Developing STEAM Educational Scenarios in Pedagogical Studies using Robotics

An Undergraduate Course for Elementary School Teachers

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Abstract-In recent years we have observed a clear trend for the transformation and evolution of teaching practices using Information and Communication Technologies (ICT) and in particular educational robotics. As modern society gives great importance to scientific and technological literacy and new technologies, the educational process must play a central role in the development of the respective skills. Thus, the training of future teachers in corresponding fields is especially important. In this paper, we present the curriculum design of a course named "S.T.E.A.M Teaching Scenarios using Educational Robotics" implemented for undergraduate pre-service teachers at the Elementary Education Department of the University of Western Macedonia in Florina, Greece. The objectives of the course include the development of critical and computational thinking, familiarity with robots, and the process of their integration in curricula focusing on interdisciplinary practices facilitated by embodied learning affordances.

Keywords-educational robotics; STEAM education

I. INTRODUCTION

STEAM is an approach to learning that uses concepts from Natural Sciences, Technology, Engineering, Arts, and Mathematics like springboards for the development of skills of active inquiry, cooperation, communication, creativity, and critical thinking. The desired result is students who are involved in experiential learning, are able to develop problem-solving skills facilitating scenarios, work together and explore learning environments within the context a creative process [1]. The "A" in acronym STEAM, introduces the dimension of creation and ingenuity, under one prism and aesthetics but also moral. In this publication we present a curriculum targeted to pre-service elementary school teachers, exploiting the symbiotic relationship between Natural Sciences, Technology, Engineering, Art and, Mathematics integrated in various educational robotics based teaching scenarios. Students learn how to combine and implement innovative scenarios within an interdisciplinary framework based on inquiry based learning, project-based learning, and developing computational thinking in parallel with design based thinking [2, 4]. The ultimate goal of deploying these STEAM based sequences is for elementary school students to be familiar with elements of engineering (simple and complex machines), to algorithmic thinking (programming), to building robots [5], design and implement experimental devices, and incorporate elements from the arts and humanities indirectly (design, aesthetics, creativity, imagination, innovation, ethical extensions, creative script writing, etc.) or directly (e.g. a robot that paints, a robot that dances, etc.). The course is based on collaborative work, within immersive embodied environments that encourage more than just basic science skills (critical thinking, computational thinking, logic and application of science methodology) but also skills directly related to the arts and humanities such as creativity, imagination ,and reflection on ethical implications [6-8]. The course, in addition to educational robotics, integrates multiple ICT tools that support and enrich teaching scenarios, such as Scratch games, Makey-Makey and augmented reality applications [9, 10], an embodied learning teaching framework [11, 12], and utilizing robots as tools for simulation [13].

II. COURSE GOALS AND DESCRIPTION

The philosophy of the course employs two distinct approaches in the teaching of educational robotics in an elementary school classroom: The first approach uses the robot as a means to teach computational thinking, algorithms, and design in and of themselves, i.e. robotics here is the goal. The second, and more interesting, pedagogical approach utilizes the robot as a "digital agent", an actor inside a wider scenario that is used as a tool that facilitates learning of various learning goals (such as fractions, or materials science, or even chess). The course focuses on creative thinking and communication/collaboration alongside design thinking and pedagogical efficacy. The curriculum didactic sequences utilize the Lego Mindstorms EV3 set and Scratch 3.0. The course material is divided into 2 phases.

In the first phase the students, who have already attended an introductory course in Educational Robotics and have a strong grasp of EV3 programming, get acquainted with advanced EV3 programming techniques (variables/constants, data logging, variable operations, advanced precision handling with sensors). In this phase we introduce the concepts of design-based thinking and its connection to the arts and creativity alongside the improvement of computational thinking skills and higher

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mental skills. In the theoretical part, on one hand we focus on scaffolding techniques and on the description and evaluation of teaching models such as SAMR, and at the same time get acquainted with digital storytelling techniques. Moreover, we give guidelines for the use of multiple ICT tools used to enhance the base teaching scenarios with multimedia or interactive capabilities (such as Web 2.0 Comics tools, e-books, Google forms for questionnaire creation, etc.). The main purpose in this phase is to begin combining computational thinking and science skills with creativity and imagination, which are grand aspects of arts and humanities. Pre-service elementary school teachers are introduced to the concept of scientific method and learn to develop teaching scenarios, using educational robotics and embodied affordances, divided in 3 stages that encapsulate the essence of the scientific method: Explore, Create and Test, Share results and reflect. Each scenario begins with an active brainstorming session where the students are prompted to explore and inquire about the subject empathizing with all its aspects and give initial input regarding the creation phase, then begin constructing and testing the robot itself, employing an iterative process of trial and error in design where they actively see what is working or not and making the necessary adjustments. Then the robot is put to work inside the scenario parameters, which induces another, final, evaluation phase. In the end, the participants share the results with the lab groups and reflect on similarities and differences. In this phase we learn that the robot can be transformed from a "simple" tool to teach programming and computational thinking to a ubiquitous interface that acts as a medium between the digital and physical world, facilitating embodied learning and transforming into a multitude of aspects: In an astronomy scenario as a simulator of the earth's movements, in a music and cryptography scenario as a decoder of colors into notes, in a fractions scenario (and football) as the tool that verifies the students' mental calculations. In this first phase that lasts 6 weeks, the students get acquainted with the overall methodology in guided short projects (1 lab session of 3 hours each). During this phase, students apart from the live sessions, are assigned two homework projects where they are called to create lesson plans and worksheets for a multidisciplinary application of a STEAM scenario in a "real classroom". The lesson plans and worksheets are based on the "Explore-Create-Share" workflow. During the COVID pandemic, where lab access was not possible and distance learning was employed, the students were also familiarized with online robotics teaching tools such as Microsoft Makecode.

In the second phase which lasts 7 weeks, the students are familiarized with tools and applications that enable them to create bigger, more immersive and demanding teaching sequences. We introduce students to Mixed Reality applications and a framework that utilizes Scratch and Makey-Makey to create augmented spaces on which our robots participate in "missions" visualised by Scratch 3, as seen in Figure 1. In this phase we focus on digital storytelling via Scratch scenarios in order to produce gamified contexts on which our robots enact their missions. This phase is designed to facilitate creative thinking and storytelling skills to the pre-service teachers, while at the same time enables them to conceptualize and create multidisciplinary teaching environments that make use of multiple technological affordances and create novel learning spaces that will motivate their future school students and keep their interest high. In this phase, pre-service teachers are given a multitude of choices among teaching subjects and focus on translating traditional teaching goals (for example Crete's Mythology or Fractions) into scenarios that make use of a "game-like" interactive canvas with robots as the story's main hero as seen in Figure 2.

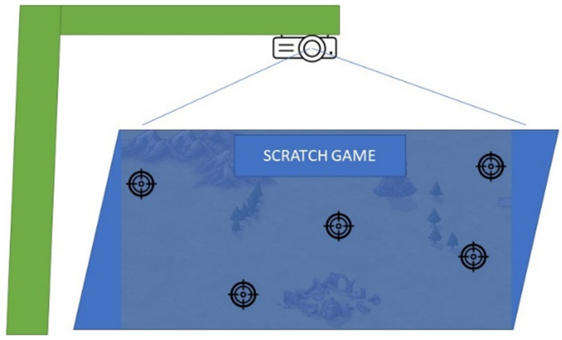

Fig. 1. Sketch depicting the "augmented space" concept. A vertically placed projector augments a canvas with a Scratch game. Black targets mark the positions of Makey-Makey interface contacts.

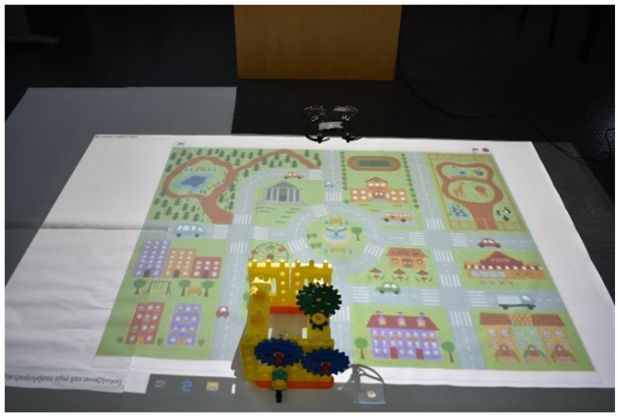

Fig. 2. A scenario combining robotics and english language teaching with EV3 and a drone, over an augmented space depicting a city.

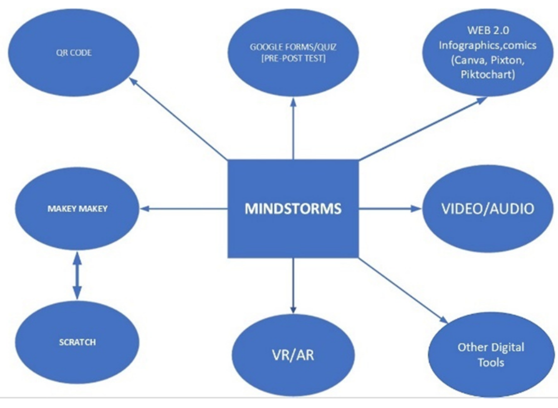

Fig. 3. Synergies between ICT tools and Mindstorms in the creation of a STEAM teaching intervention.

At the end of the second phase the students are assigned their final assignments and produce a project-based scenario that incorporates all aspects of what they have learned during the semester. In these final projects we facilitate the creation of complex teaching interventions that make use of multiple ICT affordances as seen in Figure 3.

III. CURRICULUM BREAKDOWN

The proposed curriculum is broken down in the following 13 weekly 3-hour lab sessions. In the following description we present some basic project ideas that follow the proposed framework precepts. It should be noted that in every iteration of the curriculum, assignments can change and weekly projects can vary depending on the specific needs of the students attending the course:

- Week 1: Introduction to STEAM and advanced EV3 programming. Using the model Riley Rover we cover variable operations, data logging, advanced sensors and precision.
- Weeks 2 and 3: The "A" in STEAM Design based thinking, introduction to digital storytelling. The S.A.M.R model. Bloom and SOLO taxonomies. Web 2.0 digital creation tools.
- Week 4: 1st guided project – EV3 spirograph: A scenario that involves geometry, art, the concept of symmetry as well as engineering aspects and precision handling of the gyroscopic sensor.
- Week 5: 2nd guided project – Historical weaponry, the catapult: An interdisciplinary scenario involving mathematics and physics (projectile motion), history (sieges using trebuchets) and engineering (creation of improved catapults and trebuchets, as shown in Figure 4. Begin incorporating the robotics element in wider scenarios, i.e. which siege to emulate, what props to use, what would be an appropriate diorama for the application of the scenario.

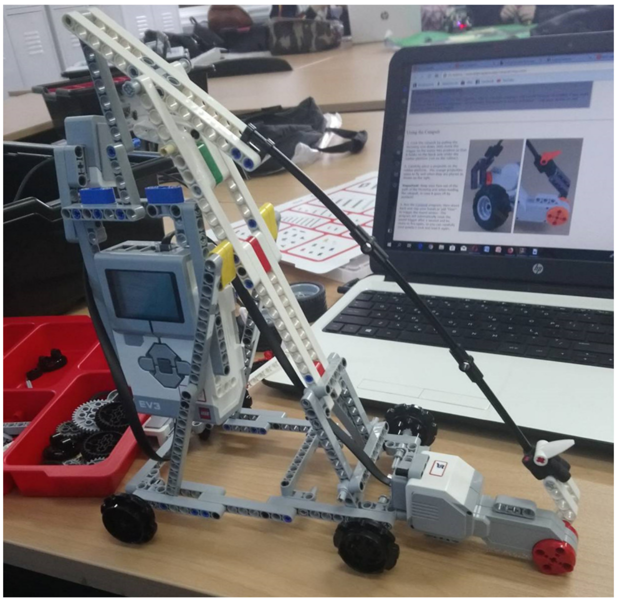

Fig. 4. Building a trebuchet for a medieval siege in the lab.

- Week 6: 3rd guided project – Astronomy: look for precious metals in alien planets using a specially designed robot (advanced sensors, color separation, data logging). Second possible scenario: Materials science, measuring the insulation properties of various types of liquid containers (depending on the availability of EV3 temperature sensors in the laboratory), graphing the rate of temperature gain after a cold liquid is placed in a specific container.
- Weeks 7-8: Scratch and Makey-Makey. Mixed reality applications with augmented spaces and robots – Assignment of final projects for week 13. Here we produce Scratch scenarios specifically designed to function as "placeholders" for our applications further on the road. The main goal here is that students are able to create treasure hunt-like games where in each stage, the story goes forward if the correct button is pressed. In Figure 5, we can see such a placeholder Scratch scenario with the traced trajectories and the "base stations" to be incorporated in the final scenario. The story here is another treasure hunt where the hero travels through his kingdom to find his kidnapped father.

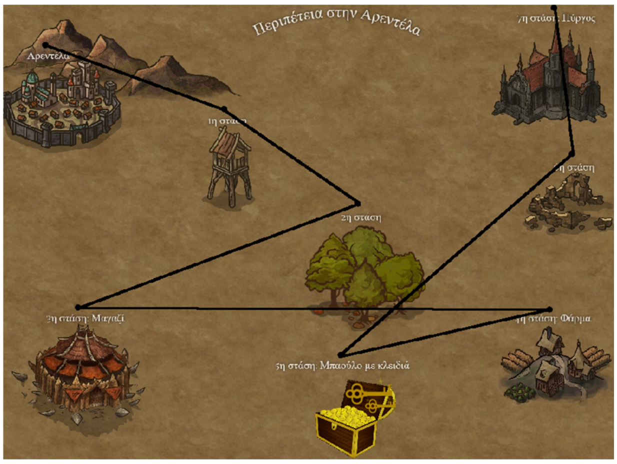

Fig. 5. A Scratch environment where we have traced the possible routes the robot should take. Each destination marks the end of a mission and involves a Makey-Makey interface base.

- Weeks 9-10: Mixed reality with Scratch and Makey-Makey – 1st unguided project. The first STEAM unguided mixed reality project here combines the mythical robot Talos that guarded Crete and the creations of artist Jackson Pollock. Students design and build a robot guardian that patrols around Crete and is ready to shoot at invaders. In the second phase of the scenario the robot transforms to a Jackson Pollock imitator and instead of shooting projectiles, shoots (or drips) paint on a canvas, creating abstract expressionist art. Makey-Makey here is used as an interface between the augmented space and the Scratch game with buttons implemented as bases where the robot can touch and interact with the Scratch scenario or as a touch interface for answering prompts by the environment as seen in Figure 6.

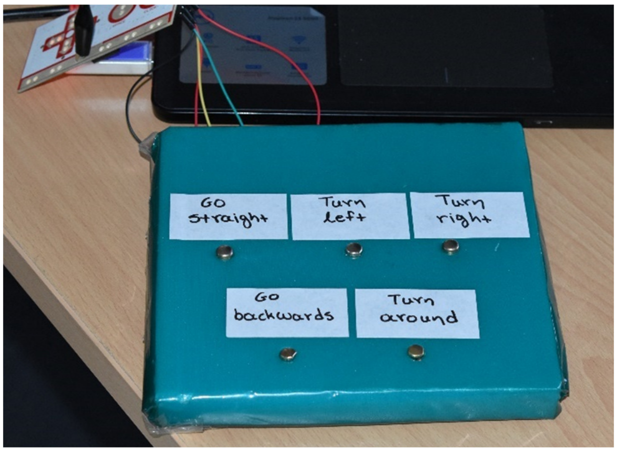

Fig. 6. A Makey-Makey built interface used for creating instructions for the robot.

- Week 11: 2nd unguided project: Cryptography and music. Here the scenario is focused on the history of cryptography and messages and students are prompted to create a scenario where we encrypt the 7 basic notes of an octave with the 7 basic colors that EV3 can recognize, and then move on an color-coded pathway that is an encrypted song of their choosing, with the EV3 playing (decrypting) the melody. Alternately, a treasure hunt scenario looking for "musical colors" can be deployed. In this case the robot as an ardent music fan, hunts for notes hidden in colors in various areas and learns about important musicians on the way, as seen in Figure 7.

Fig. 7. The "Musical Treasure Hunt" where the robot touches bases around Greece, gathers color coded notes and at the end reveals a musical piece, played by arranging the colors in a line.

- Week 12: 3d unguided project: Robot Football and Fractions. Here we work on an augmented space depicting a football field. The teaching goal is fractions and their properties and students must make use of the diameter of the basic EV3 wheel (18cm) and combine it with the dimensions of the field in order to program their robotic footballers to score a goal as seen in Figure 8, making mental calculations of fractions and programming the robot to move precisely.

Fig. 8. The template for the fractions learning scenario using football. The measurements are chosen for ease of application, not to be confused with actual analogies.

- Week 13: Create teaching spaces and robot models for the final assignments, to be presented in the semester finals. In Figure 9 we can see the result of a particularly successful intervention for teaching the day/night cycle, using a robotic model of the Earth on an augmented canvas floor. In Figure 10 we see an example from Greek mythology, where the scenario involves finding out about Minoan art and navigating through a maze.

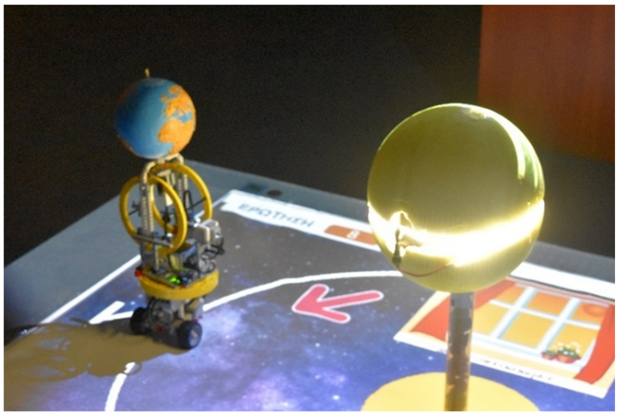

Fig. 9. The robot depicting the Earth as it moves arount its trajectory.

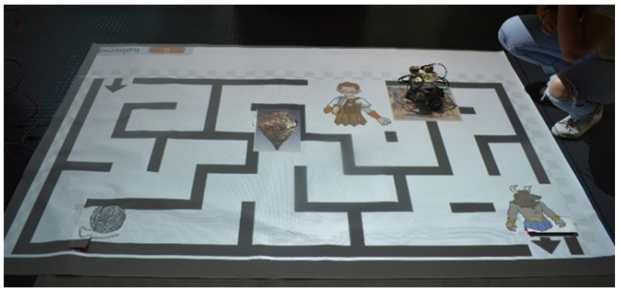

Fig. 10. Minotaur's maze and Theseus on his robotic steed, learning about Minoan art.

IV. DISCUSSION AND FUTURE GOALS

The act of integrating Educational Robotics and other ICT affordances to teaching interventions is not always straightforward or successful. The danger of using technology ineffectively and end at distracting the students instead of achieving the learning goals is always present. When we integrate technology we must always be aware of our teaching goals and use it to achieve them point by point instead of just mixing and matching various ICT tools in an effort to motivate or engage students. In their present highly technological routine, students can be truly difficult to engage, but on the other hand if the content itself, the teaching scenario is weak, then no matter how exciting or impressive technology we employ, we will fail. As more affordances are made available, the present course aims at improving its evaluation capabilities with the inclusion of affective measures such as the inclusion of cameras for adult (for students) or children emotion recognition using available algorithms [14, 15] or adding Emotiv Epoc sensors for EEG evaluation of the subject's affective response during the proposed interventions each time [16]. Moreover, the inclusion of a wider theme base, integrating issues such as inclusiveness, humanitarian aid, and design of scenarios targeted to disabled people and environmental design, inside the framework of inquiry based projects, is one of our main future goals. Unfortunately, the ongoing pandemic has put a total stop to the activities of the specific course, with distance learning providing a less than ideal substitute, since the positive effects of embodied learning -the core precept of the course- are nullified when the students don't have access to the materials and tools of the robotics laboratory. On the other hand, the pandemic provided us with new challenges and urged us to transform the teaching process, evolve it to adapt to the current needs and find new alternatives to our regular teaching routine.

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