Practices in STEAM Education: Integrating Art and Robotics at Primary Education Skills Workshops with Thymio robot

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Abstract

Skills Workshops are considered compulsory in Greek schools, paving the way for the reconstruction and update of teaching practice. The STEAM (Science, Technology, Engineering, Arts, Mathematics) educational approach in the context of workshops can widen its application, bending or removing the boundaries between disciplines. However, the differentiating element of Art is often of secondary importance, compared to Educational Robotics and the other aspects of STEAM. This study proposes an educational program integrating the Thymio robot, specifically tailored for the Skills Workshops. It outlines the pedagogical framework (a well-defined pedagogical approach that focuses at the integration of art and robotics), the implementation strategies (practical steps for classroom activities), and the outcomes of pilot activities (description of pilot application and discussion of emerging results from teachers self-reflection form that serve as case studies), highlighting the potential for a more holistic educational experience that prepares students for the complexities of the modern world.

Keywords: STEAM, Art, Thymio, Skills Workshops

Introduction

The Skills Workshop Curricula that replace the Flexible Zone in Primary Education create the conditions for the design and implementation of innovative pedagogical approaches to transform teaching. The emergence of new desired skills in terms of both Education and the labor market, entails changes in the learning content and teaching methodology. A STEAM approach incorporating Art, aspires to exceed the main goal of STEM, the training of professional scientists, who solve issues of the technological world, while at the same time applying principles of exploratory learning, cooperative learning, and learning based on problem-solving (Mikropoulos, 2021).

Educational Robotics (ER) which was intertwined with STEM now finds a place in STEAM education, although it is often integrated into the new technologies curriculum. Associated with STEM, it contributed to introducing students to learning subjects related to computer science and programming, whereas with its integration into STEAM, it is combined with literature, history, music, art curricula (Karypi, 2018). Although the growing number of STEAM

education programs worldwide testifies to their appeal to the learners and educators involved, it goes hand in hand with the prominence of technology and robotics at the expense of art. The primary purpose of this study is to design a scenario, where the basic elements of a modern pedagogical model of the STEAM educational approach, will be creatively intertwined, with a focus on Art and Educational Robotics, within the framework of the Skills Workshops.

Skills Workshops

The implementation of Skills Workshops (SWs) in Primary and Secondary Education has been met by the educational community, with skepticism regarding the readiness or adequacy of teachers to teach, the minimal teaching time about the voluminous content of disciplines, the deficiency in the facilities of school units (Pradaki, 2022). Numerous obstacles were noted among them distance learning, the absence of direct contact with students, the closing of schools due to the pandemic, the insufficient infrastructure of schools and the acceptance of the action by a large part of the teachers (Christou, 2021). In addition, teachers participating in the educational act of SWs that was piloted in the school year 2020-2021 emphasized the difficulty of the pressing timetable for the implementation of the 4 incorporated cycles (Christou, 2021).

The SWs, however, are an innovative, dynamic, educational initiative that is substantial for the development of students' basic skills. The four target circles (1.21st century skills, 2.Life skills, 3.Technology, engineering, science skills, 4.Thinking skills) correspond to the targeted skills, which are sought to be strengthened throughout life, since these, promote the development of citizens who may adjust to changing workplaces but also to social life while at the same time contributing to the response to the complexity of the modern world (FEK 3567/B′/04-08-2021). The four cycles which form the core of the design of the workshops carried out in the school units, are interrelated with the four thematic units (1.Well-being, 2.Environmental awareness, 3.Social awareness and responsibility, 4.Creative-innovative thinking) which emerged from the Global Sustainable Development Indicators and the United Nations Sustainable Development Goals.

As a parameter of the school's operation, SWs intervene in the organizational nature of education by upgrading its autonomy and redefining it from a "closed" to an "open" system. The modern program framework as formed by the application of SWs is structured with an open curriculum on a transdisciplinary and holistic basis (Asteri, 2021). In other words, every teacher who prepares the teaching plan, in order to teach SWs, organizes teaching actions considering the learning objectives but is not limited by disciplines. On the contrary, as SWs intersect the curriculum of other disciplines horizontally and vertically, they allow the merging of aimed knowledge by removing the boundaries between disciplines.

As the name "Skills Workshops" suggests, they are intended to be taught beyond traditional teaching methods of teacher-centered format. In the context of the Workshops, student-centered, group-centered and mixed teaching find fertile ground with the application of student collaboration practices, active learning, and peer teaching to approach not only life's daily but also the school community's problems. Indicative activities included construction, digital content projects, programming, and robotics.

Recent research data on their application confirm their positive contribution to the development of students' mental, social and digital skills. Pradaki (2022) investigating the opinions of 164 Primary Education teachers about the design, introduction, and implementation of the innovative action of SWs, through questionnaires, concludes that the learning outcomes of their students improved a little since the implementation of the program, while they benefited from it. Christou (2021) through 16 semi-structured interviews of Primary and Secondary teachers emphasizes the contribution of SWs in the acquisition of social, mental and digital skills of students, in the development of STEAM education and

educational robotics. Mammous et al. (2022) agree according to data collected by answers from 110 questionnaires, regarding the evaluation of the students' intended skills through the implementation of the activities of the thematic units, the educators gave a fairly high score to the learning skills acquired by the students.

Although SWs seem to improve student learning performance, research shows that this improvement might be small (Christou, 2021). Teachers express concerns about their readiness and competence to teach SWs effectively (Pradaki, 2022). In summary, SWs are a promising innovation in education, however, there are hurdles to overcome for their effective implementation.

STEAM

The STEAM educational approach, as an evolution of STEM, is increasingly expanding its application, thanks to institutions of either informal or formal education. Concerning formal education and specifically for Primary Education, the pilot introduction of SWs in the 2020-2021 school year and the universal application since then, provides the appropriate conditions for the expansion of the STE(A)M educational approach in every school unit.

The learning activities of the approach are designed to facilitate the construction, practice and expansion of knowledge as they are carried out. Indeed, it is applied in primary education, to familiarize students with the acquisition of knowledge, attitudes, and skills to solve real-world problems, and interpretation of natural phenomena, with the conclusions drawn based on the available data (Pasani, 2021). Also, students participate in assignments as citizens, constructing and reflecting on their knowledge while using ideas from science, engineering, technology, mathematics and arts. However, the STEAM approach is more than a methodological, instructional strategy. The integration of the basic principles of each field with art as interdisciplinary learning, in critical areas of mathematics, sciences, art through new technologies, constitutes a real innovation (Liao, 2019). Interdisciplinary knowledge and skills complement each other through collaborative practices, inquiry learning, active learning, working out projects with an emphasis on respect, social reciprocity, communication, promoting equality, i.e. with an emphasis on the social context of learning. Therefore, STEAM is a new vision to promote students' creativity, collaboration and collective existence through interdisciplinary awareness and consciousness (All Education Schools, 2019).

Several frameworks for teaching STEAM have been proposed internationally (Henriksen et al., 2019; Liao, 2016; Neofotistou & Paraskeva, 2017). For example, STEAM-integrated curriculum frameworks have been developed, such as the educational model which appears in the role of art but is aimed at gifted students (Lage-Gómez & Ros, 2021). Interdisciplinary and transdisciplinary approaches are also noted. For example, during experimentation with educational robotics activities for preschool students it was concluded, that educational robotics works effectively more as a means of exploring the possibilities of digital technologies in pedagogical learning environments rather than a lesson presented with instructions by teachers (Manera, 2019). The FASTER pedagogical framework consists of several key components to enhance STEAM education through educational robotics (Damaševičius et al., 2018). These components include project-based teaching, team-based learning, and educational robotics, learning scenarios, implementation and validation. Overall, the FASTER framework aims to create a synergistic relationship between different disciplines, enhancing student engagement and addressing the skills gap in STEM fields. Key aspects of the STEAM framework include interdisciplinary learning, creativity and innovation, hands-on learning, collaboration, focus on 21st century skills (Meletiou-Mavrotheris et al., 2022). Overall, the STEAM framework aims to create a more integrated and engaging educational experience that prepares students for a rapidly changing world.

Bertrand and Namukasa (2022) attempting to study which teaching stages of the STEAM approach promote a deeper understanding of Mathematics, ended up developing a new four-

stage STEAM pedagogical model. During the first stage, eliciting curiosity, which is a discovery and inquiry learning process, students are exposed to mathematical stories, photographs of real-life artifacts, drawings, and constructions of artifacts that may facilitate instructional connections. In the next stage, the design, collection and processing of data, information, elements takes place. Students deal with mathematical data, observe problems and situations, record processes, design to construct, make geometric measurements. In the third stage of construction, formation, completion, students use material from the previous stage to construct, create organize and synthesize information. During the fourth stage, diffusion and reflection on the final product, students have the opportunity to present a part of their work to an audience interested in mathematics.

Although Bertrand and Namukasa's pedagogical model contributes to the distinction of teaching stages, it is organized around Mathematics in STEAM (Bertrand & Namukasa, 2022). Thus one of the most critical elements in STEAM is the approach to Art and the rest of the STEM fields, cognitively and emotionally (Taylor, 2018). In this perspective the Arts provide the context where students enjoy experiences of success through their contribution to classroom work and receive positive reinforcement through their contribution to the learning of peers.

Arts and Educational Robotics

Incorrectly referring to the Arts only visual arts, painting, sculpture, and architecture are meant. Literature, poetry, theater, dance, music constitute art (Braund &Reiss, 2019).

The inclusion of arts, however, is not simply an addition to the list of STEM subjects. STEAM education incorporates art as both a teaching approach and inquiry-based learning. Henriksen ET al. (2016) offer examples where teachers use visual arts to demonstrate understanding of a scientific concept, music, or theater to explore a phenomenon. They also provide examples that demonstrate the deepening of understanding that can be achieved through multisensory learning, such as an experienced swimmer exploring the physics of waves, tides and currents, using prior experience, senses and additional knowledge to create new meaning (Quigley et al., 2020). It is a complex process of knowledge construction because students synthesize new knowledge through senses, experience, and new information. Arts thus lend themselves to the creative synthesis of knowledge, even though are often embodied only through the process of design, which is arguably an important component of visual art.

Several benefits of integrating the Arts into the STEM curriculum to create STEAM, have been highlighted as an outcome of research projects. Shukshina et al. (2021) suggest that the incorporation of creative elements into STEM education can increase student engagement and motivation, making learning more enjoyable and relevant. It also promotes a more holistic educational experience, encouraging students to apply theoretical knowledge in practical contexts and fostering a deeper understanding of scientific and artistic principles. Meletiou-Mavrotheris et al. (2022) support the enhanced creativity, the improved engagement, the holistic learning, critical thinking, collaboration skills, real-world connections and even diverse skill development. STEAM education nurtures a wider range of skills, including artistic, technical, and analytical abilities, preparing students for diverse career paths. Cultural awareness is remarked as the arts can introduce students to different cultures and perspectives, promoting empathy and social awareness. To sum up, integrating the Arts into STEM enriches the educational experience, preparing students to be well-rounded thinkers and innovators.

On the contrary, educational robotics as an innovation mean aims to prepare students for the future knowledge and society of information. Indeed, research attempts demonstrate learning benefits in terms of the development of social, cognitive and communication skills, although for Greece it is still at an initial, basic stage (Karypi, 2018). Robots are valuable educational tools, as they not only excite students but thanks to the multidisciplinary nature of robotic technology, they are related to fields of complex engineering, computer science,

and computer mathematics [24]. However, despite their potential, they are not widely used in schools due to cost and time. In particular, robots as modern, technological constructions have high purchase costs, which renders them inaccessible for schools that have limited budgets for educational equipment. Also, teaching reality with the integration of robots requires time for planning the activities, which are to be applied in the classroom and of course time, for teachers' training. Educating teachers on dual level, about functions and programming environment as well as the learning role robots possession beyond general-purpose tools. That is, as means that contribute to the development of creativity, cooperation and communication skills, cognitive skills, research skills (Karypi, 2018). Therefore, at a preliminary stage, it is considered necessary for the robot to be accessible, or in other words, that its basic operation does not require complex knowledge, so that it is accepted by the educational staff.

Thymio is a robot specially designed for children that include 6 ready pre-programmed robotic behaviors and ASEBA's accessible open-source programming environment. To detect obstacles in its front part there are five infrared sensors, in the back two, while to detect the black line on the ground, it has two other sensors at the bottom. It also possesses an infrared receiver for remote control, five touch buttons for its operation, speakers, a microphone, a three-axis accelerometer, a thermometer, 2 wheels with motors and 39 LEDs as color effects. Additionally, a hole between the wheels allows for a thin marker to be placed to draw while moving. At the same time the protrusions on its four upper corners are suitable for "building" with Lego-style bricks. It is an educational robot, considered suitable for elementary school students, since it gently introduces the visual programming language through exploration and experimentation (Shin et al., 2014). This robot, Thymio, offers a versatile design suitable for a wide range of age groups. In contrast, other robots like mBot are tailored for upper elementary students due to their focus on programming and coding, while BeeBot is designed for younger learners, lacking a programming interface and relying instead on directional buttons on its surface. Thus, Thymio stands out for its adaptability, incorporating both programming capabilities and arrow-based movement, making it suitable for integration into both upper and lower elementary classrooms.

In conclusion, despite the increase in STEAM education programs, art still plays a secondary role in advancing science technology. On the other hand, robotics technology is increasingly coming to the fore since it integrates scientific, technological and mathematical knowledge. However, a few scenarios are identified, where art is creatively combined with the use of robots and programming tools.

Methodology

Attempting to narrow the gap of the integration of STEAM and educational robotics in the unprecedented - for the Greek educational system - SWs, a pedagogical design was structured based on the model of Bertrand and Namukasa (2022). The choice of this model was not accidental. Firstly, it can be considered flexible in the sense that it allows its application to any age group regarding primary education. Secondly, it is not complex but realistic, i.e. based on it, there is the possibility of developing an educational program for every type of primary school. Third, it is identified as STEAM, so it is characterized by its interdisciplinary nature, even though it focuses on mathematical elements. Finally, it is up-to-date, as it was only shared in April 2022, so it is compiled with recent and older, scientific research data. Specifically, the model adopted the theoretical frameworks of Doppelts' creative design process (2004, 20099) and English, King, and Smeed's (2017) engineering design process as bases for analyzing the instructional models of four STEAM programs, resulting in the final model, as well four stages (Table 1).

Table 1. STEAM model of Bertrand and Namucasa

STEAM PEDAGOGICAL MODEL	
1st stage	Intrigue, generate curiosity
2st stage	Design and data collection
3st stage	Construction, creation and completion
4st stage	Reflection and diffusion

During implementation, the case study was preferred and qualitative and quantitative data were collected (Creswell & Plano Clark, 2018). The process was carried out in three phases. During the first phase, the educational material for the scenario (consisting of worksheets and the required materials), the teaching scenario evaluation form and teacher reflection form were compiled. In the next phase, the training scenario was implemented and the students' engagement was simultaneously recorded through collaborative learning activities and through the final work of art of students groups. A key indicator of students gained knowledge was the construction of the floating structure for the first grade groups and the achievement of designing geometric shapes as a result of coding Thymio for the fourth and fifth grade groups. The process was completed with the completion of the evaluation form of the educational material and reflection of the participating teachers. The present research was carried out after informing the schools headmaster about the goals, content, procedures of the educational scenario and its duration, while written consent was given. The teachers after being informed, expressed their desire to participate. A total of 51 students and 3 elementary school teachers took part.

To organize the activities of the STEAM scenario, the thematic units of the SWs and the curricula of mathematics, physics, arts and ICT were taken into account. The objectives of each discipline, inherent in STEAM, were analyzed to prepare the program according to the cognitive level and background of the students. The program was therefore included in the fourth thematic section "Creative-innovative thinking", in the sub-theme "STEM-educational robotics" and addresses students of 1st, 4th, and 5th grade. Its implementation requires 11 and 9 teaching hours for the 1st grade and the 4th and 5th grades respectively.

The 1st grade students, motivated by their contact with suspended works of art, attempt to create their constructions, after being divided into working groups. For this purpose, they use building materials, Lego-style bricks, the Thymio robot, whose manipulation will cause real movement in the construction and any other material that the members of each group decide is needed based on the design they will carry out (Table 2).

Table 2. Educational Program 1st Grade

STEAM EDUCATIONAL PROGRAM 1ST GRADE CREATING A FLOATING STRUCTURE		
Stage	Works hop	Learning contents
1st stage Intrigue, generate curiosity (2 hours)	1st	Investigating the main features of Morgan, and Calder's floating artworks. Discussion of materials used in the creation of the works. Project to create a floating sculpture with Lego bricks and the robot Thymio as a driving force. The division into groups.
2st stage Design and data collection (4 hours)	2nd - 4th	Observation of suspended projects and planning on paper of each group's project. Getting to know the Thymio robot: Observing the external characteristics, and practicing with the pre-programmed behaviors.

		Emphasis on the behavior of the "obedient", the purple mode which allows it to move with a remote control or with the arrows on its top.
3st stage Construction, creation and completion (4 hours)	5th - 7th	Construction of a floating project with bricks, incorporating the robot into the construction. Control the movement of the artwork by running the robot and applying the purple mode. Improvement and completion of projects. Present the works to the whole class explaining how each group worked and indicating which artwork was a source of inspiration.
4st stage Reflection and diffusion (1 hour)	8th	Art exhibition. Reflection on the collaboration with the classmates but also the satisfaction with the final product.

4th and 5th grade students created their visual art pieces drawing inspiration from paintings by Kandinsky, Klee and Picasso. To achieve this they programed the Thymio robot to draw geometric shapes. Students worked in pairs for programming but had the option of expanding collaboration with other pairs to produce projects with a variety of geometric shapes. At the end, all students worked together and created a group art piece. The works of all classes were presented in an art exhibition at a special event and are posted on the school website (Table 3).

Table 3. Educational Program 4th and 5th Grade

STEAM EDUCATIONAL PROGRAM 4TH AND 5TH GRADE CREATING ABSTRACT, VISUAL WORKS USING THE THYMIO ROBOT		
Stage	Works hop	Learning contents
1st stage Intrigue, generate curiosity (2 hours)	1st	Investigation of structural elements in paintings by Kandinsky, Klee, and Picasso (Cubism). Discussion about the creators of the works and argument about the possibility of creating works of art using Technology and Robotics. The robot Thymio is a painter. Work in pairs of students.
2st stage Design and data collection (4 hours)	2nd - 4th	Connect the robot with a cable or USB stick to the computer and access the Thymio ASEBA visual programming environment. Program and design straight sections with a marker in the hole between the wheels, using the timer and motors. Determine the relationship between time and speed. Measure the length. Program and design angles using the timer and motors to find the best combination for 60, 90, and 120-degree angles. Measure angles with a protractor.

| 3st stage Construction, creation and completion (3 hours) | 5th - 7th | Program and design triangles, squares, and polygons (each pair of students can draw one type of geometric shape, e.g. only squares). Create group projects and create a class project on meter paper. Coloring the shapes of each project using a variety of materials and means (brushes, sprays, markers...) |
| 4st stage Reflection and diffusion (1 hour) | 8th | Art exhibition. Reflection on the collaboration with the classmates but also the satisfaction with the final product. |

The program was pilot implemented by three teachers and their classes consisted of 15 first graders, 22 fourth graders and 14 fifth graders from a rural area school in Kavala city in Greece. After its implementation it was evaluated by the 3 educators to gather feedback, through a teachers' evaluation and self-reflection paper form (Tables 4 & 5). The evaluation form consisted of 3 axes in terms of the theme of the scenario, the pedagogical approach and the educational material and was graded at three degrees, poor, satisfactory and very good.

The self-reflection form also consisted of three questions which were formulated as "I have followed the steps as suggested in the "Educational Activities" field|", "I asked for and had support in obstacles that I encountered that made my work difficult" and "Note down observations, suggestions for improvement, difficulties, thoughts that you think can contribute to improving the model" (Table 6). There was also a provision of free space for the brief formulation of the methods in the first two cases, and a 3-point scale was applied to determine the degree of the manifesting behavior (poor, satisfactory, and very good).

Table 4. Model evaluation in terms of its theme

The theme of the model	Poor (1)	Satisfactory (2)	Very good (3)
It is aligned with the syllabus			
It corresponds to the cognitive level of the students			
It corresponds to the proposed implementation time			
It is current, modern			
Comments			

Table 5. Model evaluation regarding the pedagogical approach of STEAM and group-centered teaching

The STEAM educational approach and team-centered teaching of the model	Poor (1)	Satisfactory (2)	Very good (3)
It is aligned with the syllabus			
It corresponds to the cognitive level of the students			
It corresponds to the proposed implementation time			
It is current, modern			
Comments			

Table 6. Teacher reflection

	Poor (1)	Satisfactory (2)	Very good (3)
I have followed the suggested steps. **Briefly describe the method(s).**			
I asked for and had support in obstacles that I encountered that made my work difficult. **Briefly describe the method(s).**			
Note down observations, suggestions for improvement, difficulties, thoughts that you think can contribute to improving the model.			

Step-by-step instructions for implementing Thymio robot activities in a classroom setting, particularly for the proposed STEAM program were provided. During the preparation step they gathered materials like Thymio robots, building supplies, and computers with Thymio programming software. After the class was set up, desks were arranged for collaboration, and a dedicated robot activity area was created.

The introduction to the Thymio robot step followed where students were introduced to the Thymio robot. Its features, applications in robotics and art, and programming capabilities were explained. A demonstration showcased turning on the robot, pre-programmed behaviors, and button experimentation. Next step was the activity planning, consisting of the group formation, the project brainstorming, and design discussion. Divided into small groups, students brainstormed project ideas like floating sculptures or geometric drawings. They sketched their visions and discussed material choices and robot integration. The adventure then shifted to programming. Students were motivated to connect the Thymio robots to computers and opened the ASEBA programming environment, in order to learn basic programming tasks like controlling movements and practiced following lines or avoiding obstacles. Finally, each group wrote a program for their project, enabling the Thymio robot to draw shapes or move as part of a sculpture. The building phase saw collaboration and creativity blossom as students constructed their projects using the chosen materials, seamlessly integrating the Thymio robot. Testing followed to ensure everything functioned as intended, with troubleshooting sessions ironing out any kinks.

Finally, it was presentation time! Each group proudly showcased their project, explaining the design process and the role of the Thymio. An art exhibition displayed their creations, inviting other classes and parents to witness their ingenuity. A reflection session solidified their learning, prompting discussions about robotics, art, collaboration, and how to improve for future endeavors. The project culminated in feedback collection. Students openly discussed their experience, while the teachers assessed projects based on creativity, functionality, teamwork, and presentation skills and noted their experience at the self-reflection form.

Results

This section details the findings of the study on designing a STEAM program for Skills Workshops (SWs) that emphasizes Art alongside Educational Robotics (ER).

The current implementation of SWs prioritizes technology and robotics, neglecting Art's role in STEAM education. This program addressed the gap by incorporating Art and ER

creatively within the STEAM framework of Bertrand and Namukasa (2022). The program catered to 1st, 4th, and 5th graders, aligning with the SWs' thematic units and curriculum objectives. It leveraged the four-stage STEAM model by Bertrand and Namukasa (intrigue design & data collection, construction & completion, reflection & diffusion). Students of 1st Grade created floating sculptures with Lego bricks and the Thymio robot, inspired by renowned artists like Alexander Calder. Students of 4th & 5th Grades drew inspiration from Kandinsky, Klee, and Picasso to create abstract art pieces. They programed the Thymio robot to draw geometric shapes and collaborate to produce a group artwork (Figure 1 & 2). The program culminated in an art exhibition showcasing student creations and was further disseminated on the school website.

Figure 1. Students' engagement snapshots

Data collected from evaluation and self-reflection form evaluation offered insight to the relevance of the models theme, the educational approach. Participating teachers admitted that the model outlined in the syllabus, ensuring focused and relevant learning experiences and that the activities catered to the appropriate students' cognitive level. Furthermore they underlined the fact that it was effectively implemented within the allocated timeframe, allowing for proper execution and student engagement. Teachers agreed that the model utilized up-to-date concepts, resources, and approaches, keeping students connected with contemporary practices and trends. In terms of the pedagogical approach of STEAM, it seamlessly integrated with the syllabus content, fostering interdisciplinary connections and collaborative learning. The model leveraged group work efficiently within the timeframe, promoting interaction and knowledge sharing. During their self-reflection the educators recorded they followed suggested steps, so that the implementation adhered to the recommended sequence of activities and instructional strategies, ensuring a well-structured learning experience. They sought support from researchers when encountering difficulties, crucial fact that demonstrated a commitment to overcoming challenges and improving the learning experience. Its significance cannot be overlooked as it demonstrated the successful integration of Art and ER within SWs, fostering a more balanced STEAM approach. It encouraged creativity, collaboration, and problem-solving skills in students throughout elementary grades during the engagement with the incorporating activities in order to complete the suggested task, the creation of art, as teachers observed at the self-reflection form.

Overall, this research highlighted the potential of STEAM education with a strong emphasis on Art and ER to enhance learning experiences and develop essential skills in primary school students.

Discussion

The findings from the implementation of the STEAM program integrating the Thymio robot reveal significant insights into the potential of this interdisciplinary approach in primary education. The positive reception from both students- as their broad-based participation and involvement in all program activities was perceived- and educators- as recorded at the evaluation and self-reflection form, highlights the effectiveness of combining art with

educational robotics, fostering a balanced STEAM curriculum that enhances creativity, collaboration, and critical thinking skills.

The pilot program demonstrated that students engaged deeply with both the artistic and technological aspects of their projects taking into account that the robotic art products were created. By creating artworks using the Thymio robot, students not only learned programming and robotics but also explored their creative capacities. This dual engagement aligns with current educational theories advocating for a holistic approach to learning, where cognitive and emotional development are intertwined (Manera, 2019; Damaševičius et al., 2018).

Plan teaching based on the STEAM educational approach is a new fact for Greek, public education, which is increasingly gaining ground and at the same time is facilitated thanks to the establishment of SWs. Of course, individual attempts to apply STEM, which are not widespread in schools, have been noted for a decade, but they are shown and encouraged, because they incorporate ER. Teachers need training on STEAM education frameworks and integrating Art and ER into their lessons. The provided program can be a starting point for educators to design similar activities for their classrooms. Thus, emphasis should be on using robots as tools for creative expression alongside technical skills development.

However, the vast majority of public schools do not have equipment for robotics activities. The instructional design, which is based on scientific evidence, is modern and adapted to the data of the Greek school classroom, is admittedly of decisive importance for public, formal education. The didactic proposal that was attempted is compatible with the above criteria, given that it includes affordable equipment. Even educational robotics equipment presents low procurement and maintenance costs, as well as unlimited possibilities of utilization by all age groups of primary education (Mondada et al., 2017; Shin et al., 2014). At the same time, the STEAM educational approach with the integration of art unites the disciplines in a wider field of application (Henriksen et al., 2016), attracting all students even those who may feel insecure about the sciences and mathematics. Schools must ensure access to necessary resources, including educational robots and art supplies. Budgetary considerations should reflect the importance of STEAM education, allowing for the procurement of diverse materials that support innovative projects. At the same time schools should prioritize the integration of arts within STEM curricula to create a more cohesive STEAM framework. This can involve developing interdisciplinary projects that allow students to explore concepts across multiple subjects.

Policymakers should consider supporting STEAM education initiatives and providing resources for teachers to implement them effectively. Funding for professional development programs on integrating Art and ER into SWs would be beneficial. In addition, accessibility of educational robots like Thymio needs to be addressed to ensure wider implementation. Further exploration of integrating other art forms like music, dance, and literature into STEAM programs with robotics would be valuable. By addressing the educational needs and providing necessary support, educators and policymakers can make STEAM education a reality in classrooms.

Patently practical challenges may arouse. Implementing a STEAM program that integrates the Thymio robot across various types of schools can present several technical and logistical challenges. Addressing these challenges is essential for ensuring the program's success and sustainability. Many schools, particularly those in underfunded areas, may lack the necessary technology infrastructure, including computers and educational robots. The establishment of partnerships with local businesses, universities, or non-profit organizations to secure donations or sponsorships for technology resources or the application for grants specifically aimed at enhancing STEM education may constitute viable solutions. Educators may not be familiar with programming or using robotics in the classroom, leading to hesitation in implementing the program. Training workshops focused on both the technical aspects of the Thymio robot and pedagogical strategies for integrating it into the curriculum or even

implementation of mentorship program where more experienced teachers can support their colleagues in using the technology effectively offer practical overcoming of the obstacle.

Logistical challenges may concern time constraints, as teachers often face tight schedules, making it difficult to allocate sufficient time for STEAM projects that require in-depth exploration and classroom space limitations because not all classrooms are equipped to handle group activities involving robotics, particularly if space is limited. Flexible scheduling within the school day to allow for extended project time like block scheduling or dedicated STEAM days might be interesting ideas. About space limitations, outdoor learning, when appropriate, for certain activities, especially those involving movement and exploration and utilization of common areas such as libraries or computer labs for STEAM activities, could allow for more room to collaborate and create.

By proactively addressing these technical and logistical challenges, schools can create a more effective and sustainable STEAM program that integrates the Thymio robot. With the right resources, training, and support, educators can overcome barriers and provide students with enriching learning experiences that prepare them for the future.

In conclusion, it is generally accepted that teaching practice is not carried out smoothly. However, ER combined with STEAM facilitates the modernization of teaching and learning while aligning with global technological progress and school reality (Karypi, 2018). Art, whose birth coincides with human existence, contributes to the authentic and attractive teaching of Sciences (Braund & Reiss, 2019). The fusion of these elements may provide instructional designs that are flexible, adaptable, contemporary, applicable and effective. The integration of art and ER through the Thymio robot not only enriches the learning experience but also prepares students for the complexities of the modern world. By addressing the outlined implications for practice, policy, and research, educators can foster a more inclusive and effective STEAM educational environment.

Limitations

This pilot study presents several limitations that should be taken into account. Firstly, the generalizability of findings is restricted due to the small pool of participants. Secondly, the scope of implementation was focused on data emerging from the teachers' point of view rather than the students. Student engagement was evaluated primarily based on the final outcomes of each group's project, specifically whether they successfully constructed their floating sculpture or designed a geometric shape with the robot. For future iterations, it is advisable to incorporate a comprehensive evaluation tool for the educational materials that is directed towards the students, rather than solely focusing on the teachers as was the case in the current application. Additionally, this evaluation should assess the students' acquired knowledge to further reinforce the findings. Each of these limitations suggests areas for further research.

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