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Implementation of STEM Tinkering Approaches in Primary School Education in Greece

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In this paper, they are presented the experiences that emerged from the implementation of STEM approaches in primary education in Greece, given the context in which schools operate. The aim is to stimulate discussion on the possibilities and feasibility of introducing STEM activities in Greek schools. Two public schools in Attica were selected as pilot schools to test the proposal in which eight different actions were implemented in different grades. Indicatively, one of the actions implemented for nine classroom hours in elementary school (K5) is presented. From the literature review and the implementation of these actions, it has been demonstrated that while existing curricula have not incorporated the STEM education methodology into their goals, there are links that allow teachers to apply it. In addition, it appears that the scenarios will have to be carefully designed, be clearly depicted and receptive to accepting solutions proposed. In parallel, the positive effect of these actions has multiple levels of impact on students (cognitive domain, affective domain, and psychomotor domain).

Keywords: STEM, primary education, educational application, Greece

Introduction

In an increasingly complex world, it is more important than ever for today's students and tomorrow's citizens to acquire the knowledge and skills they need to solve problems, gather and evaluate the data available to them, and understand the meaning of the information given to them. These are the kinds of skills that students develop through the study of science, technology, engineering, and mathematics, an educational approach known as STEM (U.S. Department of Education, 2015). The importance of these approaches to (either all of them will have the or none of them will) education, society, and the economy is reflected through the emphasis on funding, with significant sums being devoted to developing strategies for integrating and implementing STEM educational approaches for primary and secondary students, which are the future generations of scientists and citizens (Britt, 2015). At the same time, in many countries, we come across modern curricula that introduce STEM approaches from early education into formal education but also through non-formal education activities. On the other hand, in Greece, there are no explicit references to the current curriculum for applying STEM approaches (Hellenic Paidagogical Institute, 2003).

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According to researchers (Glancy & Moore, 2013), the fundamental goal of any STEM program should be for the students to develop evidence-based thinking of mathematics, design thinking in engineering, and research in science and computational thinking in technology, while being separate and independent approaches are interconnected through problem solving and experiential processes.

Focusing on the results of a meta-analysis of approximately 500 studies on STEM education, it appears that students through STEM education acquire skills and abilities that they do not acquire in the conventional teacher-centered way of learning. STEM education empowers students to solve real life problems and acquire logical thinking (Mustafa, Ismail, Tasir, Said, & Haruzuan, 2016).

Tinkering and Open Source Programs

STEM education is highly dependent on the appropriate supportive environment for human resources and training tools. Much of the STEM activities that are widespread are educational robotics, for which teachers need the right educational platforms, software tools, and educational material to implement them, and the school needs a respectable budget to achieve this. The cost of educational robotic kits is seen as the main obstacle for a school to acquire the technological tools needed to implement them (Chatzopoulos, Papoutsidakis, Kalogiannakis, & Psycharis, 2019).

An alternative way to implement STEM activities is through tinkering. We could describe tinkering as a playful approach to problem-solving through experimentation, exploration, and direct involvement of students with the creation of low-cost self-builds.

The Arduino and Raspberry Pi platforms are suitable for planning simple materials. They provide students with a more expansive space and opportunities to develop initiatives, use, and handle materials with more technological capabilities, a wealth of experimentation and exploration tools. However, there is greater difficulty in handling them from younger pupils.

The playful nature of these activities, which draw on students' past experiences, arouses greater interest in students and increases their motivation for active participation. Tinkering could be seen as an endless playful exploration that promotes problem-solving skills, creativity, and innovative thinking. Students develop problem-solving skills, use of tools, and develop scientific thinking, within the framework of collaboration develop relationships of trust and support among team members and leadership skills (Vossoughi, Escudé, Kong, & Hooper, 2013; Bevan, Petrich, & Wilkinson, 2014; Vossoughi & Bevan, 2014).

STEM in Greece

In Greece, the education system is structured based on a centralized design followed by all schools, leaving little autonomy in the school units. The curricula are common to all schools and are taught by specific textbooks. Similarly, the curricula allow a limited number of hours that only to the first grades of primary education, where teachers can choose the subjects to teach according to the needs of their class. In recent years, the amount of syllabus has been reduced to allow teachers to apply alternative approaches to most subjects. Where there is greater freedom, they are in schools that participate in research programs where they are given the opportunity to implement and test alternative approaches.

In the current curricula of primary school education in Greece and the educational material that is common to all schools, there is no interdisciplinary methodological approach. At the same time, more modern curricula have been developed describing activities that correspond to the philosophy of STEM education, but there is no formal structured integration into schools (Hellenic Institute of Educational Policy [IEP], 2014).

In the last quarter of 2017, the Educational Policy Institute (IEP) as national coordinator for Greece of the European Project H2020: "Open Schools for Open Societies (OSOS)", advanced in the call for interest of school units for their participation in the pilot phase of the OSOS project which has been implemented from the 2017-2018 school year. The focus of the project is on STEM approaches in topics that enhance both the connection of the (natural sciences) with technology, mathematics and engineering, as well as the connection with modern social concerns.

For the pilot phase of the project, 10 pre-primary, primary, and secondary schools were selected which also have the role of multiplier/coordinator in expanding the project to 90 schools in the country in the 2018-2019 and 2019-2020 school years (Hellenic Institute of Educational Policy [IEP], 2017).

Researches (Smyrnaiou, Petropoulou, & Sotiriou, 2015; Kotsifakos, Kostis, & Douligeris, 2017; Psyharis, 2018; Psycharis & Kotzampasaki, 2019) on STEM approaches to formal and non-formal education in Greece have shown that positive results of these approaches, such as promoting and improving the educational process, enhance student performance in coding, and most teachers and students view positively the prospect of integrating STEM methodology into teaching.

The above figures highlight a growing dynamic for the introduction of STEM activities in the educational process in Greece. However, it is found that the implementation of STEM activities is fragmented and isolated without the systematic and long-term implementation of STEM in schools.

The paper analyzes the effort to introduce STEM education into two publicly owned Attica elementary schools selected as pilots of the European H2020 Project: "Open Schools for Open Societies (OSOS)".

Sample Characteristics

Our research has been based on the 26th and 29th Acharnes Primary Schools which are located in the Olympic Village of Athens and have been operating since 2006 and 2008 respectively with approximately 280 pupils. The two schools are co-located and co-operated in their full range of activities.

Due to the very low educational and socio-economic indicators of the region and the high proportion of students with learning or other disabilities, since 2010, they have been included as pilot schools in the National Strategic Reference Framework (NSRF) 2007-2013 Program of Priority Educational Zones (ZEP) which was extended to 2015.

In the framework of the Priority Educational Zones for the school years 2011 to 2015, approximately 70 educational actions were implemented. All the actions were designed and implemented by the teachers after being first evaluated by a special ZEP scientific committee and approved by the Education Ministry of Greece. In implementing the actions, in addition to the pupils and teachers of the schools, parents and local community stakeholders were also involved, thereby enhancing the dynamics and effectiveness of the actions.

In these school actions, there was no explicit reference to STEM education, but after evaluating them based on official data, it is observed that 18% of the actions involve three STEM subjects while 23% of the actions are involved in all four STEM subjects (26th-29th Primary Schools of Acharnes, 2017, http://www.ovs.gr). At the same time, almost all of the actions involved inquire procedures for solving everyday life problems.

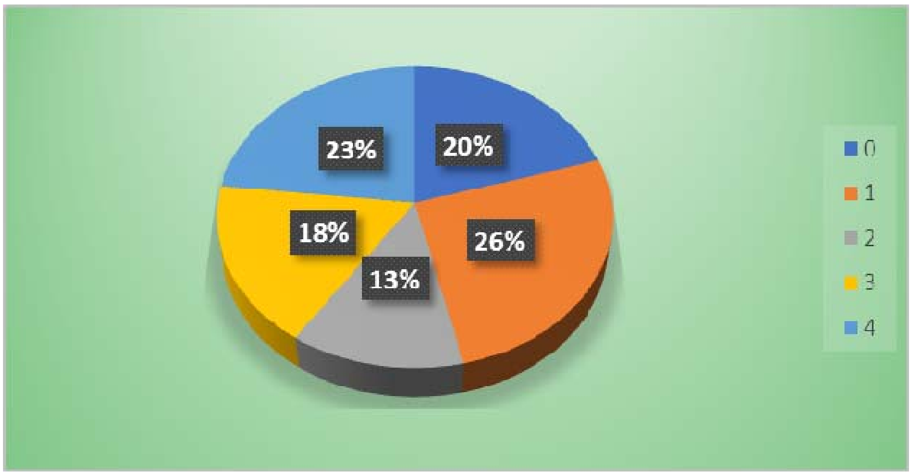

Figure 1. Percentage of actions depending on the number of STEM objects.

After the end of the ZEP pilot program in June 2016, teachers have been continuing to design and implement educational activities. By integrating schools as pilots into the OSOS program (October 2017-), they were given the opportunity to reshape their curriculum into a coordinated framework of actions.

As part of the OSOS program, teachers have implemented STEM educational approaches in different grades, following differentiated and interdisciplinary approaches.

The actions were:

- Bridges;
- Help from above;
- Low flights;
- Tall buildings large constructions;
- The wonderful world of bee;
- We paint like Mondrian;
- I respect myself, I want to eat healthy;
- The journey of a drop;

The activities were carried out in collaboration with teachers of different specialties.

The Application

An example of the activities is the action "Bridges" implemented in 5th grade for nine hours. This activity was integrated into the school's action series entitled "Small Engineers Large Buildings".

The materials used in the activity were simple cardboards, cords, and various connectors, whereas the material used for the digital interconnection of the constructions was Arduino microcontroller, LEDs, servo motors as well as step motors.

The educational tinkering approach was structured in three phases, with increasing degrees of difficulty. Students worked in groups of five or six students. Since the teacher knew each student's interests and skills when dividing the groups, there was intervention by the teacher so that the team members could combine different skills.

At each phase, a "challenge/problem" was given to the teams that had to work collectively in order to suggest, design, control, and create their constructions with the materials available.

In the first phase, on the occasion of the module of the Greek language lesson of “Constructions”, the students got to know different kinds of bridges, discussed their impact on human societies, their materials, the basic design structures applied to give them maximum stability, while special attention was paid to traditional stone bridges. The first challenge for the teams was to build cardboard bridges with the aim of building the most durable bridge using a smaller amount of cardboard. The teams followed different designs and implementation approaches, resulting in multiple designs, some of which were particularly effective. In the next phase, the challenge changed, and the teams were called upon to build bridges that could open their centerpiece. The teams had simple materials at their disposal. The teams again moved on to different design ideas and came up with imaginative solutions. The lifting mechanisms that they chose show great interest since they included winches, electric motors, and hydraulic systems made of syringes’ plungers. The last phase of the activities took place at the computer lab, where students used Arduino-controlled devices to turn on traffic lights and lift their bridges. The students work is available on the schools website at http://1dim-olympic.att.sch.gr/?p=751.

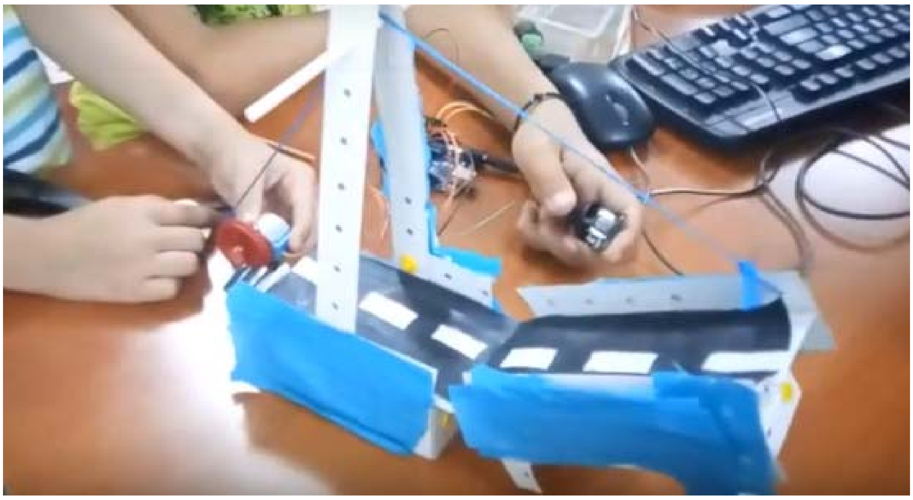

Figure 2. Bridge lifted by a mechanism using Arduino.

Results

Through the “Bridges” action and in general all the actions implemented in the schools under the OSOS program the pupils who participated in them:

- Acquired skills in using modern technological tools.
- Developed communication skills.
- Engaged in solving authentic semi-open type problems.
- Understood the concepts of the sciences and associate them with the technological applications that utilize them.
- Were concerned about the selection of best practices for resolving the problems presented.
- Were trained in the scientific way of thinking and working.
- Used simple and complex materials and tools that are not usually included in school usage.
- Developed collaborative and self-regulation skills within their teams.
- Everyone had an active role that was defined based on their individually skills and opportunities presented to the team.

- Had a positive change in attitude towards school and science.

Difficulties encountered by students in trying to create their own constructions were usually resolved within the group or with limited teacher support, but these difficulties led to the most interesting steps.

The differentiated and transdisciplinary approach that has been implemented has produced yet another remarkable result; the students who had the biggest positive change are the ones we would classify as “the two extremes”. About 1/3 of the students who participated in the activities were diagnosed with learning difficulties. Children who in a typical approach have significant difficulties and in many cases experience frustration have reduced self-esteem and interest in the lesson. As a result of these actions, what was recorded is that most of these students acquired active roles in their groups (by understanding and interpreting natural phenomena and principles), which resulted in changing the perception that others and themselves have about their individual. Students with higher than average performance also found space within the group to develop new ideas, skills, and especially interests.

We should point out that in many cases, the solutions that the students suggested were often far more creative and imaginative than we expected, which is the element that was common to all actions taken at school.

Furthermore, it appears that teachers who had already participated in similar actions in the past were more easily able to plan, organize, (nope) implement, and manage time and difficulties compared to teachers who did not have the relevant experience.

Conclusions

The paper is an empirical record of the data of a STEM approach application in a school classroom that has been implementing STEM activities for about 10 years and teachers have some experience in STEM activities. The overall process has shown that STEM activities in primary education, as supported by other researchers (Bottia, Stearns, Mickelson, & Moller, 2018) besides being pleasant, provided they have the appropriate conceptual framework, allow students to think, seek solutions by developing their imagination and creative thinking, but also to collaborate, communicate, and self-regulate their teams. A key element in these interventions is the selection of appropriate scenarios, and as reports by researchers (Moore & Smith, 2014), allowing the students to feel that they are involved in solving real problems, which they are trying to solve and control their results immediately.

In an exploratory process, the difficulties and possible failure of the constructs and/or the experimental processes are part of the learning process and with proper management lead to learning, as other researchers support the mistakes and difficulties (Vossoughi et al., 2013), are not negative but necessary steps to develop methodological approaches that will allow them to discover new ideas that will lead them to the solution they are thinking. The phrase “learn from my mistakes” could be said to represent tinkering and making activities.

Summarizing, we might argue that with these direct student engagement processes, we have a positive impact on cognition, skill development, and classroom climate—turning the learning process into a dynamic interaction between students, highlighting each student’s unique abilities. The results are consistent with findings from a meta-analysis (Freeman et al., 2014) that demonstrates the positive effects of active learning. In our implementation, we were interested in collaborating with teachers of different disciplines who highlighted multiple dimensions of STEM education, combining different perspectives in approaching problems. An important role in the effectiveness of the intervention is to delineate the conditions of implementation of the activities, so that the educational process does not deviate, leading the students to wrong conclusions.

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