίσια ανάπτυξης και εξάπλωσης της, τόσο παγκοσμίως όσο και στην Ελλάδα, αρχίζουν να ενσωματώνονται στην διδασκαλία της οι έννοιες STEM (Science, Technology, Engineering, Mathematics). Εκτός απ' τη συμβολή της στην ανάπτυξη δεξιοτήτων απαραίτητων για την ψηφιακή εποχή του 21^{ου} αιώνα, αναλύονται τρόποι και καλές πρακτικές που έχουν εφαρμοστεί ή/και μπορούν να εφαρμοστούν στο μέλλον ώστε η εκπαιδευτική ρομποτική να αποτελέσει τόσο για τα παιδιά όσο και για τους ενήλικες μια προσιτή μορφή μάθησης των νέων τεχνολογιών χωρίς κοινωνικούς, οικονομικούς ή κάθε άλλης μορφής περιορισμούς. Στην παρούσα εργασία γίνεται επίσης μια εισαγωγή στις έννοιες STEM και πως μπορούν να βρουν εφαρμογή , παρά την ύπαρξη αρκετών εμποδίων, στη σύγχρονη βασική εκπαίδευση των πολιτών, αξιοποιώντας κατάλληλες διδακτικές μεθόδους. Ιδιαίτερη έμφαση δίνεται ακόμη στην εισαγωγή της τέχνης στα πλαίσια της εκπαίδευσης STEM και στην προσέγγιση ενός πιο ολοκληρωμένου εκπαιδευτικού προγράμματος STEAM (Science, Technology, Engineering, Arts, Mathematics) που θα μπορούσε να αποτελέσει κίνητρο, χωρίς να αποκλείει άτομα μεγαλύτερης ηλικίας ή χαμηλής τεχνολογικής εμπειρίας, να ασχοληθούν δημιουργικά με τον προγραμματισμό. Τέλος, επιλέγεται η υλοποίηση ενός project φωτογραφίας με τη χρήση του raspberry pi και της γλώσσας προγραμματισμού python , ως ένα απλό παράδειγμα που έχει ως σκοπό να παροτρύνει παιδιά και ενήλικες να έρθουν ένα βήμα πιο κοντά στη ρομποτική και τις έννοιες STEAM.

Λέξεις – κλειδιά: Εκπαιδευτική ρομποτική, εκπαίδευση STEAM, δια βίου μάθηση, δεξιότητες του 21ου αιώνα, διδακτικές μέθοδοι, υπολογιστικοί μέθοδοι, raspberry pi

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CHAPTER 1

INTRODUCTION

1.1 Introduction

The first steps in Educational Robotics (ER) started in the 1960s with the work of Seymour Papert who later developed the Logo programming language (Papert 1980). Papert expanded Piaget's ideas on constructivism by promoting the view that learning is more effective when students become active by building specific meaningful objects. Later on, Papert's ideas were the base of the first commercial robots that entered the classrooms like those developed by Lego and MIT Media Lab. Having the foundations in the sociocultural Vygotsky's theories along with Papert's constructionism and Piaget, educational robotics aims to develop high-level intellectual skills and knowledge through problem solving, discovery and collaboration (Blanchard, Freiman and Lirrete-Pitre 2010). Over the last decade, educational robotics has attracted the interest of teachers and researchers as a learning tool that supports the development of students' cognitive and social skills (Alimisis 2013). Educational robotics appears to be a practical learning tool that enables students to express their ideas and imagination by developing simple or advanced mechanisms and robotic entities. Especially, the connection of educational robotics with play and enjoyment is considered to be an important factor that encourages children and enables intrinsic motivation especially in primary education (Ryan and Deci 2000; Sapounidis and Demetriadis 2013). Educational robotics activities focus on the research and analysis of a simple or complex real-world problem that gives students the opportunity to directly observe the results of their solution and effort. This appears to promote creativity and problem-based learning by combining abstract design ideas, into one construction (Druin and Hendler 2000). Thus, students go from the "learn about technology" to the "learning with technology" (Carbonaro, Rex and Chambers 2004). Educational robotics is considered as cross-thematic and facilitates teaching mainly on STEM education (Alimisis 2013; Rogers and Portsmore 2004). In most cases, educational robotics mechanical constructions are combined with simple, physical tangible or graphical programming environments that enable users to transform their constructions to intelligent objects interacting with the environment and responding to external stimulations (e.g., Erwin, Cyr and Rogers 2000; Sapounidis and Demetriadis 2017; Sapounidis and Demetriadis 2009). However, according to Pedaste and Sarapuu (2006) the effectiveness of problem solving through discovery or research depends on the characteristics of the students and should be supported accordingly.

In recent years, robotics has been integrated into several curricula worldwide. In Greece, robotics has now been integrated into many schools as a group of activities. At the same time, it is indicative that every year a significant number of robotics activities (seminars, competitions, coding camps, workshops, european/ international programs) are organized all over the Greece, in which students of all ages take part. In addition, most research on educational robotics has focused mainly on its contribution to the IT, (information and technology sectors). It is important to study the contribution of educational robotics to the involvement of students with concepts of more fields of STEAM but also its effect on students' interest in STEAM sciences and professions. STEM education is an interdisciplinary approach to learning, where strict concepts are combined in real-world lessons and problems so as students to apply STEM to the school environment and beyond, (McComas, 2014). In addition, STEM training aims at literacy, which is a dynamic process that changes over time and aims at the transition from STEM training to the ability to use the knowledge acquired in an ongoing learning process (Zollman, 2012).

The interdisciplinary nature of STEM education focuses on the multifaceted exploration of a subject that includes, in addition to knowledge from different disciplines, the connection of these disciplines. Through STEM education, this interconnection of sciences is strengthened, with the ultimate goal of connecting knowledge with the student's daily life at school as well as outside it. In addition, students are actively involved in group activities, where they develop collaborative skills, utilizing their pre-existing knowledge and experiences. Studies have demonstrated that educational robotics activities have increased student interest in STEM (Eguchi, 2016). Since robotics is an inherently collaborative activity, such opportunities can provide a greater motivation in further exploring STEM fields of study (Gura, 2011).

1.2 Bibliography Review

The literature review was carried out in two stages. Initially, a review of scientific articles and books was conducted to study the subjects of educational robotics, STEAM and how adults can engage with them. Regarding the use of robotics as a learning tool were investigated, while the introduction of STEAM concept as a pedagogical term, the definition of the concept and its pedagogical development were studied. This first investigation was conducted in order to establish a well-structured theoretical background, which will be the basis for the research process.

In the second stage, all the research that has been carried out and related to the application of robotics in educational practice as well as its connection with STEAM objects was gathered. Bibliographic sources in this section were mostly articles published in conference proceedings and some articles in scientific journals. For the best possible documentation of the objects to be studied, some secondary sources were used, such as educational manuals, newspaper articles, scientific magazines and online sources. Research at this stage has led to the establishment of the framework of skills that can be developed through educational robotics, as well as the pedagogical consequences of its implementation in the classroom. Furthermore there was a specific research about using Raspberry pi as an educational tool and after some experiments with different projects there was an intention to present a photography project using raspberry pi as an example of introduction arts to active learning of technology tools for kids and adults. The bibliographic review as a whole, laid the solid foundations for the conduct of the research that followed.

CHAPTER 2

EDUCATIONAL ROBOTICS

2.1 Robotics as a learning tool

Robotics is a field of engineering science that has evolved rapidly over the years, to the point where it is now a self-evident part of basic human activities. In recent years, robotics has attracted the intense interest of both teachers and researchers, due to the many possibilities it can offer in the teaching and learning process. The introduction of robotics in education and especially in primary and secondary education became more possible, with the appearance on the market of robotic construction packages, which have low costs and are characterized by ease of operation (Frangou, 2009).

Educational robotics is considered a branch of educational technology (Mubin, Stevens, Shadih, Mahmud & Dong, 2013) and includes activities in which students assemble and program small robotic systems to perform specific behaviors of an educational nature (Stergiopoulou, Karatrantou & Panagiotakopoulos, 2017). The literature review presents educational robotics as a multifaceted tool, which can very effectively support the teaching of STEAM courses and bring positive learning outcomes. Stergiopoulou et al. (2017) believe that robots can be the "next step" in student education, while Karim et al. (2015) treat robots as the next innovative add-on to traditional education.

The literature on educational robotics is quite extensive, although the integration of robots in education is a relatively recent development. The strong interest of educators and researchers is based on the multiple benefits that robotics can offer in the classroom as a learning tool and on the supportive role that robotics can play in 21st-century skills acquisition and the teaching of STEAM concepts, two key requirements of modern educational reality. The applications of robotics in education as well as the benefits that arise through the teaching of robotics are varied.

The success of robotics as a learning tool lies in the fact that it shapes a learning environment in which students learn while having fun (Eguchi, 2013). Children have many stimuli in their daily lives related to robots either through the use of various technological devices and products or through games, movies and competitions. Most students react enthusiastically when building and programming robots (Afari & Khine, 2017). This is due to the originality of robots in a classroom, as well as the fact that the experiences they offer to students are tangible, helping learning become more accessible (Stergiopoulou et al., 2017).

Another aspect of robotics is the construction process. Students in robotics activities are asked not only to mechanically build the robot but also to program it, to "construct" the behavior it will have. The contact they have with innovative tools and the opportunity to build a product with their own hands (hands-on learning) is an important experience for students who becomes a helper of learning (Eguchi, 2014b). The active involvement of students in the design and construction of real objects, in which they give meaning more naturally, helps to build knowledge more effectively (Alimisis, 2008, Vounatsos, Mega & Stamatidou, 2009, Stergiopoulou et al, 2017) while offering an excellent framework for the development of creativity and critical thinking (Afari & Khine, 2017). Students are constantly studying the problem, planning the next moves they will make, handling tools and objects, reflecting and collaborating throughout the construction of a robotic system (Mikropoulos & Bellou, 2013).

An important skill at the core of educational robotics activities is problem-solving. Students during the design, assembly and programming of robots are constantly faced with problems, which are called to solve through interaction and collaboration with their team members (Sullivan, 2017). This process helps develop problem-solving skills, collaboration, creative thinking, reflection and critical thinking as children discover new ways to work together, encourage their co-workers and express themselves through technology. Problem-solving is included in the skills of the 21st century and is a key skill in how to study, research and apply in many fields of science (Eguchi, 2013). The activities of educational robotics lead students to deal with real-world problems, thus acquiring an authentic character and reducing the distance that often exists between the reality of the outside world and the object taught.

The playful nature of educational robotics in combination with the tangible learning experience it offers attracts students' interest and creates motivation for learning. Creating motivation and maintaining students' interest in engaging in a learning object has a high pedagogical value. Students through their involvement with robotics, approach technology intuitively, based on their existing cognitive structures and develop motivation for learning (Armakolas, Alimisis, Sapoundzaki & Mitroulia, 2010, Kyriakou & Fahantidis, 2012, Costa, Sousa, Cousa Morais, 2015), while motivation retention increases when students participate in robotics competitions (Kraetzschmar, 2009).

Another important feature of robotics is that it helps students gain a more in-depth understanding of technology, a fact that despite young children's familiarity with technological products, is not self-evident and should not be neglected, as it is a key skill of future job market candidates. Educational robotics brings students into contact with how technology works in everyday life (Eguchi, 2014). Through the experiences offered by educational robotics, they develop a more scientific way of thinking and approach the attitude and behavior of a researcher (Baras & Vassilopoulos, 2014).

Obviously the use of robotics in education can offer many positive elements and be a great tool in the hands of teachers. In summary, educational robotics as a learning tool:

- It is fun and attracts students' interest.
- Actively involves students in the learning process, helping to build knowledge more effectively.
- Creates authentic learning environments, educating students to solve problems that correspond to reality.
- Supports the development of important cognitive and intellectual skills
- Helps students to motivate and positively influence their attitudes towards learning.
- Supports the teaching of courses and concepts in the context of STEAM.
- It has a strong interdisciplinary character, covering a wide range of subjects.
- Suitable for all ages and levels of knowledge and familiarity with technology.
- Helps students gain a thorough picture of how technology works.

In conclusion, the integration of robotics in education seems to be very promising. The entire literature, as well as the bibliographic review that has been done in recent years on educational robotics, refers many of its successful applications in the context of education and especially about the subjects of mathematics, natural sciences and technology. Both researchers and educators are encouraged by the inclusion of robotics in school curricula while being cautious about the lack of official data on the influence of robotics, derived from valid and reliable measuring tools (Eguchi , 2008). Alimisis (2013) emphasizes the need to evaluate robotics and the influence it exerts on students through quantitative research, for its contribution as a learning tool to be scientifically established. According to Benitti (2011), the existing research on the application of robotics in education consists of descriptive research data conducted on the personal initiative of teachers and despite the benefits, they present are not enough to draw a commonly accepted conclusion about the effectiveness of robotics in learning. The critique that has arisen on this subject is supported by many researchers and its investigation is considered crucial, especially at the level where robotics is increasingly integrated into the structures of education.

2.2 The concept of educational robotics

The object of educational robotics is the development of applications in the preparation of children for technologies. Educational robotics is an innovative learning methodology that combines elements of basic sciences, new technologies and the study of human behavior. Jonassen played an important role in the development of educational robotics, providing the foundation as well as the theoretical infrastructure for the integration of robotics in university programs aimed at preparing teachers. More specifically, Jonassen in 1996 defined MindTools as computer applications that when used by their students engage in critical thinking. The integration of MindTools took place first in universities and then in schools using educational robotics packages along with appropriate programming environments.

The object of educational robotics is the programmable robot. According to Vernon (2006) having as a basic principle "I feel - think - act" the robot incorporates a microcomputer capable of fulfilling specific missions in an ever-changing environment. It can be used as an effective tool for the development of knowledge in children. The pedagogical utilization of the technological innovations of robotics consists in the design, construction, programming and improvement of electromechanical constructions within the educational process.

Robotics, machine learning, artificial intelligence (AI) and automation have been taught in higher education as part of the curriculum for several decades. However, their integration in education has become possible in recent years, due to the appearance of special construction kits of low cost and simple operation (construction kits). These packages include microprocessors, sensors, motors, and other machines, which with the help of building material can compose robotic constructions. They are usually accompanied by the appropriate software that allows them to plan their behavior.

According to Hadjichristodoulou (2011) the reasons that contributed to the integration of robotics in primary and secondary school children are the following:

1. The ability to process robotic systems has greatly increased, despite cost reductions, while the existence of many different sensors allows interaction with humans in a more natural way than in previous years.

2. The cost of a robotic system has been reduced to an extent that is affordable for everyone. Ready-made and programmable robotic packages are now available on the market. One of them is Lego Mindstorms, which is now used in more than 25,000 institutions worldwide, from municipalities to universities.

3. The need for children, young and old, to deal with the technology they see around them, led teachers to introduce robotic systems in their teaching as a means to stimulate the child's interest.

4. The development of new software tools, simpler and more accessible to the ordinary user, even to a small child, helped to introduce robotics in schools.

5. Many of the new robotic systems are now anthropomorphic. This allows, especially children, to become familiar with the robot and to accept the interaction with the robotic system and consequently learning through it.

6. Many international organizations, such as the European Union and UNESCO, encourage the integration of technology in education by even sponsoring related programs.

2.3 Educational robotics and STEM

STEM training incorporates a coherent learning model based on real applications and problems. Science is everywhere in the world around us (Benitti, 2012).Technology is constantly expanding in every aspect of modern life. Engineering governs basic road and bridge designs, but it also addresses the challenges of changing global weather and environmental change. Mathematics manifests itself in every activity of people's daily routine. The natural sciences study natural phenomena, and computer science in conjunction with mathematics defines the algorithmic way of thinking. Educational robotics can be applied to STEM scenarios based on which students will come into contact with "problems" of everyday life and will approach them interdisciplinary.

Educational robotics is gaining more and more the trust of teachers, while its presence in schools, to support the teaching of various subjects, is becoming more frequent. An important feature of robotics is that it can be an interdisciplinary learning tool offering opportunities to teach even cognitive subjects that do not belong to the category of "technical courses" (Karim et al., 2015) and is addressed to all types of learning groups (age, particularities, etc.).The educational restructuring that has begun in the last decade in America's education systems first, and then in Europe, is centered on the development of skills that will make students ready to meet the demands of the future. The main aim is to integrate STEAM philosophy and practices into school systems. The realization of this check is not a simple matter and is not simply transformed into the creation of an acronym by the theoretical union of the mentioned scientific fields. The transition to an educational reality, where the STEAM philosophy is applied and is essentially understood by students and teachers, requires preparation and appropriate training of teachers, the corresponding adaptation of the curricula and textbooks, the remodeling of the cognitive objects taught in the school institutions. Therefore, it is understood that the effort to change education in the direction of STEAM, requires a reasonable period of time, capable of preparing the ground for the transition to the new conditions of education. In this context, educational robotics is for many a great tool to support STEM learning, providing many opportunities to develop the desired skills.

As mentioned earlier, the design and construction of robots by students are processes that revolve around problem-solving. The development of problem-solving skills is also central to the STEM philosophy and with appropriate pedagogical support can be acquired by students through robotic activities (Kraetzschmar, 2009). Introduction of students to the philosophy of STEM should be done as early as possible, for students to become familiar with scientific concepts and to avoid creating stereotypes about the concepts of science (Bers, Seddighin & Sullivan, 2013). According to Benitti (2011), educational robotics helps increase academic success, offering learning experiences through which students experiment and interpret STEM concepts in their way, presenting significant results. Through experimentation, self-directed learning and personal interpretation, STEAM concepts are naturally introduced as students construct, control and define their robotic constructions. Educational robotics involves students in the learning process in ways that other teaching techniques cannot (Nugent, Barker, Toland, Grandgenett, Hampton & Adamchuk, 2009). Educational robotics can be used by the teacher to attract students' interest in teaching STEAM courses. In addition, through robotics students seem to better understand the concepts of STEM (Khanlari, 2013).

Educational robotics is a transformational tool for learning, computational thinking, coding and engineering, which are increasingly seen as critical components of STEAM learning in education. It can be used to conduct experiments and explore relationships in short-term teaching interventions. Examples are a robotic device that allows the study of linear smooth motion (Litinas, 2013) (time-displacement ratio, time-velocity ratio) or a robotic device that allows the temperature of a heated liquid to be measured. The proposed and best way of organizing teaching is the model of synthetic work, which allows the full utilization of the tools of educational robotics in the context of constructivism since it can accommodate the personal reflection of the students, lead to various experiments and be implemented through collaborative activities. Students build knowledge more effectively when they are actively involved in the design and construction of real objects that make sense to them, whether they are sandcastles or robotic constructions and computer programs.

Students are transformed from mere observers into active participants, thus developing a large number of mental skills as researchers and creators of new knowledge. Robotic packages utilize a black and white box technology that enables students to implement and extend their ideas, using ready-made building blocks (Williams, 2007). Thus, it becomes possible to arouse students' interest with remarkable learning outcomes. Robotics changes the traditional character of teaching as follows:

- Actively engages students in their learning by solving authentic problems.
- Supports exploratory learning and strengthens students' exploratory attitude.
- Motivates students to study science and technology.
- Allows free expression and the development of creativity and imagination.
- Through construction poses real problems and provides immediate feedback.
- Allows the acquisition of knowledge and skills related to many disciplines (and therefore the promotion of interdisciplinary approaches).
- Educational robotics provides mentors with opportunities to solve problems with personal meaning for themselves through the handling and construction of real or imaginary objects.
- Supports experiential learning.

The exploratory learning model through STEM robotics activities, aims to allow students to experience different ways of learning and problem solving (Zygouris N., 2017). The "teacher-authority" is abolished and its place is taken by creation, search and inspiration. STEAM education also offers students a learning environment where students explore, invent, discover, resulting in not only 21st-century skills but also the opportunity to develop new skills in the future. STEAM education, using educational robotics, contributes to the change of pre-orientation of the learning process to the traditional classroom. Through the design and implementation of appropriate robotics activities, it is possible to achieve all the goals set by the STEM spirit, as follows:

- Interdisciplinarity: The activities of educational robotics cultivate in children knowledge from the above disciplines, but also develop skills that emerge from their combined teaching (Benitti, 2012).
- Problem solving: In an activity that involves the use of training robots, students are asked to face numerous problems, which stem from the obstacles they have to overcome to achieve the goals of the activity.

- Imagination and creativity: The idea of "innovation" is directly related to imagination, which is related to the process of solving a problem.
- Logical and abstract reasoning: The process of building a training robot requires designing and assembling it in such a way that it is capable of operating in a specific environment and performing specific actions. This requires the student to model the robot and its environment abstractly to predict its behavior.

2.3.1 Educational robotics and STEM in Greece

Educational robotics itself is an innovative approach to education for the greek system, as it broadens learning objectives, incorporates a combination of different scientific fields and techniques, offers opportunities to switch roles, develops collaboration and promotes a positive climate in the school environment.

The interest that has developed worldwide in recent decades for the benefits of educational robotics and STEM practices, is also observed in Greece. More and more teachers recognize the value of robotics in teaching STEM courses and in the development of student's cognitive and emotional skills. However, robotics in school is not approached as a learning tool but purely as a cognitive object. In addition, the inclusion of robotics in the curriculum does not imply at the same time the compulsory teaching of the subject but is a teaching proposal complementary to the core of the existing curriculum. The integration of robotics in greek schools as a learning tool is currently appearing as part of activity groups. These groups operate in some schools, either private or experimental (Grizioti, Xenos & Kinigos, 2016), and aim through the use of innovative methods and tools teachings, such as robotics or STEM practices, to develop to youth the skills needed to cope with 21st century demands of society and future labor’s market. The same logic is based on the private bodies of educational robotics, which today reach a large number, as a result of which in most cities children are allowed to work with robotics, out of school. At the same time, the non-profit company WRO Hellas encourages the development of science and ICT (Information and Communications Technology) applications and especially methods of automation and robotics in education. The main issue of the whole effort of WRO (World Robot Olympiad) Hellas is the introduction of STEM in education as well as the cultivation of 21st- century skills in students promoting innovation and engagement of youth technological initiatives.

The teams that emerge from this competition are promoted to the international olympiad, a competition in which teams from all over the world participate. It is noteworthy that the participation of the greek team in the olympics of educational robotics in Costa Rica in 2017, brought significant distinctions, a fact indicative of the evolving interest and opportunities that exist in Greece for the flourishing of educational robotics. The expression of interest in educational robotics in Greece, as in the rest of the world, is not a coincidence but is based on the concern that school systems do not prepare a sufficient number of scientists in the field of STEM. STEM education is currently the benchmark for school systems internationally. America has incorporated STEM practices into all levels of education (Jess & Nikolakopoulos, 2004).

At this point, it's also worth referring to three initiatives taken by greek universities and academies:

- The Academy of Robotics, University of Macedonia, Greece

Thanks to its innovative structure, the Robotics Academy achieves the development of applications, services and technologies that expand both the utilization of social robots and the approach of cognitive objects through experiential and exploratory learning. The experience of the Robotics Academy team, in the multifactorial and interdisciplinary nature of the design and development of robotic applications, guides educational and Social Robotics actions, ranging from specialized pilot research to large scale applications. The Robotics Academy is a program of the department of education and social policy of the University of Macedonia. In September 2015, it began, in its legal form, after 15 years of robotic activities in schools, museums, places of informal education and entertainment, research and cooperation with institutions in Greece and abroad. For further information: https://robotics.uom.gr/

- Eduact - Action For Education, Greece

From 2013, while giving particular emphasis to new technologies, coding and educational robotics, Eduact takes initiatives in the field of modern education implementing practices that aim at the introduction of innovation in the educational process. In order to create a

better tomorrow, with quality and innovation in education, Eduact pays great attention to the equal participation of all social groups in programs that shape youth with leadership skills and social sensitivity. Thus, with the support of a large network of volunteers with passion for their subject, and the additional contribution of educators, entrepreneurs and university faculty from around the world, initiatives have been organized through which children cultivate their knowledge, broaden their horizons, discover science and technology in the most entertaining way and, above all, gain valuable skills for their social life. These initiatives include the Innovative Educational Robotics Workshops, the Robotics World Championship, the Panhellenic Robotics Championship, the Robotics and STEAM Program for schools that was designed and developed for the 'Skills Labs' of greek schools in collaboration with the Ministry of Education and many more. For further information:
https://eduact.org/

- Talos Team, University of Thessaly, Greece

Its work is based on the philosophy of active engagement of children, in playful scenarios of creation, learning and expression. Its goal is the all-round development of their personality, the experiential approach to the world and the phenomena around them as well as the emergence of multimodal skills through a combination of modern and traditional practices. The TALOS team of the University of Thessaly has been inspired, designing and acting since 2016 in the field of STEAM/making workshops with children (providing robotics, coding labs from preschool to university students). It consists of a broad interdisciplinary team of trainers and researchers and is actively supported by the Property Utilization and Management Company of the University of Thessaly and a scientific team of faculty members of significant field experience. For further information:
http://talos.uth.gr/

2.4 Reasons for introducing robotics in education

Nowadays, the positive climate for the application of robotics in the field of education is increasing, due to the experience and relevant research that has been carried out. While the training programs include math / physical scenarios, there does not seem to be a real emphasis on understanding the value of numbers, the problem-solving process, and the research process (RomeroE. Et al, 2012).The main reason for the emphasis on educational robotics is the fact that abstract ideas and scenarios take on a specific substance, as students automatically observe the effects on their constructions, through the programming commands they use, (Educational robotics , Kazakoff et al, 2012). Children from the first years of their youth and later acquire various skills by constructing, designing and creating. Educational robotics was also based on this assumption to be applied at all levels of education and to be an interesting and fun activity for the student, which puts him in action. How it will be integrated is easily achieved, depending on the interests of the class, such as the creation of "inventions", the construction of an environmental phenomenon, etc. (Cejka E. Et al, 2006). It also helps in the teaching of various concepts, which - most of the time - are not directly perceived by the learners and mainly come from the Natural / Positive Sciences, but also other cognitive objects. Specifically:

- In Physics for the study and understanding of natural phenomena and concepts. Indicative is the utilization of the Lego Mindstorms training package for the teaching of some basic principles related to heat, melting-coagulation, etc.
- In Mathematics and Geometry for the best learning of proportions, distances and the understanding of geometric properties, such as perimeter, area, etc. The dynamic representation of mathematical concepts and phenomena helps in their more complete understanding (Savard A. et al, 2015).
- In Informatics. Kagani, Dagdileli, Satratzemi & Evangelidis (2005) proposed an alternative approach to teaching the basics of programming, based on the use of physical models, such as the Lego Mindstorms RCX, and the application of concepts and ideas by students, to solve real problems.
- In Engineering for the construction, testing and evaluation of mechanical solutions.
- In Technology for the observation and learning of various technological achievements.
- In History for the acquisition of knowledge about the technological tools used at that time, while evaluating the work or personality of previous historical figures and personalities.
- In language teaching, if it can enhance expressiveness, entrepreneurship and lexical skills of students through the explanation they provide after the end of their work.

- In the development of interdisciplinary works or courses, as robotics is suitable for the simultaneous teaching of several subjects, such as Physics, Mathematics, Informatics, but also theater, literature, arts, history, etc.

The term "interdisciplinarity" or "interdisciplinary teaching" means a series of educational approaches that attempt to "unify" school knowledge. The interdisciplinary approach to knowledge supports the principle of complementarity in education, according to which the perspectives from which every subject sees the same system are not completely independent or compatible with each other (G. Baras, 2013). However, in addition to the cognitive area and the expected learning outcomes, educational robotics can contribute effectively to other areas, such as the emotional (self-esteem, self-confidence, mood) and the social (socialization, team spirit). Furthermore, the rapid development of technology has created a variety of modern learning tools for the teacher, to provide a more attractive, interesting and renewed lesson. Students - nowadays - take for granted and self-evident access to any information via computer, mobile phone or tablet. This whole situation contradicts the reality of the school, where the approach to knowledge is dealt with even more "traditionally" through the book and notes. This does not mean that the basic knowledge that needs to be taught is far from the older one, but that it would be legitimate for the teacher to be more in line with the everyday environment of the children. Finally, in addition to the positive consequences of the introduction of educational robotics for students, it is noted that teachers are familiar with different pedagogical approaches and methods, creating innovative collaborations between teachers (responsible for creating the curriculum), engineers and teachers, renewed technology-based school curricula as well as facilitating people with disabilities (Bers M. et al, 2006).

2.4.1 21st century learning skills and robotics

Digital competence is about use of digital media for work, leisure and communication with ease, safety and confidence. Digital competences are related to logical, computational and critical thinking, high-level information management skills, and well-developed communication skills. The aim is not just to learn technology, but through technology to change substantially the whole perception of education (GI Deli, 2012).

Critical thinking and problem-solving skills are enhanced through robotics activities. Problem-solving skills relate to the ability to evaluate situations, identify problems as well as find immediate ways to solve them. This process presupposes the recognition of long-term consequences as well as the conception, implementation and evaluation of an appropriate action plan and is constantly cultivated through educational robotics. Its use provides continuous and constructive feedback during the problem-solving process (Blancharda S. et al, 2010). In the work environment, those people who maneuver in critical situations are highly valued, they do not panic, but explore and implement useful changes (Smyrnova-Trybulska E., et al 2016). Critical thinking is the mental and emotional function in which the individual evaluates the reliability and validity of information with the ultimate goal of drawing the right conclusions. It includes the ability of analysis, synthesis and comparison and needs to be cultivated from pre-school age, so that students can apply it in various situations (Smyrnova-Trybulska E., et al 2016). In the RoboCupJunior competitions, students may use any robotics platform, but the focus is on student learning, rather than competition (Eguchi, 2016). The leagues, or challenges, are based on topics of interest to students to motivate and attract them to STEM activities – especially robotics (Eguchi, 2016).

Robotics activities promote also communication and collaboration skills, which are vital skills to be successful in STEM fields (Eguchi, 2016). Interpersonal and communication skills include the ability to listen and observe, to comprehend and discuss effectively, and to express ideas (orally or in writing), (SmyrnovaTrybulska E., et al 2016). It usually requires several skills, such as willingness, consistency, honesty, contribution, negotiation, decision making, flexibility, and compromise (Smyrnova-Trybulska E., et al 2016).In a one-week summer robotics camp at a large university in Texas, Yuen et al. (2014) found that elementary and middle school students demonstrated both cooperation and collaboration while designing and building robots. Overall, the robotics activities provided engaging, challenging activities that promoted collaboration as students worked together to design, construct, and troubleshoot their robots (Yuen et al., 2014).

Robotics also connects to social-emotional learning for students. Stergiopoulou et al. (2017) list an impact on student cooperation and trust between students and teachers.

Peer social interactions are can be cultivated using robotics stated by Kazakoff et al. (2013). Robotics supported social competencies, including communication and teamwork skills, according to Smyrnova-Trybulska et al. (2017). Kim et al. (2015) also reported growth in communication and collaboration skills due to robotics learning. Gomoll et al. (2016) specifically cite how human-centered robotics may be important for connecting girls with STEM. The emphasis robotics places on the social side of science and technology-led teenagers in an after-school club towards social-emotional growth – including students taking on leadership roles they had not previously (Gomoll et al., 2016).

To promote such collaborative classroom activities, classroom organizations should change from traditional teacher control to student-led projects with teacher assistance (Gura, 2011). In addition, changes in the behaviors of students and teachers are vital, as students engage in project-based learning activities (Gura, 2011). When students are provided with informal instruction on STEM concepts, they can learn problem-solving skills through project-based learning (Barak & Zadok, 2009). To promote more meaningful learning in class, the teacher should adjust from strict teaching to a more flexible manner so that students can have more control while working on their projects (Barak & Zadok, 2009). As control shifts from the teacher, students can take control and trust themselves, which gives them more ownership and power in their learning (Martinez & Stager, 2013). An inherently collaborative activity, robotics projects closely resemble real work efforts, as students divide efforts, brainstorm ideas, and work together for a group project (Gura, 2011).

Robotics is a cross-disciplinary field, which helps students better understand how different subjects interact with each other (Gura, 2011). Technological literacy is also increased with robotics as learners are called to solve real-life problems, such as realistic engineering scenarios through design challenges. For example, the engineering design process to solve a robotics problem allows students to connect and apply science concepts of current, voltage, and resistance (physics) and applying math through scaling, graphing, calculating wheel rotation, predicting the final positon of the robot, etc. Participation in robotics programs contributes to demonstration an enjoyment in creative and design-based activities (Blanchard et al., 2015). Such hands-on lessons give students a better understanding of the work of engineers. Many students might not understand the role that engineers play in society and need real-world connections for them to learn about the skills and education required for STEM careers (Blanchard et al., 2015).

Fifth through eighth-grade students, in a study by Leonard et al. (2016), increased computational thinking skills, reinforced science subject matter, as well as learned engineering and technological skills while creating a game. Kim et al. (2015) shared how robotics improved both elementary and middle school students' math achievement and STEM knowledge, elementary students' science achievement, and middle school students' physics content knowledge. Kazakoff et al. (2013) described robotics as a new form of manipulatives that can support student understanding of mathematical concepts. Even non-STEM content areas are impacted by robotics. Kindergarten and pre-kindergarten students showed a significant increase in picture sequencing skills after taking part in a robotics and programming intervention using both physical and computer-based robotics blocks, while a control group showed no significant increase in the same skills (Kazakoff et al., 2013). Kim et al. (2015) also reported a link between robotics and picture sequencing skills.

As in actual engineering problems, robotics requires a change in the order of learning (Gura, 2011). With the experimental nature of robotics, students first envision and construct a model. Then they attempt an initial "build" and try to create a program that provides instructions for the robot. After program adjustments, with a "back-and-forth" manner, they can later understand the learning concepts in the activity (Gura, 2011). Robotics requires much "trial-and-error testing" as students make modifications to the robot, the program, or both (Gura, 2011). Robotics is informal and discovery-based, even though much learning is involved (Gura, 2011). This constructivist approach to student learning allows students to make discoveries, since they better understand and communicate their successes and failures from a shared learning activity that is largely student self-directed (Gura, 2011). Lastly, robotics has been reported to lend itself to the growth of 21st-century skills. Smyrnova-Trybulska et al. (2017) recorded a robotics connection to critical thinking, logical thinking which shows how important is educational robotics for developing 21st century skills to youth and adults.

2.5 Ways to introduce robotics in education

Through educational robotics, growth and development are achieved, while stagnation and crisis are avoided. To achieve this, there are plenty of already tried and effective ideas in the field of training to support robotics. These are:

- Organization of summer camps and courses with the object of robotics, which include speeches, group work, activities and educational trips for the participants.
- Encourage students to participate in robotics competitions, which provide students with the opportunity to work in teams within a specific time frame, to test their skills and to acquire new skills in a spirit of noble rivalry. In addition, such competitions provide strong and consistent motivation to students, resulting in their most substantial interest in robotics (Kraetzschmar GK, 2009).
- Creation of free laboratories with robotics activities.
- Teaching informatics and programming through the use of robots.
- Frequent use of robots in the teaching of mathematics, with the aim of better explaining and understanding difficult concepts and phenomena.
- Use of robots in the teaching of physics and the various sciences.
- Assignment of interdisciplinary projects at regular intervals using robots.
- Development of special courses, aiming at the introduction of robotics.
- Introduction of lectures on robotics.
- Development and creation of robotic applications.
- Using robots as educational toys from an early age
- Support and encouragement of robotics on the part of parents. Although they recognize the positives provided by educational robotics, they often feel insecure and lack the knowledge they need to inspire children (Lin et al, 2012).

Constructivism is today one of the main models in the study of modern pedagogical software. It aims to offer teaching activities subject to methods of solving teaching activities to bridge the gap between school and extracurricular activities. The goal of teaching according to the constructivist perspective is not so much the transmission of information, but the encouragement of the learner to create knowledge and develop the metacognitive processes of evaluation, organization and acquisition of new information

(Korombili & Togia, 2015).The primary methods for designing learning environments using robotic and constructivist theory are: the offer of experiences related to the creation of knowledge the introduction of knowledge and learning in real environments, the stabilization of knowledge through social interaction, the encouragement to use different types of representation, the encouragement in this consciousness during the function of knowledge production.From the above one concludes that educational robotics mainly comes from:

- Piaget's theory of construction, where it is argued that learning is not transferred, but is an active process of knowledge production based on daily empirical activities (Koutsoukos & Smyrnaiou, 2007).The constructionist teaching tactics of S. Papert, according to which the production of new knowledge happens more effectively as soon as the learners engage in the practical and tangible construction of a project which will have a tangible value to them. The concern of constructionism is nothing more than providing students with the appropriate feedback to push them with their inner motivation to self-teach and learn more effectively than before, (Papert, 1980).
- Vygotsky's social-constructivist theory, where students, once engaged in a construction process, will gain access to new school concepts of the curriculum - and more.

The formulation of a framework for the design of activities and their implementation, including the definition of stages that encourage specific processes such as brainstorming, jam, experimentation, investigation, creation, presentation/evaluation, (D. Alimisis, 2008).The action of the students during the elaboration of a task with programmable robotic constructions is proposed to be organized in a series of separate but interconnected stages. The stages of work should not be understood as "serial" events but as phases of a single work that may be repeated circularly and/or overlap. These are:
Involvement stage: a first version of the problem is formulated and students are involved in identifying it through free dialogue.
Experimentation stage: students experiment with programmable simple mechanical structures (gears, pulleys, shafts, etc.), motors, and sensors, so as to become familiar with the relevant software, through simple problems they are asked to face to understand the operation of programmable robot as well as the capabilities that this software has.

Exploration stage: The students redefine the problem and the questions they formulated in the first stage through the experience they gained after getting acquainted with the basic material and undertake the solution of the individual problems working in groups.

Composition and Creation Stage: Students are asked to compose the individual elements and materials (programs) that were presented in class in a final form that answers the initial problem. At this stage, students self-organize and record the course of their work in diaries or follow-up sheets. Each group works to compose a single solution.

Evaluation Stage: the final products of the groups are presented to the class and evaluated. Students are asked to critically approach their work, express opinions and compare based on the criteria they have set, (D.Alimisis, 2008).

The choice of the appropriate training robot depends on various factors, such as cost, age of the students and the subject matter. Today there are numerous robotic construction kits (Robotic Construction Kits) that address the field of education and range in price and properties, from low-cost robots that perform a function, such as the robotic package OWI9910 Weasel Robot, to Lego Mindstorms up to anthropomorphic robots costing thousands of dollars (Mubin et al., 2013). Lego Mindstorms is a production line of Lego robotics training packages consisting of programmable bricks with electric motors, sensors, Lego bricks, and Lego technical components (such as tools, shafts, spokes, and hydraulic parts).

Brandt and Colton (2008) consider the reasons that make the use of Lego Mindstorms packages suitable for training:

- Flexibility in their use, as the student can design, build and program a variety of constructions, while Lego bricks can be used over and over again in different ways, allowing the student to design, build and control easily without requiring special assembly skills.
- Attracting students' interest, as today children are familiar with Lego Mindstorms as toys. So the students are excited about the idea of assembling it and creating a moving machine. They get immediate satisfaction when they realize that they can successfully build a robot.

The first release of Lego Mindstorms coincided with the founding of the First Lego League, a partnership between the non-profit organization FIRST (R) (For Inspiration and Recognition of Science and Technology) and the LEGO (R) education sector year, since 1998, in more than 80 countries worldwide. The organization aims to enhance children's interest in engineering and technology (http://www.firstlegoleague.org/). At the time of the release of the Lego Mindstorms NXT package in 2006, the term STEM had already begun to be heavily used in the education sector. Since then, educational robotics has been considered a great tool, able to attract students' interest and enhance their involvement in STEM activities.

Lego toys are a safe and educational choice for parents who seek to offer the best options for their children from the first months of their lives. For more than a decade, Lego toys have been identified with remarkable toys that promote the child's skills and imagination in construction. Over the years, they have evolved to keep pace with the needs and interests of today's children, especially preschool and school children.

The robotic kits to be used should be suitable for the construction of simple and medium difficulty robotic structures. It should be possible to develop many different final structures and not one structure with the ability to add or remove sensors. The durability and reliability of the materials are crucial for the smooth running of the activities. There are special kits for all ages. A typical example is the Bee-Bot and Blue-Bot robots (Figure 1). BeeBot is designed for use by young children. It is colorful, easy to use and friendly and for these reasons it is an ideal tool for teaching space orientation, appreciation, problem solving and fun.

Figure 1, Bee-Bot, educational robot designed for use by young children. The Bee-Bot educational robot can store up to 40 commands and thus encourages more and more sophisticated programs. The latest model of this educational robot for the very young is the Blue Bot. (https://www.robot-advance.com/EN/cat-beebot-187.htm)

The programming software should be easy to use by children who have no previous programming experience and knowledge. A modern international practice with excellent results is the use of a graphical integrated programming environment through icons. Developing a program in this way is an easy process, as little or no knowledge of English is required. According to Druin & Hendler (2000), robotics enables students to implement abstract design ideas, to reflect and to observe the results of their efforts directly.

2.5.1 Examples of Good Practices

For a successful implementation of educational robotics in schools is necessary to take first into account the technical considerations .The most popular (open) hardware and software platforms that are often used in educational robotics over the last years are presented below:

Open source hardware platforms

- Arduino
- Elegoo
- Makey Makey
- Micro: bit
- Raspberry pi

Software and programming environments

- IDE-Arduino
- Open Roberta
- Scratch 3
- Snap4Arduino

In Europe, it has been taken initiatives for promoting educational robotics and developing digital skills to youth. Some examples of good practices are:

- **Coding for Inclusion, Belgium:** Teenagers in schools are trained in a 15 hour methodology based on computational thinking, Scratch, Makey Makey, and Micro: bit and robotics.
- **Digital Welcome, Belgium**: The core program is based on four modules on: coding with scratch, digital storytelling, digital journalism, and soft skills. (digitalwelcome.eu)
- **D-clics numériques: robotics educational path, France** lead by La Ligue de l'enseignement. Robotic education path propose an initiation to the robotic science through the discovery of a ROSA (robot open source Arduino). A ready to use education path divided in 12 lessons with several offline education games proposed. (d-clicsnumeriques.org)
- **Poppy Station, France** is the result of a transfer of Inria (the French National Institute for computer science and applied mathematics) research from its open source Poppy robot ecosystem to a multi-partner external structure. One of their aims is facilitating experimentation and the creation of innovative robotic tools in the fields of education, research and the arts. (www.poppystation.org)
- **Litera-robot: blending robot and literature, Italy is** a seven-lesson program dedicated to boosting appreciation in young people and high school students for international literature throughout the use of robots.

Robotics competitions are also playing a great role in challenging and motivating the students and are considered to be one of the best practice to increase student's interest in educational robotics and STEAM fields. The most important international contests about educational robotics are:

- **NAO Challenge**
- **The FIRST® LEGO® League**
- **Robocup**

Last but not least, it's important to mention **the Horizon Europe** which is the EU's key funding program for research and innovation. Horizon program which has taken and will continue to take place these years in Europe (2021 to 2027) aims to maximize the scientific, economic and social impact of Union investment in research and innovation. It helps teachers, researchers and organizations across the Europe to implement projects and take actions in order to promote technological growth at all levels. Many of these projects are referring to education and new technologies. In this way, educational robotics and STEAM become more supported not only in schools and universities but also in lifelong continuous learning programs for adults.

CHAPTER 3

FROM STEM TO STEAM

3.1 Introduction to STEM Education

The STEM acronym was introduced in 2001 by scientific administrators at the U.S. National Science Foundation. It is the acronym of the words-scientific fields: Science (mainly Computer Science), Technology, Engineering and Mathematics. STEM is an interdisciplinary approach that integrates the four scientific fields of STEM into a cohesive learning paradigm based on real-world applications. This chapter presents variations, definitions, characteristics and examples about STEM education. Special attention is also paid to the STEM objectives and teaching methods as well as to art integration and adult's engagement with STEAM education.

From the end of the 20th century onwards, education follows a different trajectory than the previous way of traditional education, while it seems to be inextricably linked to the social, economic, policies, cultural needs and developments where are carried out worldwide. STEM-based education is proving to be a pioneer in developing and evolving important aspects of life and the economy, as well as preparing students for the future. A dominant role in STEM education is played by the active participation of students in the discovery of learning and problem solving, through interdisciplinarity. STEM education can be applied at all levels of education, from preschool, primary and secondary to postdoctoral education, in both formal and non-formal education (Gonzalez & Kuenzi, 2012).

3.1.1 Origins of the STEM acronym

In the nineties in the USA this approach was attempted with the acronym "SMET" (science, mathematics, engineering, and technology) which was later replaced by "STEM" (science, technology, engineering, and mathematics). It is an approach that considers modern issues to be of considerable complexity to be addressed by a single science and this way of thinking must be adopted in education by students.

The term "STEM" first appeared in 2001 by biologist Judith A. Ramaley and is an approach that aims to integrate technology and engineering into the teaching of science and mathematics. The term is commonly used in education policy and school curricula to improve competitiveness in science and technological development (Gonzalez & Kuenzi, 2012). The term has been enriched over time with other letters (STEAM, which indicate the addition of other scientific fields to the "umbrella" of STEM such as that of Art).The story with the STEM educational approach has started in the USA. It started in an organized and effective way when US President Obama called on American society to take initiatives to tackle the problem of innovation in education. With the motto "Educate to innovate", a big campaign for STEM education was launched, so that every child can develop their skills in a favorable learning environment. The National Science Foundation of America has set two weighty goals in the fields of STEM. The first immediate goal that was set was that each student should know and understand the basic principles of the courses contained in STEM, as well as the connections between them. Trained students would have all the necessary knowledge to enter the workplace, ensuring them a decent job. The second long-term goal was to ensure that all the necessary changes were made so that the country could remain competitive with the rest of the world (Chesky & Wolfmeyer, 2015).STEM education is now an economic necessity for America and the whole world, because almost all of the emerging professions in the coming years will require at least some background in technology, engineering, and math.

In Europe, with a delay of a few years, the effort to integrate the STEM approach into formal and non-formal education began through and through Jointly Funded European Programs. An effort has been made in this direction since 2009 by the Brussels-based European School Network, so that some schools can pilot new learning and technology activities in the classroom, exploring the use of new pedagogical tools through STEM-assisted teaching.

3.1.2 Variations, definitions

STEM was a conglomerate term used to refer to one or several of the constituent disciplines but has since evolved into various interpretations beyond individual disciplines to refer to various integrated pedagogical models, approaches, and practices (Akerson et al., 2018; Bybee 2010, 2013; English, 2015). For example, in *A Case for STEM*, Bybee (2013) presents nine different models of STEM education: from a perspective of STEM being synonymous with science or a single science discipline like physics or biology, to STEM referring to a transdisciplinary approach for addressing major challenges such as global climate change or use of resources for energy. Similarly, Lederman and Lederman (in press) characterize STEM as an integrated approach to curriculum, not a discipline on its own. In addition, there have emerged variations of the constituent disciplines to create new, related acronyms. For example, STEAM has gained significant popularity in Korea, Japan, Taiwan, Australia, and the U.S. (see Allina, 2018; Lee & Chang, 2017; Perignat & Katz-Buonincontro, 2019). ST2EAM—Science, Technology, Transformative learning, Engineering, Arts, and Mathematics—emphasizes transformative science education (Taylor, 2015) which cultivates "five interconnected ways of knowing, being and valuing: *cultural self-knowing, relational knowing, critical knowing, visionary and ethical knowing, knowing in action*" (Taylor & Taylor, 2018, p. 469). STEMSE— Science, Technology, Engineering, Mathematics, Societies and Environments prioritizes students' learning about social justice and environmental sustainability and preparing students to address ecojustice problems they identify (Bencze, Reiss, Sharma, & Weinstein, 2018). STEAMM—Science, Technology, Engineering, Art, Mathematics, and Medicine—is a variant predominantly used in postsecondary education discussions (e.g. Miller & Kimmel, 2012). Recently, STREAM has surfaced to refer to the integration of Reading and wRiting into STEAM as well as STEM+C to refer to the integration of computing into STEM (National Science Foundation, 2018).

The ubiquitous use of the term STEM, with little definitional consistency, runs the risk of diluting its potential value for enhancing, reforming, and informing K-12 (from kindergarten to 12th grade) research, policies, programs, and practices. As many variations exist of the meaning of STEM, STEM education continues to be a significant feature of reforms at the national, state, district, and school levels in countries all over the world. Rather than striving for a singular definition of STEM, it is incumbent upon researchers, policymakers, educators and other education stakeholders to articulate and clarify in their work what they mean by their use term STEM or any of its variants.

3.2 Purpose and objectives of STEM training

STEM education aims to promote and improve the learning of the scientific subjects to which its acronyms correspond. In addition, it aims to address these different scientific fields as a single entity, whose teaching is integrated and defined through application to the solution of real-world problems faced by students, (Sanders,2009).The goal of STEM education is to educate people so that they can apply their knowledge and understand how the world around them works. This is achieved through, (National Governors Association, 2007):

Scientific literacy. The ability of the individual to use scientific knowledge but also scientific methods and procedures for understanding the physical world, participation and decision making.

Technological literacy. The ability of the individual to use, understand, evaluate and manage the technological means at his disposal.

Mechanical literacy (engineering). The ability of the individual to understand, to design, to create through scientific applications and machine methods, technological objects.

Mathematical literacy. The ability of the individual to justify, interpret, resolve, analyze and communicate ideas and thoughts, in a mathematical way in different cases and situations.

The purpose of STEM training is to prepare and educate students, with all those supplies and skills that are necessary in modern times. Through STEM teaching, students acquire knowledge, skills and abilities to become future inventors and innovative scientists.
Through rational thinking and the use of technological means they will become excellent problem solvers (Morrison, 2006).

Through STEM, students approach learning about the world around them holistically rather than piecemeal and piecemeal through the learning of individual parts of phenomena. According to the National Academy of Engineering and National Research Council (2009) the fields that are part of the STEM philosophy are described as follows: making the boundaries between scientific areas narrower. According to the National

Academy of Engineering and National Research Council (2009) the fields that are part of the STEM philosophy are described as follows:

Natural Sciences: concern the study of the physical world, including the laws of nature relating to physics, chemistry and biology, and the treatment or application of the principles, activities and concepts associated with these fields. The natural sciences are all the knowledge that has accumulated over time as well as the process - scientific research - that produces new knowledge. The teaching of science with the STEM approach differs significantly from the traditional one, while promoting scientific literacy. It is suggested that students be promoted from an early age to develop skills that will enable them to acquire scientific skills. Problem-solving through experimental questioning activities is very important, including additional planning and planning to solve the given problem (Harlen, 2010).

Technology: While it is not a field in the strict sense of the term, technology applies to the entire system of human activities as well as to the organizations, knowledge, processes and devices involved in the creation and operation of technological objects, as well as to the technological creations. Much of modern technology is a product of the natural sciences and engineering, while technological tools are used respectively in both fields. Literacy - often referred to as "digital literacy" - is a person's ability to use, manage, evaluate and understand technology. The aim of STEM education is for the future citizen to become technologically capable of understanding what technology is, how it works, how society changes and as a result, how society ultimately changes technology in continuous interaction. A technological education that is adapted to the modern era should include programming and robotics.

Engineering: is on the one hand all the knowledge about the design and creation of human constructions and on the other hand it is a problem-solving process. It is a design process with limitations. A limitation of the design process in engineering is the laws of nature, or the natural sciences. Other limitations are time, money, available materials, ergonomics, environmental regulations and the ability to build and restore. Engineering is the least developed field of STEM in terms of compulsory education. Engineering training allows students to develop skills such as developing devices and solving real problems with these devices. In addition, it allows students to understand concepts such as the design process, efficiency and constraints, which they must take into account throughout the design and creation process (Shahali et al., 2017).

Mathematics: this science studies patterns and correlations between quantities, numbers, and spaces. Mathematical literacy is the ability of a person to identify, understand, engage with mathematics, and make informed decisions about their role in current and future personal, professional and social life, as well as their life as a creative and conscious citizen, (Milaturrahmah, Mardiyana, & Pramudya, 2017). Unlike the natural sciences, where empirical data seeks to justify or overturn assumptions, the claims in Mathematics are established through logical reasoning, based on commonly accepted principles. Logical reasoning is part of Mathematics, as claims. As in the natural sciences, the field of knowledge in mathematics is constantly evolving. Mathematics is used in all three of the aforementioned sciences. The current way of teaching mathematics in school, approaches them as an object with no or minimal relationship and response to the real environment of the student

Literacy in the scientific fields of STEM includes interdisciplinary approaches, which are related to each other, are overlapping, and at the same time promote each other. The idea of merging sciences is not so recent. Professor of mathematics Calvin Woodward in the 1870s distinguished the connection between the scientific fields of mathematics, natural sciences and engineering and began to apply new manual teaching methods to students of engineering and mathematics (Sanders, 2009). Nevertheless, for about a century the fields of mathematics, science and engineering in education remained strictly distinct (Sanders, 2009). However, it is now understood that STEM cognitive subjects should be taught holistically and not individually, as this approach does not correspond to reality and the field of work, where the knowledge of all sciences is applied in combination. The essence of STEM education is not in the synthesis of a word that simply describes the whole of the scientific fields. STEM training should be seen as "An interdisciplinary and applied approach, which is inextricably linked to reality and learning through problem -solving." (STEM Task Force Report, 2014, p.7). The need to integrate the STEM philosophy into education arose in the last decade initially in the US, as there was concern that the number of students, teachers and professionals employed in the fields of mathematics, science, engineering and technology was not sufficient for the country to be considered competitive. Student failure and declining enrollment in these disciplines make the US role as a world leader in economics and innovation questionable for the future (Gonzalez & Quenzi, 2012). This, combined with the rapid development of China and India (Sanders, 2009), necessitated a change in the strategy for educating students in the above areas.

The aim of STEM training is not only to learn the cognitive subjects mentioned above. What is mainly sought through STEM practices is the development of skills, such as critical and creative thinking, problem-solving skills as well as research thinking, with the ultimate goal of adequately preparing students to be able to interpret the world around them. Through STEM education, students are expected to acquire the appropriate equipment to join to the scientific potential that will be necessary for the future and to be able to cope with the demands of the labor market and complex daily life. According to Morrison (2006) the students who will complete an education based on the STEM philosophy will be:

- Able to solve problems - ask questions and problems, plan research on data collection, collect and organize data, draw conclusions, and apply their findings to new and innovative situations.
- Innovators - creatively use the concepts and principles of science, mathematics and technology by applying them to the engineering design process.
- Self-sufficient - able to use their dynamism and strong internal motivations to set an action agenda, develop and gain self-confidence, and work within strictly defined time frames.
- Logical thinkers - able to apply logical thinking processes of natural sciences, mathematics and engineering design to innovation and invention.
- Technologically literate - able to understand and explain the nature of technology, develop the skills required, and apply technology appropriately.

3.3 Characterizing integrated STEM

In some cases, engineering/technology design has been used to support science and/or mathematics instruction. In this approach, science and mathematics learning goals are foregrounded, and engineering/technology design is integrated in a manner that allows students to apply their science and/or mathematics knowledge and practices to find viable solutions for design problems. Occasionally, engineering design pedagogies are used to introduce engineering concepts and practices while also providing students opportunities to explore focal science and mathematics concepts. Integration of some or the entire group of STEM disciplines is complex and requires that teachers have a robust understanding of not only the content and practices of each of the integrated disciplines, but also the alignment and coherence among integrated STEM teaching approaches, learning goals and assessments (NAE/NRC, 2014; Wang, Moore, Roehrig, & Park, 2011). In short, the integration of STEM disciplines is much more intentional than teaching two different subjects in one lesson or using one discipline as a tool for teaching another (e.g., using equation mathematics to determine average velocity).

However, understanding culture, practices, and ways of knowing and sharing knowledge of the STEM disciplines constitute only part of the path to integration. One of the key challenges in integrated STEM teaching and learning is connecting core content knowledge and processes across the disciplines (English, 2015). Students need opportunities to engage in discipline-specific practices, while at the same time recognizing and understanding how the individual disciplinary knowledge, skills, and practices support and inform each other. Problem- and project-based approaches (Barron et al., 1998; Blumenfeld et al., 1991; Hmelo-Silver, 2004) are commonly used in integrated STEM education. Both problem- and project-based learning approaches focus on providing learning experiences that incorporate inquiry, problem-solving, creativity, and other 21st century (Partnership for 21st Century Skills, 2011) skills to design solutions to an open-ended question, problem, or challenge (Blumenfeld et al., 1991; Roth 2001). Students work collaboratively, utilize multiple tools, collect and analyze various data sources to solve the question, problem, or challenge. It is essential with integrated STEM learning that the pedagogy that drives instruction has an integrated focus that deepens students' understanding of core ideas and practices in the STEM fields and of concepts and practices that are shared across the STEM fields, while engaging and sustaining students' interest with an important topic, problem, or issue that has real-world applications (NRC, 2011).

Finally, an emerging trend in integrated STEM teaching and learning that is showing promise for fostering the creating, designing, and innovating aspects of STEM is the “maker movement” (see Halverson & Sheridan, 2014). According to Halverson and Sheridan (2014), the maker movement “refers broadly to the growing number of people who are engaged in the creative production of artifacts in their daily lives and who find physical and digital forums to share their processes and products with others” (p. 496). As part of this movement, a growing number and diversity in types of makerspaces are becoming popular features in both formal and informal STEM learning environments (Peppler & Bender, 2013; Sheridan, Halverson, Brahms, Jacobs-Priebe & Owens, 2014). Making and makerspaces are seen as a potential way of expanding opportunities for participating, and hence learning, in STEM education; re-envisioning and expanding the learning outcomes (e.g., practices and mindsets) of STEM education; and enriching the experience of learning in STEM by encouraging students’ identity development as a member of a community of practice (Calabrese Barton, Tan, & Greenberg, 2017; Sheridan et al., 2014).

3.4 STEM in preschool and primary education

STEM education is starting to apply even in pre-school education. Children - according to researchers - are born scientists, researchers and engineers, with creative collaboration between them, (StoneMacDonald, Bartolini, Douglass, & Lu Love, 2011). Investing in quality preschool education, which will offer all those opportunities to develop their talents, is very important (Chesloff, 2013). Scientific findings suggest that brain development in preschool education can play an important role in the subsequent development of children. STEM education has all the characteristics of quality education, since the involvement of preschool children with natural sciences in combination with other fields such as technology, sensitizes them and stimulates their interest in science (Mantzicopoulos, Samarapungavan, & Patrick, 2009). For this reason, in recent years, researchers have suggested that STEM education should start with the pre-school education of children. Regarding the practical application of the above, Mooomaw (2012) states that objects with "sensors" or bricks can be used appropriately in a structured program as part of STEM education. For example, in preschool children come in contact with bricks, trying to set up their constructions with different heights. Most of the time the constructions fall and so they themselves draw important conclusions about their height and stability, using mathematical skills in combination with skills of engineering and physics.

A comprehensive STEM program seems to be able to be successfully implemented at a young age, where there is only one teacher. In secondary education, on the other hand, there is a fragmentation of different scientific fields, since different teachers teach only one scientific field, (Roberts, 2012). The qualified teacher with the help of the curriculum offers young students the opportunity to exploit their innate need for knowledge, learning concepts of Science and Mathematics through the interdisciplinary approach offered by STEM education, (Bishop-Josef, Doster, Watson, & Taggart, 2016). It is important to mention at this point, the special importance that according to scientists seems to have educational robotics for the promotion and enhancement of STEM education in kindergarten. Programming and educational robotics increase the opportunities that students have to work collaboratively and solve a complex problem. The recent years educational robotics become more famous helping the application of STEM education in greek Kindergarten as well. The freedom that the greek curriculum offers to teachers is something that is also harmonized with STEM education, (Ioannou &Bratitsis, 2017).

Last but not least, new prospects for the promotion of STEM at the level of primary and secondary education are being opened for Greece, as the general secretariat for telecommunications and post (GGT) of the Ministry of Digital Governance and the European Space Agency (ESA) have initiated the process for the creation and operation of an ESA European Space Education Resource Office (ESERO) in Greece. ESERO is ESA's main tool in the field of primary and secondary education for STEM promotion and provides STEM teacher training, classroom teaching material and educational projects. It was launched in 2006 and operates in 18 European countries to date.

Under the coordination of ESA, with the participation and support of national institutions and organizations active in the field, the project aims to strengthen the capacity of the educational community. The space-based ESERO stimulates students ' interest in science and supports with appropriate material the teaching and learning of general STEM subjects. ESERO provides teacher training in STEM, classroom teaching resources and related school projects. ESERO's activities are designed and implemented using state-of-the-art STEM educational methodologies, such as research-based learning, combined learning, project by-project and design-based learning, as well as the integration of interactive tools into education. ESERO also helps to establish links between the school environment and related professions in the space sector. National ESERO is established and operates throughout the country, in close cooperation with ESA and the relevant national public bodies. ESERO's activities are tailored to each member state and are therefore able to support specific national education policies and STEM objectives.

3.4.1 Obstacles to the implementation of STEM education

The problems in STEM education come mainly from the lack of information and, consequently, the misunderstandings associated with this type of education. According to Morrison (2006), some of the misconceptions that seem to have been created for STEM education, is that engineering and technology are two additional courses that are part of the curriculum. As technology, students and teachers consider only technological means such as computers, but also the work done on them, such as word processing. Another misconception about STEM education is that students should pursue professions such as engineering as not explicitly mentioned courses such as philology. Another misconception is that they believe that STEM training refers to issues that are only related to the workforce that a country needs. An important misconception about STEM teaching is that teachers in mathematics, for example, cannot teach Science at STEM or engineers cannot teach mathematics, which contradicts the basic principle of interdisciplinarity in STEM education (Morrison, 2006). In his study Ejiwale (2013) mentions the obstacles that exist for the successful implementation of STEM education:

- Poor preparation and lack of specialized STEM teachers.
- Lack of investment in teacher training at STEM.
- Poor preparation of students.
- Lack of cooperation between teachers.
- Inadequate support from the education system.
- Lack of research collaboration in STEM scientific fields.

- Poor preparation of educational content.
- Poor evaluation methods.
- Poor facilities and insufficient logistical infrastructure.
- Students' limited internship.

3.5 Teaching methods in STEM education

The interdisciplinary approach to STEM education is based on constructivism which provides it with an active learning environment where students are at the heart of teaching while the teacher is the facilitator. Students acquire new ideas and structures and adapt them to pre-existing knowledge, which they had acquired through their previous experiences (Piaget, 1972)

According to Erdogan and Stuessy (2015) for the effective application of STEM education in educational reality it is necessary to use appropriate teaching methods. Teaching methods should lead students to think critically, innovate and find solutions to problems they may face in their daily lives. In addition, students should be allowed to work together to set goals and ultimately present the results of their work. Ideal teaching methods for education STEM is the project method, the problem-based method (problem based learning, PBL) and the exploratory teaching method (inquiry-based learning), (Erdogan & Stuessy, 2015).

The project method has its bases in the discovery teaching method, but focuses on group work (project) and finding solutions to real problems from the real environment of the student (Sahin, 2013). The advantages of the project method is that it offers the possibility of cooperation between students, creating internal motivation while strengthening the initiative of students to create and ultimately solve a problem that may play in their environment, (Hakim, Sulatri, Mudrikah, & Ahmatika, 2019).

Learning through problem-solving is also a student-centered teaching strategy. Students collaborate, interact, answer questions and solve problems, according to the ideas and knowledge they have gained from previous experiences. Students work together in small groups, while the role of the teacher is to intervene only to facilitate learning. Students in this way have the opportunity of an interdisciplinary approach to knowledge, (Crippen & Antonenko, 2018).

An additional student-centered teaching approach is the discovery method and is based mainly on the search and questions that are created in students. The student's effort for exploration and discovery was systematized, organized, and documented primarily through Bruner (1977) theories. The effectiveness of exploratory learning depends on individual factors such as attitude, motivation and readiness for learning, but also external ones. According to Bruner, the desire to learn is an endogenous motivation, which when activated, leads the student to the acquisition of knowledge (Bruner, 1977).

STEM education, as mentioned, is an interdisciplinary approach where teachers are required to switch from traditional teaching methods to active student support for the acquisition of new knowledge. According to Kennedy and Odell (2014), teachers should work to challenge students to research and innovate. They should mainly use as a teaching method the project method and the problem-solving method that contributes to the achievement of the previous goals, more than the traditional teaching methods (Kennedy & Odell, 2014).They should also provide students with interdisciplinary and multicultural approaches, where through collaboration students gain deep knowledge, modeling real -world concepts and situations beyond the narrow confines of the school or a local community into a wider STEM education community. , (Kennedy & Odell, 2014).

3.5.1 Problem-based learning (PBL) and computational thinking (CT)

Problem –based learning (PBL) as a teaching method is very useful as it contributes to develop computational thinking (CT) to students. The students have firstly to determine whether a problem exists and define what they believe to be the problem. After identification and deep understanding of the problem, they are searching for resources from which further information can be obtained. In this stage, it’s possible to start generate some first solutions in collaboration with other students. After some final brainstorming and experimentation, students analyze the possible solution they have found and if desired they recommend the best solution (final presentation).

As a result of engaging in the problem-solving process, students are developing their computational thinking skills. The power of this educational approach is that students not only acquire personally meaningful knowledge that is learned in a relevant (problem-based) context, but they also come to a personal understanding of how to acquire knowledge to resolve a situation. Coaching and supportive questioning are at the heart of the educator's role in problem based learning. By more accurately mirroring real-world activity than traditional approaches, students come to understand the inherent ambiguities involved in learning. The potential experiences to be gained from a problem-based approach, seem to reflect a very real degree the experiences that will be encountered during life as a professional. Rather than thinking of an expert or a professional as someone who possesses a great reservoir of knowledge to solve problems as they arise, expertise might be better thought of as a process of progressive problem solving in which people continuously rethink and redefine their tasks.

The introduction of STEM in education, as a scientific approach, has provoked much discussion on how to implement it in school and tertiary education but also on the nature of the epistemological content. Related to the introduction of STEM is the issue of the introduction of computational thinking in conjunction with STEM, engineering pedagogy and methodology to be followed - at a practical level - completion of STEM epistemology in the curriculum such as the "didactics of specialty courses" and in training programs for the acquisition of pedagogical competence. Computational thinking includes problem-solving, systems design and understanding of human behavior, using concepts from computer science. Wing (Wing, 2008) argued that computational thinking "connects" mathematical thinking with engineering, emphasizing the design of systems that will help solve complex problems. The dimensions of the computational thinking include the following (Psycharis, 2015):

- The ability to think "algorithmically"
- The ability to think in terms of "disintegration" of the problem
- The ability to generalize and use-by standards

- The ability to think "abstractly" by choosing representations
- The ability to evaluate a model

Therefore, at the core of computational thinking is the student's ability to break big problems into smaller ones (NRC, 2011). Computational thinking is directly related to the ability of students to create models, both mentally and mechanically. Thus they learn to develop and create new ideas to solve their problems (Vossoughi, 2013 - Bers, 2014). Finally, it becomes obvious that teaching methods like problem based - lastly also called challenge based – learning contribute to the development of computational thinking to students, which will have a positive impact in their future life.

3.5.2 Game based learning

Engagement and motivation are very important in any learning environment. The inclusion of game design principles, or game-like experiences, in a curriculum shows how ''gamification" has evolved the last years. Nowadays, it's noticed that online gaming platforms like kahoot are often used not only by educators to teach kids in a more fun way but also by adults in presentations to increase the motivation of the participants and have some extra measurements/statistics of their knowledge. STEM education as well as educational robotics are ideal for implementing game based learning. The fact that robotics combines games with learning allows students to create a positive attitude about what they have been taught (Stergiopoulou et al., 2017). The term "gamification" is recently introduced as the application of game-like accelerated user interface design to make electronic transactions both enjoyable and fast. The purpose of gamification is to create or transform experiences so that they transmit the same feelings, the same engagement, as when playing games, even when the main purpose is not entertainment. However, there is no consensus about a gamification definition, the most accepted one in the literature is "the use of game design elements in nongame contexts". Several frameworks have been proposed in the recent years, ranging from fully defined formal processes to a loose list of guidelines with a few examples tacked on. Even though the specifics may be a bit different between the existing proposals, they tend to agree in three basic design principles: defining the expected behaviors, identifying player types, and deploying the appropriate game design principles, given the player types. Regarding the learning scope, the potential of gamification is reflected in the amount of educational experiences. Therefore, gamification of learning seems to increase student motivation and engagement.

3.6. From STEM to STEAM

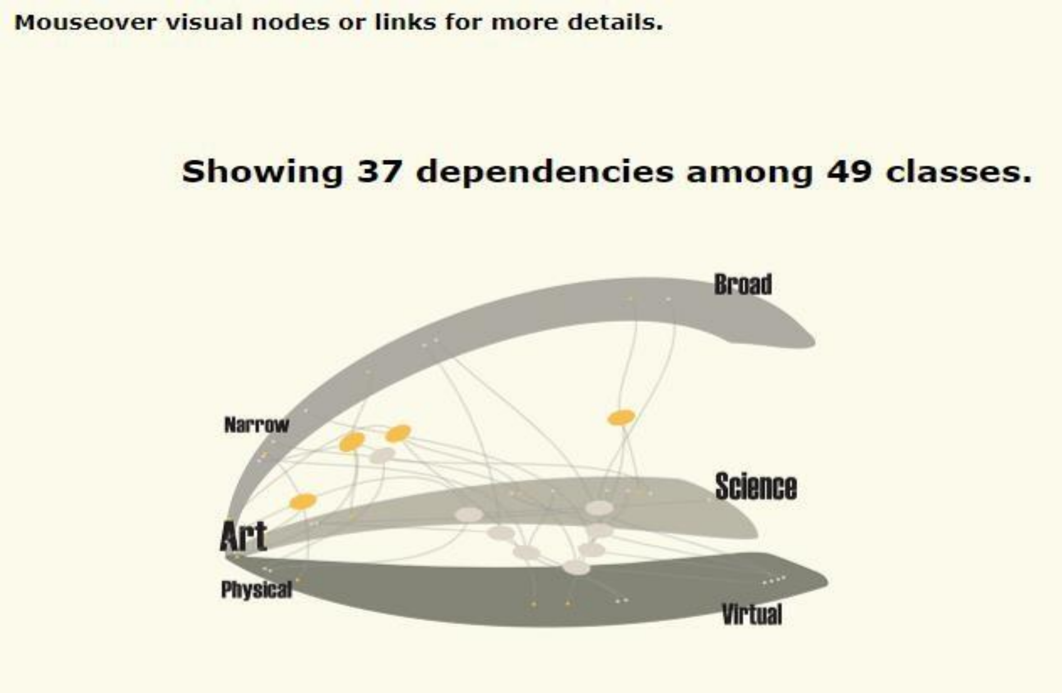
The last years, as STEM education becomes more popular, a new field (Arts) has been added to its acronym (STEAM), making STEAM education even more attractive for educators as well as for learners. The inclusion of art enhances creativity, design and students' imagination. The STEAM approach promotes creative, critical and divergent thinking in STEM's scientific fields. Rapid economic developments require citizens with flexibility, originality and the ability to express new ideas to enrich and evolve the various fields of science and technology. The skills required by the arts such as precision observation, collaboration, kinesthetic perception can be useful scientific skills for all scientific fields, while promoting innovation with new ideas to emerge (Robelen, 2011).The arts in a classroom should be the tool that develops creativity, critical thinking, teamwork and initiative. At the same time, this increases the interest in the other sciences included in STEM, (Radziwill, Benton, & Moellers, 2015).

3.6.1 Art-science-technology integration

The basic skills for education and society involve: a) problem- solving skills for complex problems, related to complexity, b) critical thinking and divergent thinking and c) creativity (ambiguity and uncertainty for ill-defined complex problems). An interdisciplinary approach chances for generating new knowledge which lies in between disciplinary boundaries integrating knowledge to address the complex problems of the world. In such approaches which involve multiple disciplines the interaction of methodologies in the space between and at the intersection between the disciplines offers the possibility of new perspectives 'beyond' those disciplines. At this point, there has been an effort to justify the intersection between STEM disciplines and art and more specifically the relationship of arts with engineering design. Art and science –engineering have a common history and interconnectivity between the arts and sciences is an area of research and practice that can be traced throughout history (Ghanbari, 2015).

According to Daugherty (2013) : “Modern cell phones and PDA’s (personal digital assistant) use a form of encryption called frequency hopping to ensure your messages cannot easily be intercepted. Frequency hopping was invented by the composer George Antheil in collaboration with the actress Hedy Lamarr and computer chips are made using a combination of three classic artistic inventions: etching, silk screen printing and photolithography. The STEM to STEAM movement presents new language to frame such interdisciplinary thinking.” Mishra and Yadav (2013) have argued that human creativity can be augmented by computational thinking, which could move students from being consumers of technology to create new forms of expression build tools and foster creativity an essential characteristic of art. “The creative process doesn’t exist in a vacuum—it’s a highly integrated activity reflecting history, aesthetic theory, and often the technological breakthroughs of the day. This was certainly the case during the renaissance, when artists, engineers, scientists, and thinkers all came together to create truly remarkable works of art and engineering” (Ira Greenberg, processing creative coding and computational art, 2007). Arts integration is connected with the didactic strategy of the inquiry-based teaching and learning approach.

According to Greenberg (2007), even programming can be learned very easily through the creation of screen art by using the processing language. A framework for understanding of the diverse and complex nature of art-sci-tech collaborations (Campell & Samsel, 2015) put together a basic visual cognitive tool with which to facilitate thinking and build a dialogue (see Figure 2). Robotics is connected to arts. Umass Lowell (Martin et al., 2009) created a university project called Artbotics, which combined computing, robotics, and interactive arts, and all students were expected to be engaged in all these areas. Students engaged in hands-on work with robotics materials in the service of creating new media art.



Mouseover visual nodes or links for more details.

Showing 37 dependencies among 49 classes.

Figure 2, a Creative tool for categorizing each artist’s work in a 3D space. (An interactive version is available on the Web at http://bdcampbell.net/ieee/cga/).

Psycharis (2019) asserted that, for an art-sci-tech implementation, teachers should possess the following qualifications:

a) Good knowledge of science ideas and capacity in technological concepts

b) Experience in connecting computational thinking (main abstraction in different levels) with science and technology courses

c) Willingness to apply crosscutting (transversal/crosscutting ideas) in courses in alignment with disciplinary core ideas and

d) Capacity to connect scientific concepts with real-life phenomena. In addition, experts should promote the development of curricula that contain examples of the use of e.g. concepts from engineering in arts.

Student perceptions of STEM and engagement can also be affected by robotics learning. Students in research by Stergiopoulou et al. (2017) made STEM connections, recognized relationships among STEM subjects, and realized the value and importance each content area provided robotics curriculum. Stergiopoulou et al. (2017) reported sixth graders enjoyed robotics activities and that math and science skills supported their learning. Smyrnova-Trybulska et al. (2017) also related how creating a robot kept students engaged and motivated, and even teachers had recognized the importance of self-motivation in the study. Gomoll et al. (2016) reported robotics held student interest and that students were engaged both cognitively and socially. Behavioral engagement (students taking initiative and participating fully without distraction) and emotional engagement (including confidence boosts and greater interest in STEM) – described as autonomous motivation – were reported by Kim et al. (2015), as well as greater STEM interest, motivation, and self-confidence. Scientific inquiry, engineering design skills, and problem-solving skills are also benefitted by student robotics exposure.

Science and arts are linked in many perspectives. For example, solar equation is a large-scale public art installation that consists of a faithful simulation of the sun, scaled 100 million times smaller than the real thing. The solar animation is constructed by live mathematical equations that simulated the turbulence and flames that can be observed on the surface of the sun (Figure 3). Another example is the musical instrument; theremin. A theremin works by generating electromagnetic fields around two antennas. A straight, vertical antenna controls pitch; a horizontal, looped antenna controls volume (Figure 4). A masterful player makes very small, precise finger and hand movements in the field around the vertical antenna to change pitch and create melodies. Another recent example (posted on June 2021) is the work of Rembrandt’s “Night Watch” painting which has been restored by AI (artificial intelligence) 300 years after it was trimmed. Obviously there are many great examples of art-science-technology combination and increase over the years showing that the use of science and technology in arts can have great results.

Figure 3, Solar Equation by Rafael Lozano-Hemmer,

https://www.lozano-hemmer.com/texts/downloadable/SolarEquation2LQNB.pdf

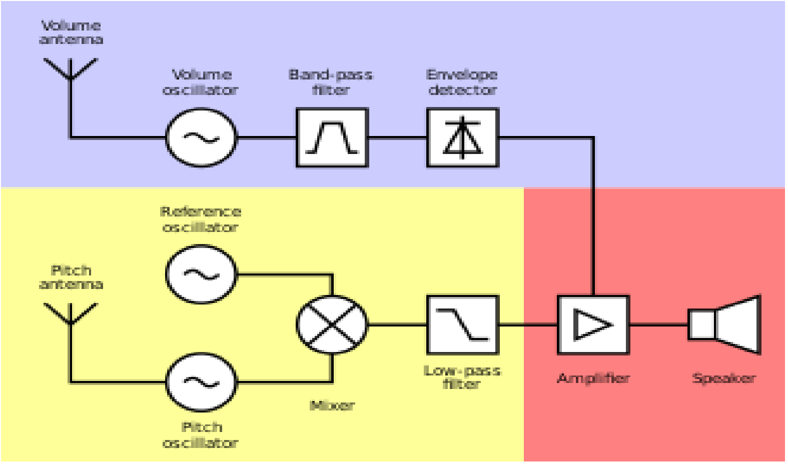


Figure 4, Block diagram of a Theremin. Volume control in blue, pitch control in yellow and audio output in red. (*https://en.wikipedia.org/wiki/Theremin)*

3.6.2 STEAM for adults

Practical STEM skills are crucial not only for preparation of today's students for tomorrow's world but also for adults to be better adapted to new technologies evolution. Developing STEM skills makes adults capable of mentoring youth in these fields. Adults who continue lifelong learning will model intellectual curiosity and a willingness to experiment. Adults interested also in teaching and learning could use their newfound knowledge and start an after-school club, lead STEAM activities or just share their motivation with the next generation.

Adults learn differently than children do. For adult brains to absorb new information is required a different neurological process. Instead of building new neural pathways, adult brains need to draw connections from existing schema, or thought patterns, and new ideas. This means that adults will learn best when new information is made relevant to their current experiences and interests. STEM is well-suited to adult learning in this regard, as hands-on experimentation allows to make scientific ideas practical in everyday life. Adults also need flexibility in their learning to fit new courses into their busy lives. Asynchronous online courses that allow to log on and study at own convenience are ideal. It's also important for adult learners to feel respected by their instructors and comfortable trying something new. No matter age or previous computer experience of adults, there are many ways to engage with STEM. These are some ideas:

Keep reading for leisure and knowledge: Subscribing to high-quality publications that have great resources about technology evolution is a way to keep informed with interesting news and ideas.

Face-to-face adult education classes: Many organizations offer classes or programming /coding boot camps. The local university community is also a good place to start looking for lessons that will provide legit skills to improve STEM knowledge of adults.

Open educational resources (OERs): There are thousands of lesson plans, games and videos online that address every imaginable STEM topic (for example videos or projects on Instructables).

Massive open online courses (MOOCs): These are online courses that cover a wide range of topics. Information may be delivered via text, video or a recorded lecture, and there are often assessments to check understanding along the way. Some well-known options are EdX, Coursera and Khan Academy, Alison Courses, Future Learn, Udemy even LinkedIn Learning. Many are free or are relatively inexpensive, and most can be completed at own pace.

As it’s mentioned in previous chapter, there have been taken serious initiatives, especially the last years in Europe in order to promote educational robotics, STEAM and generally help people developing digital skills. A great example is **Digital Inclusion of Low Skilled Adult People – Project.** Europe is undergoing a digital transformation and citizens should be equipped with the appropriate skills to perform jobs and increase economic growth.

Keeping this in mind, the project addresses the need to provide low skilled adults with necessary digital competences for supporting them in becoming more employable and socially integrated. The project aims to strengthen adults' capacity to efficiently use digital instruments as a precondition to improve their personal and professional lives, reducing significantly the inter-generational digital divide trend. In particular, the project provides a friendly learning environment for low skilled adults in order to support them in reaching specific digital competences. The partners (countries that participate) are Italy, Greece, Sweden and Romania.

3.6.3 Future Research – Conclusion

Future recommended research includes the areas of STEAM program material content, the balance of activities that will positively impact student motivation and interest, best practices for STEAM instruction to support underrepresented or underserved students, as well as on the benefits of robust STEM teacher training. First, research is needed to identify STEAM activities that can be applied in settings with students of differing levels of ability – STEAM programming which will allow for differentiation to meet the needs of individual students. Second, research that will identify an appropriate balance between exploration, free-play, and structured learning/application of scientific processes is needed to maintain student motivation and interest yet support the learning of content area material. Meeting the needs of and provide opportunities for underrepresented or underserved students is vital to removing barriers to their exploration of and participation in STEM learning and future STEM work trajectories. Lastly, research to clarify and refine teacher training and staff development, which will best support educators to find success in integrated STEM classrooms and programs, is critical to STEM reform and the future of effective STEM education.

The importance of integrated STEM, and ensuring educators, students, and stakeholders understand and support the efforts of integrated STEM instruction is the first step towards successful STEM programming. Learning by doing, using a constructionist approach, is vital to providing classroom experiences that support student exposure and growth in scientific inquiry skills, application of the engineering design process, problem-solving (including real-world scenarios), social-emotional growth, content literacy, as well as understanding connections between and among not only STEM subject matter, but across all content areas. Effective STEM curriculum will also engage student interest, keep students motivated, and build student self-efficacy. Beyond the classroom, students will build 21st century skills that will impact future learning and preparation for society and careers. Two specific examples of integrated STEM which currently stand out in STEM programming are robotics and coding. These two areas can be a reference point for emerging trends in STEM fields and how to integrate them into student instruction. Ongoing training for educators and proper preparation of new teachers is continually necessary so that instructors and programs remain effective and relevant for student learning.

Furthermore, in recent years STEAM training seems to have been researched a lot, as well as educational robotics. However, after the literature review in the present work, it is observed an information gap regarding the introduction of arts in STEAM and how this new field can be effectively and practically integrated into education while promoting STEM concepts. Another area that has not been sufficiently researched to provide sufficient information for observation and study is how STEM education can approach adults in the context of lifelong continuous learning (not just for interested STEM trainers/educators). STEAM education has a lot to offer and is an open field for more research and findings. STEM education is something that is constantly evolving, since it is no coincidence that the adaptation of art has taken place in recent years. In conclusion, STEAM education is an open field for researchers from different backgrounds (scientists, engineers, artists, educators) and it’s very interesting its evolution in the coming years and if it manages to be applied at every level of education as a learning tool for children and adults without any restrictions.

CHAPTER 4

RASPBERRY PI EXAMPLE

4.1 Raspberry pi as a learning tool

The raspberry pi computer has been successfully used for many electronics educational projects. Its low cost have made it easy-accessible for do-it-yourself (diy) experiments and generally hands-on activities. However it's a considered to be a general purpose computer, its low cost has also made it possible to be used as a component in single-purpose devices. The projects that can be created through raspberry pi have impressive results and useful applications in everyday life. However, the original aim of the creation of the Raspberry Pi had an educational value. In this chapter, it'll be analyzed the original purpose that led to the development of this low cost card-sized microcontroller: "Getting an easily programmable machine into the hands of kids to motivate them to learn programming and engaging more with computer science". Before some years there was still the problem that the typical home computer, in contrast to earlier generations such as the BBC Micro, Commodore 64 or spectrum ZX, was not a toy to program and experiment with electronics, so kids needed another learning environment.

The original aim when creating the raspberry pi was to encourage youngsters to engage with programming and increase their interest in computer science. The method to achieve this was to give them their own, low cost computer that they could use to program on, as a replacement for a family personal computer (pc) that often did not allow this option. With the original release, the raspberry pi included two programming environments in the standard distribution software: scratch and IDLE, a python environment (In fact, the "Pi" in the raspberry's name derives from "Python" as the envisaged main language offered to users.).

4.1.1 An overview of raspberry pi

Raspberry pi is powered by an ARM-based processor. Raspberry pi is a system on chip, as usually called SoC and of course a single-board computer (SBC).The major components are: HDMI, USB ports, Ethernet ports and SD card. The default operating system is Raspbian, a Debian-based Linux distribution. Latest models can also run Window 10. Raspberry pi has also numerous interfaces to interact with small electronic devices (display serial interface (DSI) for connecting a touch screen, camera serial interface (CSI) for taking pictures or videos, sensors or/and actuators can also be attached to the general purpose input/output (GPIO) pins to monitor and react to the environmental change). Raspberry pi is considered to be the third best-selling computer brand in the world.

The advantage of raspberry pi is that it provides a general programming environment (e.g., Linux) and allows direct control of the hardware through the interfaces. Raspberry pi adopts python as a main programming language, but also supports other mainstream programming languages, such as C/C++, java, perl and ruby. Raspberry pi became popular for its small size, low price, powerful computation capability and versatility. The image below shows the main components of raspberry pi model B, which has been also used for the present photography project in this diploma thesis (Figure 5).Nowadays is available the raspberry pi 400, which is the complete personal computer, built into a compact keyboard. Featuring a quad-core 64-bit processor, 4GB of RAM, wireless networking, dual-display output, and 4K video playback, as well as a 40-pin GPIO header, it's the most powerful and easy-to-use raspberry pi computer yet (Figure 6).

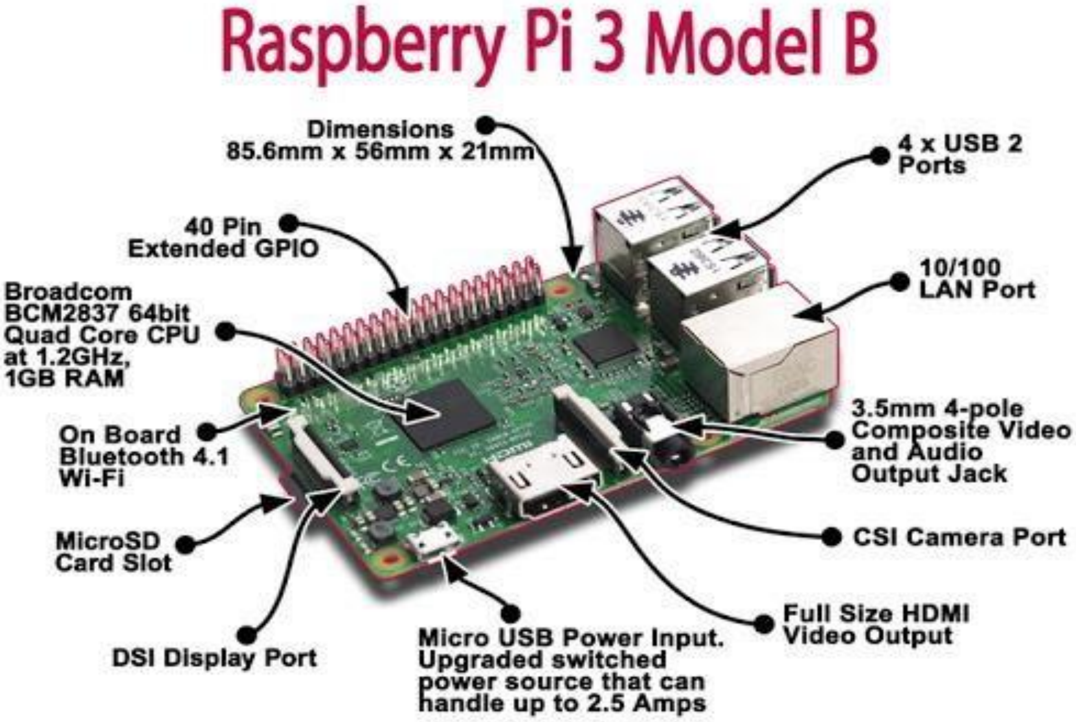


Figure 5, an overview of raspberry pi 3, model B (https://binaryupdates.com/introductionof-raspberry-pi-3-model-b/)

Figure 6, an overview of the new raspberry pi 400 Keyboard Computer (https://www.cytron.io/raspberry-pi-400)

Today, there are many choices to start a raspberry pi project. There are about ten different raspberry pi types/models with different characteristics in order to cover different kind of needs. They have speed from 700 to 1800 MHz and their RAM can be from 512MB to 8GB.They have USB ports (1 to 4), usually 1000Base-T Ethernet connection and 802.11n wireless internet connection. The most raspberry pi models have also bluetooth and their price ranges from 20$ to 100 $. There are available separately or as complete kits in the market. Last but not least, it's very important and recommended to buy and use the original raspberry pi power supply. About the software, it's also important to keep the system always updated. Two useful command lines about updates and upgrades are: "sudo apt update" and "sudo apt full-upgrade".

4.2 Raspberry pi photography project as an example of motivating adults to engage with educational robotics, STEAM and IoT

Time-lapse photography uses multiple images taken over a long period of time, which are then stitched together to produce an animated sequence of images. Making a GIF (Graphics Interchange Format) with a raspberry pi is an easy way to make the first steps in learning some basics of command line and python. This project is an alternative way to show that everyone, without gender or age permission, can do it. GIFs are gaining popularity because, like memes, they're useful for communicating jokes, emotions, and ideas that's why they are used everywhere in social media. Nowadays there are of course many different paths to make a GiF (GIF-making websites and apps or by using a digital art software) but through raspberry pi is also a way to increase the creativity and experiment with time lapse photography or similar projects in the future. In this resource it's explained how to write a small script to take a photo or a video using command line or python code. Then it's presented of how to capture multiple images, using a raspberry pi camera over a long period of time. These images can then be combined into an animated GIF, allowing the view of very slow events in a few seconds, using the power of time-lapse photography.

Learners can write short programs demonstrating awareness of simple programming concepts, such as sequencing, repetition, variables, and selection. Learners also can write programs which use active and passive electronic components. They can receive data from input components and control output components using a computer or microcontroller.

Example learning outcomes

- Use of simple control flow statements
- Use of variables and simple data structures
- Use a variety of logical, arithmetic, and comparison operators
- Design and construct simple prototype circuits using components connected directly to GPIO pins
- Recognize and use polar components, such as LEDs and capacitors
- How to capture still images with the raspberry pi camera module
- How to use a for loop to capture multiple images with different file names
- How to use command line programs within a python script
- How to use ImageMagick to create animated GIFs

Raspberry Pi photography project is an example of how it's possible adults to engage with IoT (Internet of Things) in a creative and maybe artistic way. What is more, in recent years a new acronym Of IoE (Internet of Everything) has been usually used to describe the connection between everything, not only electronic devices but also people (students/teachers) and places. Obviously, raspberry pi can be used not only to educate kids but also to help adults developing digital skills in an alternative way. Adults who try this or similar projects are more likely to understand and support robotics or steam activities in their life. A raspberry pi project could be seen first as a personal challenge or a hobby and then become a bridge for adults to feel more familiar with new technologies. Finally adults who engage with raspberry pi or other similar platforms like Arduino or Micro:bit become aware of how robotics function, feel more comfortable with technology evolution and could give inspiration to new generation to be ready to deal with ease and safety the new digital age.

4.2.1 Basic project’s needs (hardware and software)

Hardware

- A raspberry pi computer (in this project has been used the raspberry pi model B)

- SD card (16GB recommended) with latest version of Raspbian OS installed

- Raspberry pi camera module

- A monitor with a cable (and, if needed, an HDMI adaptor)

- A USB keyboard and mouse

- A power supply / power adaptor (5V, 2.5A)

All the hardware stuff that have been used in this project are shown in the picture (Figure 7) below.

Figure 7, hardware parts used in this project, photo captured at the beginning of the project

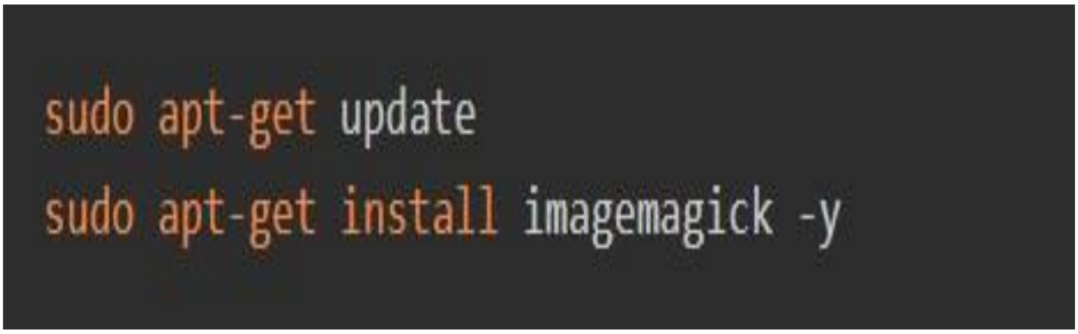
Software

- Raspberry pi OS, installed using the Raspberry pi Imager (*Figure 8)*

Figure 8, downloading and installing raspberry pi Imager to a computer with an SD card reader, photo captured at the beginning of the project

Some extra software installation also needed.

This project requires ImageMagick, a command-line program for image manipulation. To install ImageMagick, run the following commands in a terminal window (Figure 9):



```
sudo apt-get update
sudo apt-get install imagemagick -y
```

Figure 9, *photo captured at the beginning of the project*

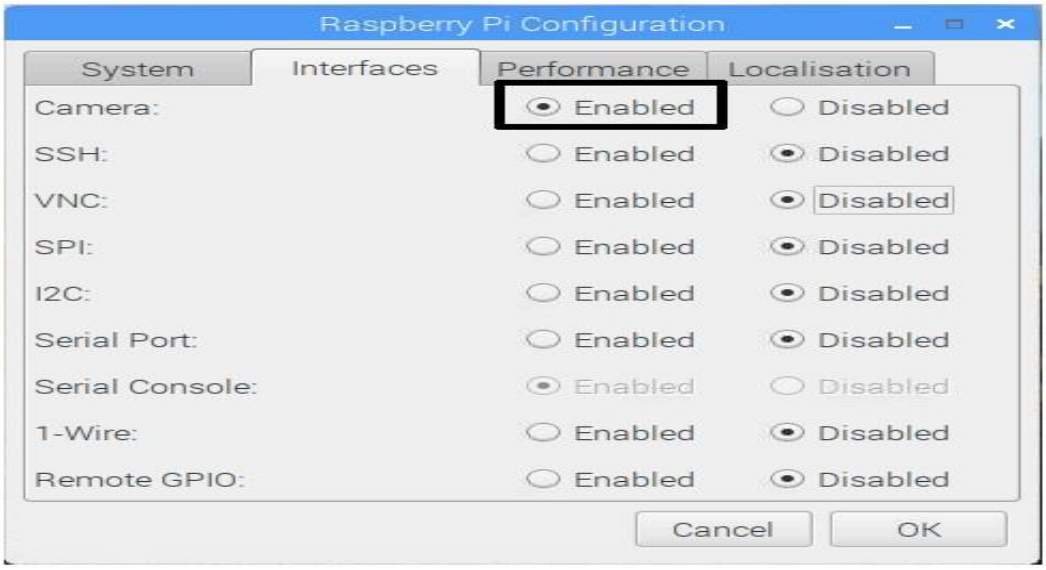
4.2.2 Short-explained step by step project’s guide

After the camera is connected and the software is enabled (Figure 10), open a terminal window and type in the following command:

```
raspistill -o Desktop/image.jpg
```

When the command runs, the camera preview open for five seconds before a picture is taken (images usually saved to Desktop). Creating a video (usually played with VLC MediaPlayer) using the following command:

```
raspivid -o Desktop/video.h264
```

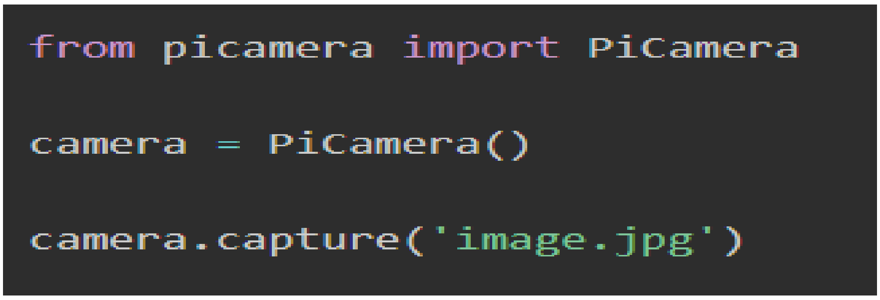


Camera: ● Enabled ○ Disabled
SSH: ○ Enabled ● Disabled
VNC: ○ Enabled ● Disabled
SPI: ○ Enabled ● Disabled
I2C: ○ Enabled ● Disabled
Serial Port: ○ Enabled ● Disabled
Serial Console: ● Enabled ○ Disabled
1-Wire: ○ Enabled ● Disabled
Remote GPIO: ○ Enabled ● Disabled

Figure 10, following these steps: “from main menu→ preferences→ raspberry pi configuration→ interfaces→ camera: enabled “to ensure that camera is ready to use, photo captured at the beginning of the project

For more information and other options, the documentation for raspistill and the documentation for raspivid are available in raspberry pi’s official website.

It’s also possible to take pictures and videos by writing some python code. By using the python pi camera library is possible to control camera module and create amazing projects. Open a python 3 editor, such as Thonny Python IDE. Create a new file (note: never saving the file as picamera.py.) Enter the following code (Figure 11):



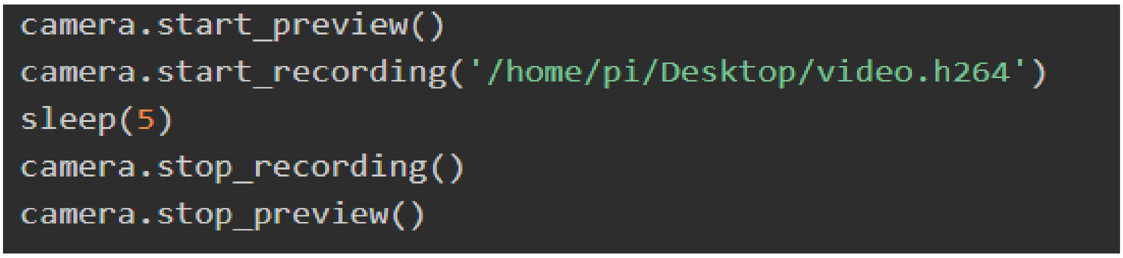
```
from picamera import PiCamera

camera = PiCamera()

camera.capture('image.jpg')
```

Figure 11, screenshot taken in progress of the project

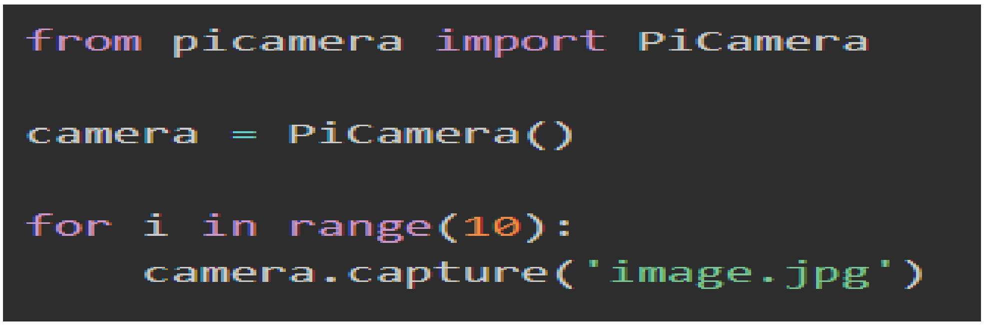
This code is about to make a video (saved to Desktop) (Figure 12):



```
camera.start_preview()
camera.start_recording('/home/pi/Desktop/video.h264')
sleep(5)
camera.stop_recording()
camera.stop_preview()
```

Figure 12, screenshot taken in progress of the project

Taking multiple images is also possible using the camera module by capturing images with a loop. A 'for' loop can be used to capture a set number of images. In this example, the raspberry pi camera will capture 10 images (Figure 13):



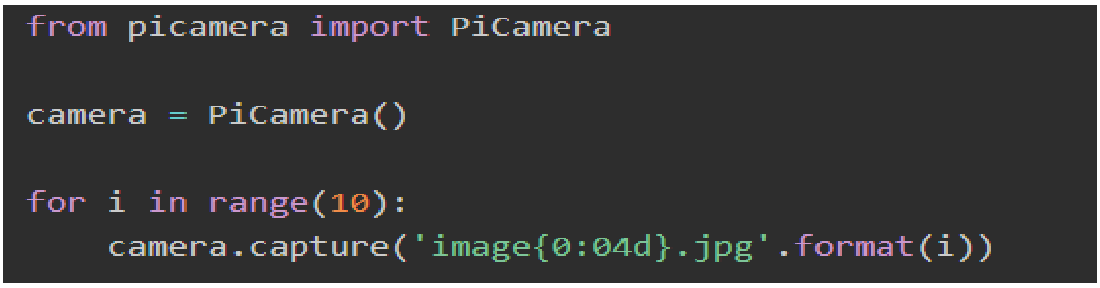
```
from picamera import PiCamera

camera = PiCamera()

for i in range(10):
    camera.capture('image.jpg')
```

Figure 13, screenshot taken in progress of the project

Search the File Manager to see what has been created. There's only one image there, and it's the last image that was taken. Each image has the same file name, so it's overwritten by the next image to be taken. This is a problem which can be solved by a little modification of the script (Figure 14):



```
from picamera import PiCamera

camera = PiCamera()

for i in range(10):
    camera.capture('image{0:04d}.jpg'.format(i))
```

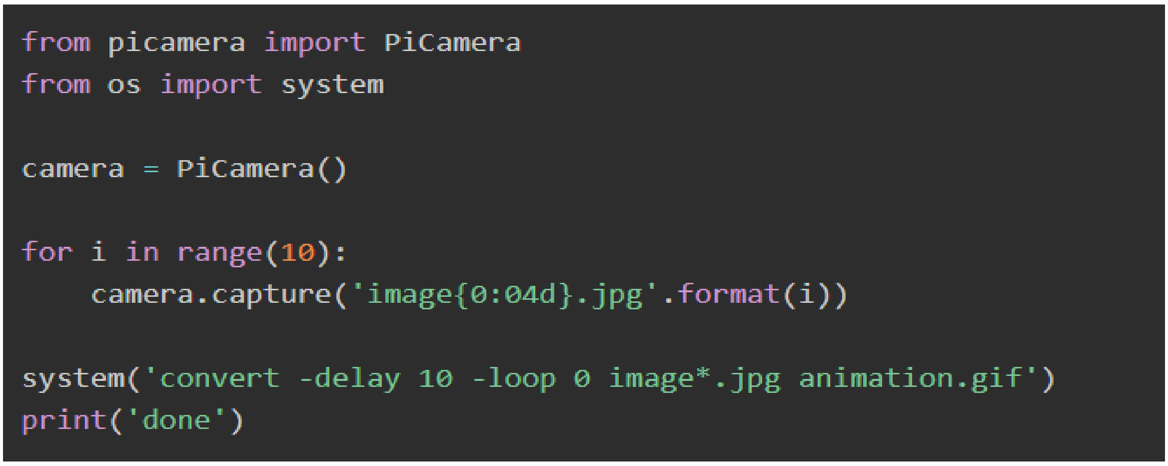
Figure 14, screenshot taken in progress of the project

Now that it's clear how to take multiple photos, let’s see how to turn that sequence into an animated GIF. At this point there is a need of ImageMagick program. ImageMagick is a command line program that can be used to manipulate images (It has been shown in previous subsection 4.2.1 in basic software project’s needs). For example typing the following command line:

```
convert -delay 10 -loop 0 image*.jpg animation.gif
```

The -delay option sets the amount of time (in 100ths of a second) between frames. The loop option sets the number of times the GIF will loop. Here the 0 tells it to loop forever.

This will take a little time to run (until “done” is printed), but once it’s complete the file animation.gif will be created in the File Manager. By double-clicking on this, the animation in Image Viewer appears. Again, maybe it needs a little time to open as it’s probably a fairly large file. The code for this final part is shown in the picture below (Figure 15).



```
from picamera import PiCamera
from os import system

camera = PiCamera()

for i in range(10):
    camera.capture('image{0:04d}.jpg'.format(i))

system('convert -delay 10 -loop 0 image*.jpg animation.gif')
print('done')
```

Figure 15, screenshot taken in progress of the project

This will take a little time to run. It should be appeared the word done printed in the shell when the script has finished. The new animation.gif will be playable from the File Manager after a couple of minutes. Reducing the file size and adding a delay are some extra lines of code that could improve the program execution. It can also be used 1920:1080, or lower resolutions, depending on project’s requirements. Note the raspberry pi can only play back up to 1080p video. The resolution of the image can be changed. The maximum resolution is 2592×1944 for still photos, and 1920×1080 for video recording. The minimum resolution is 64×64. For more information about raspberry pi camera module, hardware specifications, hardware and software features someone can check the appropriate manuals and documentation at official raspberry’s pi community website. Time lapse photography is slightly different from GIF making. The python needs some final edit, so as images to be taken every hour rather than every five seconds (Figure 16):

```
from picamera import PiCamera
from time import sleep

camera = PiCamera()

image_number = 0
while True:
    sleep(3600)
    image_name = 'image{0:04d}.jpg'.format(image_number)
    camera.capture(image_name)
    image_number += 1
```

Figure 16, screenshot taken in progress of the project

After finishing with taking the first photos, videos and making a GIF, someone can experiment more with this photography project and discover new possibilities. By adding the appropriate python code, it’s possible to add text, add cool image effects, or change the image white balance. These maybe are a little challenging for beginners but through trial and error (in difficulties such as the above) learners experiment, discover and keep themselves motivated for next more demanding projects. All this information is available at the official raspberry pi website, where someone can take not only inspiration through a big variety of step by step guided projects but also find the appropriate books, magazines, manuals and documentations in order to solve questions/problems , that may occur through a project's process.

In this chapter has been presented how to develop a simple time-lapse photography device with raspberry pi 3 and pi camera. For time-lapse photography the film frames are captured at much lower rate than the normal speed used to view the frames in sequence. When the final video (similar to GIF) is played at normal speed, time appears to be moving faster. One example where time-lapse photography can be used is the scene of the sun rising (Figure 17).

Figure 17, Time-lapse photography of the sun rising, https://www.electronicsforu.com/electronics-projects/time-lapse-photography-raspberrypi-3

The process includes: A camera fitted on a place from where the natural scenery can be shot. The duration is fixed by the appropriate command lines and python code. After the camera has finished taking photographs for the preset duration, there are two options: selecting individual photos among the bunch of photos taken by time-lapse technique or combining all photos to make it into a video (maybe a GIF), depicting how nature changes with respect to time. Applications of time-lapse photography may include: landscapes and celestial motion, plants growing and flowers blooming, fruits rotting, evolution of a construction project, people in a city. The process of time-lapse photography using raspberry pi 3 is described in an abstract way in Figure 17.

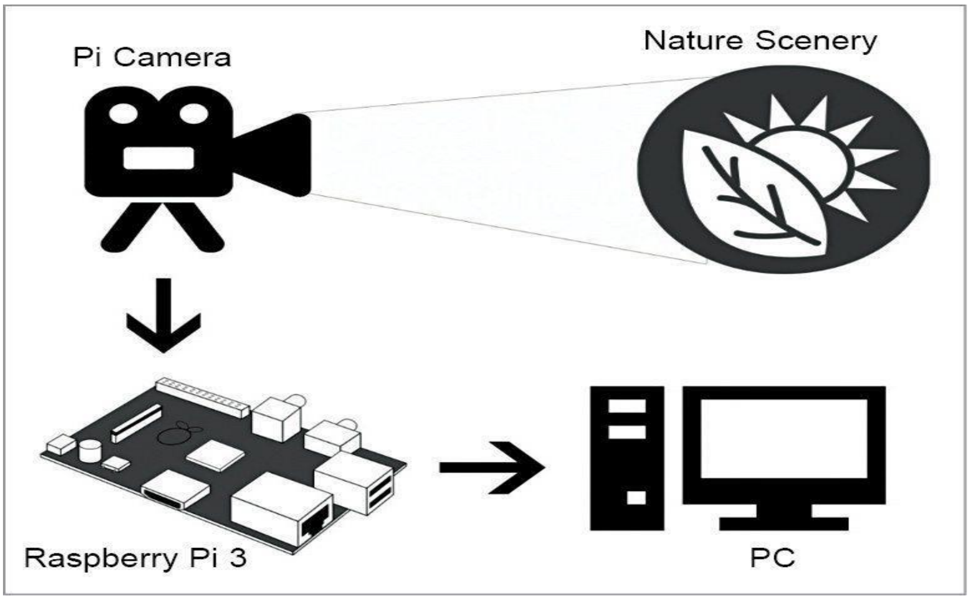


Figure 17, Time-lapse architecture, https://www.electronicsforu.com/electronicsprojects/time-lapse-photography-raspberry-pi-3

4.2.3 Final thoughts and concepts for project’s improvement and future applications

Raspberry pi is considered to be an affordable learning tool that can make the first introduction of kids to programming and coding a lot more fun. Making projects using raspberry pi’s platform is an alternative way of teaching kids how various things they see around in their daily routine work. Computer education becomes nowadays a need for children as everything around them become computerized and digitalized. This basic knowledge of applications found on a computer makes kids more confident about the technical world around them. In this way, they are developing useful skills and maybe evolve to creators rather than staying mere learners.

After getting started with the camera module to test camera and learn how to take a preview using python, there are many ways to explore new photography projects. For example, time-lapse video is also possible, use of button, motion sensor and create a push button stop-motion film. The raspberry pi community suggests also other projects that use raspberry pi camera module. These are: make a minecraft photo booth, tweet messages and pictures, build a parent detector, use the NoIR camera module to create an infrared bird box, and a tweeting touchscreen photo booth using a Raspberry Pi. All these projects can also be used to solve every day problems like controlling remotely the growth of plants using pi camera combined with the appropriate sensors, warning for a better parking place or just a security camera for home.

The photography raspberry pi project that has been presented above is an easy way for adults to make their first steps with coding (python programming) and robotics. The python language is one of the most accessible programming languages available as it has simplified syntax, which gives more emphasis on natural language. Due to its ease of learning and usage, python can be easily written and executed much faster than other programming languages giving the opportunity to adults to experiment in programming with ease. What is more, the project can be improved by using some 3D (third-dimensional) printed parts in order to make a personalized case that will cover both the raspberry pi and pi camera. This will improve the whole design and will make the raspberry pi looks like a real vintage stylish camera. Even 3D printing is not used in this project, it’s a new technology which is highly recommended to be used from educators and learners as it promotes educational robotics and STEAM. An issue that occurs when taking photos outdoors is that is difficult to carry a keyboard and make changes to the code. However, using a good power bank, taking as a monitor a small LCD raspberry pi touchscreen and having already the appropriate program written , there will be no problem taking photos and videos even outside. Finally a challenging idea for future development of this projects is using AI-based technology software that can track subtle changes of facial expression. This could find application in case of emergency (if there is a negative emotion-detection) to help people by providing them the appropriate phone call (to police, hospital etc) or as a useful tool for actors’ rehearsals.

CHAPTER 5

CONCLUSIONS

In conclusion, robotics has opened up new horizons in the field of education. In recent years there have been remarkable efforts by both european/ international and local bodies to disseminate and consolidate educational robotics in schools and in general at every level of education. In parallel with the flourishing of STEM education, there are additional activities to integrate art, so that learners cultivate their skills as holistically and multifaceted as possible. The application of innovative teaching methods certainly leads to the more efficient transmission of STEM and robotics concepts in education. However, for a complete integration of these into any educational system requires time and collective effort. The addition of art ('a' letter for Arts) to the acronym STEM and its change to STEAM shows that it can be a learning incentive for a wider audience (old aged, different social/cultural groups) and help them familiarize themselves with the digital skills required by the new digital age, while perhaps previously felt excluded from the use of technology. The photography's project using the raspberry pi platform presented in this paper is a simple first step of contact with programming in python. Similar platforms such as Arduino or Micro:bit can be used from all ages, enabling trainers and trainees to choose from a huge range of projects (beginners/advanced) whose completion has tangible results with utilitarian value , giving users not only the joy of creation but also the prospect of evolution in the field of information technology. As conclusion, let's keep the idea that the construction process of building any kind of object (for example even a home) need much more time and effort if there is no collaboration between different kind of team members/characters. At this point, educational robotics and STEAM find truly a creative path to apply and thrive. Finally, a balanced learning environment between theory and practice is the key for a more successful implementation of innovative contents to education like robotics and STEAM activities. However, educational robotics and STEAM leave space for further research and especially the education of adults in these fields is a topic that has not been deeply investigated yet.

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