ROBOAQUARIA: ROBOTS IN AQUATIC ENVIRONMENTS TO PROMOTE STEM AND ENVIRONMENTAL AWARENESS

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Abstract

This paper examines the effectiveness of a funded program, called ROBOAQUARIA, running in five different countries. It focuses on using Robotics in the marine environment. Its main aim is to promote STEAM education, integrated with environmental topics, in elementary schools. This is attempted through both theoretical and practical activities. The effectiveness of the program is approached by examining how participants respond in what concerns the impact of the program in teaching practices, content knowledge, and professional development. The data for the research came from reports submitted by each country. The findings are generally positive.

STEAM Education

STEAM Education has gathered attention of researchers, teachers, policy makers over the last decades. Initially, it is perceived as a new field of study, which encompasses topics from different areas: Science, Technology, Engineering, Arts and Mathematics. However, STEAM education, and the research interest around it, is not restricted only to the new cross curricular content. It is considered as an innovation, which reflects general changing trends in schools, teaching practices, and perceptions. Due to its interdisciplinary nature, researchers and educators treat it as opportunity for greater change in school functions (Quigley et al, 2020).

STEAM Education Implementation

STEAM is linked to implementation of problem-solving activities oriented towards inquiry-based approach. Certainly, this type of approach is not new. In STEAM, it is considered the most appropriate approach, since through this, learners will deal with actual circumstances and challenges. They will be encouraged to construct knowledge, develop skills, and adopt attitudes on how to deal with issues relating to the component subject areas of STEAM, in a creative, cumulative and substantial way. The session should not be limited to asking the learners to memorize concepts or describe phenomena. They should be asked to design, plan, and create too. The problem-based approach facilitates a shift from traditional dominating, direct instructional teaching (Perignat & Katz-Buonincontro, 2019).

Moreover, STEAM is linked to a higher level of technology integration in teaching and learning. While dealing with everyday life issues and challenges, which can derive from fields such as Science, Engineering, Mathematics, learners will become familiar with how to use technology to deal with them, come up with solutions, and justify their work. Skills of digital literacy are crucial. STEAM should not be seen as a common usual Information Communication Technology (ICT) class. It should go beyond that. In combination with the problem-solving approach, thanks to technology integration, learners are expected to gain qualities and competencies that will help them become more creative, active, and competitive in their future lives (Cohen, 2017).

Simultaneously, STEAM is linked to Arts integration. The addition of the Arts factor can enhance even further the synthetic creativity of the new knowledge. This integration has different aspects. Initially, it is important for learners to understand basic points such as the fact that engineers and designers might focus on visual arts to improve their products or output. They would not only focus on function and productivity. Aside from that, they will understand how creativity integrates with problem solving situations, with the help of imagination, in planning and programming. In this context, the term “Arts” may describe not only visual and fine arts, but generally humanities and social sciences (Guyotte et al., 2015; Henriksen et al., 2016).

All these factors—problem-solving, technology integration, and art integration—prove that STEAM is not just a new subject but an opportunity for greater changes in the education context (Quigley et al., 2020).

STEAM and Environmental Education

STEAM is, therefore, associated with educating learners about crucial problems, including challenges of environmental nature.

Hsiao and Su (2021) carried out research on students who engaged in STEAM activities within classes that emphasized sustainable development. A total of 303 elementary school students took part in tasks that aimed to help learners develop self-efficacy skills and self-motivation towards acting to help the environment. These activities were based on Virtual Reality applications. With pre-tests and post-test questionnaires and a thorough application of inferential statistics, the researchers found a statistically significant correlation between an increase in self-efficacy and experiential learning and their impact on learning motivation, satisfaction, and learning effectiveness. They conclude "A good learning environment is all about undergoing an experience, and the improvement of students' self-efficacy greatly affects their learning satisfaction and learning outcomes" (p. 19), further suggesting that STEAM education can indeed help learners develop qualities that might help them become more environmentally concerned and conscious. They stress the importance of teaching through gamification, as a form of problem-based learning.

Chen and Lu (2018) carried out research focused on using STEAM for environmental matters around nutrition and agriculture. This research included designing six activities around relevant themes: environmental ethics; sustainable development; climate change; disaster prevention and response; sustainable energy resources usage; and quantity meter. These activities existed in the distributed Food and Agriculture Curriculum of Taiwan and used various applications of ICT, as part of STEAM Education. They implemented these activities in 106 elementary school students who completed questionnaires, as pre-tests and post-tests. Their analysis was both qualitative and quantitative. The results were encouraging as learners developed deep understanding expressed motivation to work towards working out relevant challenges in future.

Santi et al (2021) published a bibliometric study around the connection between environmental education and STEAM. By searching with the help of VOSViewer, the authors collected 30 articles from 25 journals, published between 2013 and 2020. The journals were focused on various research areas, such as physics, mathematics, environmental studies, computer studies, social sciences, education or humanities. The articles were written by a total of 91 authors, from 13 different countries, with the United States of America having greater number of contributions. This shows that there is a rising trend in researching how STEAM can indeed assist in environmental matters, at an international level. The main keywords identified were: Research and development; Educational technology; Flipped Classroom; Electronic platform for education; Critical Thinking; Teacher Effectiveness Steam oriented educational environment; Comparative effectiveness; Electronic assessment; Learning STEAM oriented approach; Technological science; Educational resources; Educational environments; and Integrated steam education. This proves that the themes investigated have to do with learning approaches, contexts, themes and goals.

In conclusion, the relationship between STEAM and Environmental Education is complex. That is why researchers, from various fields, over the last years tend to examine it thoroughly (Santi et al., 2021). Teaching environmental education with the help of STEAM, according to researchers, should be well-planned and should be focusing on setting the conditions for conscious adults. This way, it will set the foundations for long-term solutions (Chen & Lu, 2018; Hsiao & Su, 2021).

Dimensions of Educational Innovation through STEAM

The implementation of STEAM in schools is approached as an attempt for educational innovation. This innovation is observed in different levels of the school functions. Starting from the main elements of problem-based learning, technology integration and art integration, STEAM affects different dimensions, regarding the work of teachers and members of the educational community (Quigley et al, 2020).

Certainly, the first dimension is about *teaching practices*. To achieve the appropriate methods, such as problem-based learning and integration activities, teachers need to become familiar with new practices, which will help learners understand the necessity of STEAM and their potential to deal with various problems. Teachers—who are the moral agents of reform (Fullan, 2020), as they will have to implement any attempt to reform and innovate in education—should understand what the better ways are to deliver the new learning outcomes. It is important to estimate teaching practices, actual or new, so that they can see which fits better to their work and goals. In doing so, they should see which practices are more appropriate for the learners they have and the place where they work (Cohen, 2017; Fullan, 2020).

The second dimension is about the *content*. STEAM has to do with Robotics, which includes understanding what robotics is, how it works and how it can be used to analyse and learn around issues. In the case of this study, it is important to stress how Robotics relates to environmental subjects, how it can promote environmental awareness and lead to environmentally literate and concerned citizens. Within this, teachers should help learners understand how integration works, so that learners will also be generally able to combine knowledge, skills and attitudes of different subjects (Guyotte et al, 2015; Cohen, 2017).

The third dimension is about *professional development*. Teachers need continuous training about STEAM and innovation. This will help them deepen their knowledge and expertise in teaching STEAM, in theory and practice. The topics that this professional development should focus on will have to do with content and practices, but other issues too regarding innovation. Challenges always arise whenever innovation is implemented. Moreover, there should be continuous evaluation and assessment. Professional development should therefore pay attention to challenges and assessment. It is especially important to establish cooperation and collaboration. Teachers should interact among themselves and with members of education community. This will increase discourse, exchange of experiences, and information, and can lead to more effective professional development (European Union [EU], 2023; Fullan, 2020; OECD, 2019).

In short, three basic dimensions of innovation through STEAM, particularly in environmental education, are: the practices that teachers should adopt and apply; the content knowledge they should deliver; and the professional development they receive generally and specifically about the innovation. These dimensions are interrelated. By examining them, it is possible to gain insight into the effectiveness of STEAM innovation (Cohen, 2017; European Commission [EC], 2023; Fullan, 2020; OECD, 2019).

The Study

This research project was planned bearing in mind the potential of STEAM to assist in promoting important skills to learners. The project named "ROBOAQUARIA: Robots in Aquatic Environments to Promote STEAM and Environmental Awareness" is program funded by the EU. It is planned to run from 2022 until 2025 as a consortium of ten partners from five European countries, Italy, Greece, Cyprus, Croatia and Italy (Scaradozzi, 2022).

Rationale and Design of ROBOAQUARIA

The idea of this project was based on the finding that STEAM can assist in developing active citizens, who are critical thinkers and can implement combined knowledge from different fields, to overcome challenges or real life (OECD, 2019), along with the general policies which call for promotion of green skills, teacher training, behaviour shift, and awareness of environmental challenges (EC, 2023).

The project therefore aims to design marine robotics equipment in the shape of fish and deliver learning activities in schools. This aims to introduce an innovative approach to environmental education, through STEAM.

A curriculum on marine robotics is planned to include guidelines on how to construct marine robots, with emphasis on teaching, through a wholistic, interdisciplinary approach. Educators and members of school communities will engage on hands on activities, which will aim at the development of green skills, and environmental and sustainability awareness as well as coding. There will also be an electronic platform for information and further assistance (Scaradozzi, 2022).

Additionally, through these classes, learners are expected to boost further knowledge, skills, and attitudes around science and mathematics (OECD, 2019).

The main target groups of this project are the teachers, who will receive training not restricted to only assembling kits and superficial coding. Instead, it will go deeper into issues around the need for STEAM Education, its potential and challenges. In fact, by the end of the program teachers will expand their expertise in carrying out interdisciplinary training programs related to the promotion of sustainability and green skills through coding and robotics. They will also improve their capacity to influence policies around using digital technologies in education at local, regional, or national levels. Through the distribution of material with the websites and through actions such as conferences, activities, and participation in education events, the project, its rationale and progress, will be presented in the academic community and the wider public too, including policymakers and stakeholders (Scaradozzi, 2022). This way, the project will set the foundations for further and greater reforms within the schools. The support provided to teachers, school leaders, and school communities will go beyond a temporary pilot application of an individual teaching approach. Instead, it will be an initiative for further reform in functions and ideas of the school system (Fullan, 2020).

The innovation of this program lies in several points. First, it includes implementation in several countries. Moreover, it focuses on elementary school students, who are expected to learn about Robotics and carry out activities to deepen their knowledge, skills and attitudes towards environmental issues and make decisions (Scaradozzi, 2022). The previous research linking STEAM with environmental education seems to emphasize other parts (Chen & Lu, 2018; Hsiao & Su, 2021; Santi et al, 2021). Here, the combination of theoretical and practical teaching of STEAM can make more precise the potential of the elementary school context to embed STEAM activities regularly. In other words, it can give insights into the level at which the school culture changes, to lead to more STEAM-friendly schools (Fullan, 2020; EU, 2023).

Methodology

The scope of the study therefore is to examine whether the schools that participate in this program adapt so that they can accommodate STEAM activities effectively, specifically for the program ROBOAQUARIA and more generally as well. Any innovation implemented in schools should have such focus (Fulan, 2020). This scope can be achieved through three basic research questions, which reflect the dimensions of innovation through STEAM (Cohen, 2017; EC, 2023; Fullan, 2020; OECD, 2019). The questions are formed as follows:

1) Do the teachers adopt new practices to apply STEAM activities?
2) Can the content knowledge be delivered appropriately?

3) Is there sufficient professional development provided generally and specifically about the innovation?

The data for the research were collected through reports that each country must submit, as part of the program. These detailed reports present the progress of the programs' implementation in the schools. They include questions regarding the three dimensions, the practices, the content knowledge, and professional development. They are completed by a group of participants and researchers who are in direct communication and cooperation with the schoolteachers and include data from the implementations in schools. Since they are formally part of the funded program, it is strictly evaluated that they are substantial, cumulative, factual, meticulous, and correct. Therefore, they are considered accurate data sources.

These reports were submitted by June 2023 and collected to be analysed. Analysis was based on qualitative methodology through coding with themes and codes (Yin, 2015). Three basic themes or categories were used. There were "practices", "content knowledge", and "professional development". Each corresponded with the relevant research question.

Each theme included several codes. The theme of *practices* included the codes: problem-solving, technology integration, arts integration, planning, learning outcomes. These reflect the basic points of practices related to STEAM (Perignat & Katz-Buonincontro, 2019). The theme of *content knowledge* included the codes: environment, technology, digital literacy competencies. These reflect the basic points of content knowledge teaching through STEAM (Cohen, 2017). Lastly, the theme of *professional development* included the codes: training, challenges, evaluation, school culture. These reflect the basic points of professional development in innovation (Fullan, 2020). The relevant themes and nodes in the reports were gathered and analysed, so that basic findings and conclusions can be drawn (Yin, 2015).

Discussion and Findings

The results of coding show that the report of each country mentioned the codes. This probably indicates that all countries justified the importance of the basic dimensions or themes of STEAM teaching (Cohen, 2017; EC, 2023; Fullan, 2020; OECD, 2019).

Teaching Practices

With regards to teaching practices, there was mention of all the codes. It was particularly interesting to come across mention of specific practices in the reports, which were coded under "problem-solving", such as "*Active engagement of the* *classroom using the strategies of working in group, cooperative learning, laboratory activities, learning by doing and peer tutoring. Also, involving students in problem solving activities and problem based learning. Storytelling and debate could help integrate the 'A' of STEAM, but also tinkering and 3D printing activities".* Such responses show that teachers appreciate the necessity of problem solving through inquiry-based teaching in STEAM, which are mutually related (Perignat & Katz-Buonincontro, 2019).

Integration with technology and arts was also frequently pointed out, in responses such as "*Interdisciplinary integration plays a key role in STEAM education, as it combines science, technology, engineering, arts and mathematics to provide a holistic and integrated learning experience for students. Teachers can promote a range of core competencies and prepare students for the complexities of the modern world by integrating multiple subjects and skills into their lessons".* These quotes show that teachers appreciate integration; they believe that STEAM assists and they intend to implement it, in their practices, as is indicated by literature (Cohen, 2017).

With regards to arts integration, there were schools that mentioned that STEAM activities can be combined with activities such as storytelling, or activities that can address to learners of different backgrounds, which they stressed as issues that concern generally the teachers' work and context, which perhaps means that STEAM innovation can assist in this aspect too, by improving school culture (Fullan, 2020).

Lastly, there were codes that showed that teachers put emphasis on learning outcomes. A response that encompasses these codes was "*Many careers today require a combination of skills from multiple disciplines. By incorporating cross-disciplinary integration, educators can better prepare students for diverse career paths. STEAM education nurtures a well-rounded skill set that is highly valued in fields such as engineering, technology, design, scientific research, and entrepreneurship*."

All these responses show that teachers are familiar with practices that promote STEAM implementation efficiently and they are eager to implement them. This can enhance the school potential to embed STEAM regularly (Quigley et al., 2020).

Content Knowledge

With regards to content knowledge, all codes were marked in the reports. The partners emphasized the issue of environment, as it can "*help students understand basic principles in a tangible way (proposing tangible activities) and making them aware that issues about the environment are felt by all the local community and not only. We are all humans sharing this one Earth.*" Another report mentioned "*Environmental education was emphasized for ecological awareness and* *sustainable practices*". Such responses show that teachers can connect environmental issues within the STEAM project, as part of the content knowledge transferred, which is a desired goal (Guyotte et al, 2015; Cohen, 2017).

Technology was also frequently mentioned. Indeed, all partners mentioned that learners enhanced their knowledge, regarding ICT, Robotics, and coding. They added that they had the opportunity to teach topics that are not involved in their national curriculum, which they considered a significant advantage of the project. So, knowledge about technology is included in the content knowledge which has the potential to be delivered in the project (Cohen, 2017; Quigley et al, 2020).

Similarly, the digital skills competencies code was noted, as participants mentioned that learners managed to understand the necessity of teamwork and collaboration. One teacher reported "*Participants also recognize the potential of Educational Robotics in cultivating 21st-century skills including problem-solving, creativity, communication, and critical and analytical thinking. They discussed successful strategies such as using programmable robots, coding platforms, and national and international initiatives (e.g. competitions, involvement in European projects, etc.) to motivate students and make learning more interactive*." Responses such as this one show that teachers believe that this project can help students develop qualities of active citizens, which is essential in innovation through STEAM (Guyotte et al, 2015).

Professional Development

The nodes concerning professional development were all coded too. Training was mentioned as necessary for the effectiveness of the program. In fact, a report mentioned that teachers should propose "*More professional development opportunities, so that teachers can: a) realise the importance of STEAM education and educational robotics and their great pedagogical potential in teaching about the environment, b) gain the relevant knowledge and skills to be able to use tools and platforms available, c) develop the relevant confidence to implement innovative activities in class"*. At the same time, another report mentioned that it would be useful to seek ideas such as "*Establishing clear development strategies and priorities: Schools can benefit from developing clear strategies and setting priorities to guide the implementation of STEAM education, educational robotics, and environmental education. This includes seeking support based on specific needs and actively addressing resource and space challenges".* These responses, although they reveal that teachers might lack adequate training, also suggest they are willing to take advantage of opportunities, so that they will be able to implement innovation in STEAM, which is crucial (Fullan, 2020).

Challenges were also mentioned. Participants commented that they are concerned about having the necessary equipment, infrastructure, resources, and tools, and finding time. These are common challenges that emerge whenever innovation is attempted within a school context (Fullan, 2020; OECD, 2019). Despite these challenges, teachers emphasized that they are willing to carry on with the program, which raises the possibility for the innovation to be successful (EU, 2023; Fullan, 2020).

The method of evaluation was also discussed in the teacher reports. Participants suggested that it would be beneficial to have peer assessment and collaboration that can give significant feedback. According to a report, "*Participants highlighted the fact that there is not a structured assessment procedure to evaluate students' learning in the field of STEAM education, educational robotics, and environmental education. Different assessment methods and strategies were proposed to evaluate students' acquired knowledge"*.

The parameter of school culture was brought up as well. While making a summary of the implementation report, a participant commented that "*Throughout the discussion, participants shared valuable tips and recommendations based on their teaching experiences. They highlighted the significance of providing professional development opportunities for educators to enhance their knowledge and skills in STEAM education, Educational Robotics, and Environmental Education. They also stressed the importance of structure support from the Ministry of Education as well as the collaboration among teachers, schools, and stakeholders to share best practices, resources, and overcome common challenges*". Such comments show that participants appreciate the need and the potential of STEAM to improve school culture, which is essential if the reform is to have a long-lasting impact on school functions (Cohen, 2017; EC, 2023; Fullan, 2020; OECD, 2019).

Conclusions

This study examined the implementation of a program called ROBOAQUARIA, a funded program that includes Robotics in a marine environment. STEAM and Robotics education combine teaching of different subjects: Science, Technology, Engineering, Arts, and Mathematics. STEAM activities can help schools shift from traditional subjects to new patterns of teaching and function, with problem-based, technology-supported activities of integration that enhance qualities important to citizenship (Quigley et al, 2020). ROBOAQUARIA is a consortium of five European countries, Italy, Croatia, Cyprus, Greece and Ireland. It focuses on using STEAM to promote environmental awareness. Compared to other similar projects, it is innovative as it includes practical robotics activities in elementary schools (Scaradozzi, 2022).

To examine the effectiveness of this program, an implementation report was collected from each participant. The data from these reports were analysed through a qualitative analysis, against three basic dimensions of STEAM implementation: teaching practices (Perignat & Katz-Buonincontro, 2019), content knowledge (Cohen, 2017) and professional development (Fullan, 2020). The results show that teachers are willing to adopt new practices, which they consider as more appropriate for STEAM teaching. In addition, significant content knowledge about environment, robotics and digital technologies can be taught. Moreover, there is appropriate concern around professional development, which can lead to improved school culture and function thanks to the program. All these findings signify that this project is implemented successfully and can have significant impact in schools (Fullan, 2020; OECD, 2019).

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