Primary School STEM education through co-creative methodologies

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Abstract. Technology Enhanced Learning (TEL) in Science Technology Engineering Mathematics (STEM) Education is a well-established method for engaging learners with difficult and counterintuitive concepts such those in space and astronomy. Co-creative, participatory methods are easily applicable in TEL for STEM due to a multitude of existing platforms and services for creative technology based education. This work describes three co-creative endeavors in astronomy and solar system education for children of primary education. The cases comprised of an exploratory game teaching about the surface of the planet Mars, an interactive Augmented Reality (AR) application exploring the surface of the Moon and a team endeavor for learning through creating a general astronomy quiz. In all cases, participants were excited and engaged with the subject matter and the technology a fact that led to successful educational episodes. Beyond that the core outcome of this work was a first identification of a common co-creative workflow of introduction-toolset provision- implicit creative education –publishing content engagement in all three cases. This co-creative workflow identifies very closely with the core theoretical tenets of constructivist learning theory. In that context this work is the first step towards formal identification of the co-creative workflows with pure educational methodologies.

Keywords: STEM education, Technology-Enhanced learning, Programming, Co-creation, Augmented Reality, Primary Education

1 Introduction

1.1 Technology-Enhanced Learning (TEL) in Science Technology Engineering Mathematics (STEM)

The endeavor of supporting students in conceiving heavily the gist of STEM disciplines is strengthened by the integration of technology [12]. Considered essential to promoting innovation, productivity and overall economic growth, STEM education is considered as crucial factor in fueling the current and future STEM workforce [9]. STEM education provides students with appropriate skills that correspond to the current development of digital technologies [22], and supports them in developing new competencies which are considered crucial to their effective adaptation to our digital world [17]. 'Technological literacy' and 'ICT literacy' are terms that widely describe "the interest, attitude and ability of individuals to appropriately use digital technology and communication tools to access, manage, integrate and evaluate information, construct new knowledge, and communicate with others in order to participate effectively in society" [30].

Such technological integration into school education is supposed to be an essential means capable of reinforcing learning and raising student achievement in STEM disciplines [8]. Thus, learning that is supported and enhanced by technology, known as Technology-Enhanced Learning (TEL), could be an effective pathway to follow aiming students' smooth approach and acclimatization with STEM education. The appropriate use and integration of technology could set the ground a more learner-centered environment by allowing students to take on more responsibilities in their learning process [28]. TEL in science develops a learning environment that could help students to make their thinking visible, encourage student collaboration, promoted autonomous lifelong learning and make science concepts more accessible [21]. Because of this, TEL environments have emerged as the subject of study for many researchers with an interest in science education and technology [31].

1.2 Computational Thinking through programming activities

Technology has literally brought important and considerable changes in every aspect of our lives, including education. These days, a significant part of the discussion is about how students can end up skilled designers and makers of computer artifacts [29].

Computational thinking has been raised as an essential educational approach that has received increased consideration in the last years and focuses on bridging the gap between students and computer programming across the years of schooling [18]. That kind of pedagogical practices encourage teachers to attempt activities in the classroom that advance learning and creating, with computer programming proposed as a learning technology that can enable the improvement of capabilities and competencies, for example, critical thinking and problem-solving [14]. Besides, there have been conducted several attempts aiming introducing programming to children, though not all necessarily within the classroom, while some have created after school clubs to introduce children to computing [16].

Computer programming requires students to engage in problem-solving process that form the defining core of computational thinking [25]. However, due to the complexity of some such tasks students are possible to be confronted with difficulties. To alleviate frustration in these cases programming is taught through a game-based approach, so that the whole process becomes an enjoyable experience [26] accessible at an early age [20]. Computational thinking utilizes programming tasks successfully because these tasks incorporate a multi-dimensional and iterative process. This process runs in a number of phases including: forming and dealing with problems in a manner that using computational tools appears to be the most effective practice; organizing and analyzing data; represent data via models and simulations; adopting algorithmic thinking in order to automate solutions; assessing solutions; and applying the problem-solving practice to other contexts too [25]. Apart from domain-specific skills, developing a strong background in computational thinking competencies support students in enhancing their problem solving skills and their ability to think critically [37], as in meantime students develop their synthetic and analytical thinking, foster their skills in designing and solving algorithms, and affects in a positive way their creativity and imagination [24].

1.3 Co-creation as participatory method between students and instructors

During the past decades, the focus on the management of experience, student participation and value co-creation in education has increased [7]. In the last years there has been an increased interest in the numerous benefits of engaging students as partners, co-inquires, who produce and co-create their own learning experience [6]. As students have unique views about teaching and learning, they need to be given the opportunity to share their views on the education processes and to actively participate in the training process, to achieve improved results in learning, developing thinking skills and creativity; to obtain rich understanding of concepts, and to create knowledge and new educational processes [35].

Co-production of learning and teaching advocates a more prominent democratization of the educational process and recent work on it challenges the traditional norms in learning. When educators and pupils work cooperatively to make parts of educational module as well as pedagogical approaches, then co-production of learning and teaching take place [5].

As Biggs emphasizes [3], knowledge is constructed through the learner's activities and interactions among lecturers, students, and peers [36]. Constructivist learning reflects the principle that students discover their own truths through acting [10] while the constructionist perspective encourages students' knowledge through developing games and objects [32].

Related to the above there is a rapidly developing research literature on ''student voice'' activities, which encourage and advance a different and transformative scope in educational practices [34]. In school settings, the ''student voice'' (SV) approach includes a wide level of aspects: considering and evaluating students' views express regarding their learning experiences; communicating students' views to decision-makers; equating students to equal partners in teaching and learning processes; and

encouraging them to be more active in shaping or changing their learning [13]. Another term that incorporates co-creation is participatory pedagogy. Participatory pedagogy aiming for student centered learning and enabling learners to be part of creating both content and structure [1]. Moreover, opportunities to practice work-group skills were provided to children (aged 7 to 12) by playing games and gamification [21]. Designing games enhance the sense of classroom community, which encourages students to be active members and cooperate with others [2] and to share possible ideas and different ways of doing things in the game-making environment [33].
Concerning the roles that students can embody in co-creating they are: (1) consultant, sharing and discussing valuable perspectives on learning and teaching, (2) co-researcher, cooperating in a meaningful way on teaching and learning research with staff, (3) pedagogical co-designer, being responsible for designing learning, teaching and evaluation and (4) representative, sharing student voices in a range of university settings [11].

1.4 Aim and scope of this work.

This paper describes the methodology and outcomes of implementing co-creation methodology in primary education. Specifically it reports on the co-creation endeavors of primary school learners who, through programming tasks, became versed in computational thinking, while co-creating with their teachers useful digital content for solar system and astronomy education.

2 Co-creation support Methods

The activities reported in this work were conducted at the Experimental Primary School of the University of Thessaloniki in the city of Thessaloniki, in northern Greece. For the first time and for the school year 2017-2018 an Astronomy club “Space Explorers” was offered for 14 children from Year 5 to Year 6 aged between 11 and 12 years old, every Friday from 1:45 p.m. to 3:15 p.m. The aim of the “Space Explorers Club” was to teach students life skills through the intelligent application of astronomy and space science concepts. Students that enrolled in this club learnt about the mysteries of the universe. As the children and teacher who offered the space club at the school were the first users of this new type of club and learning activity, their role as designers and developers of the environment and the pedagogy was significant.
The “Space explorers” participants attended the club in the computer lab once per week. Integration of technology into classroom instruction was particularly emphasized. There was a SMART Board connected to the teacher’s computer and a digital projector in order to show the computer image. Students and teacher could control computer applications directly from the SMART Board display. The computer lab at the Experimental Primary School is equipped with 12 individual workstations, 6 desktops and 6 portable laptops. Each computer is equipped with Windows 10, Office 2016. Wireless internet access is available through the lab. Students of Space Club

also were encouraged to "bring their own device" like smartphones and iPads to use in the class for educational purposes.

3 Results; Collaborative game-making

3.1 Case I

While the fourteen students were playing a "Mars rover game" on NASA kid's Club site, they were motivated by their teacher to form seven pairs and come up with an idea of constructing a similar, simple game in order to reformulate their understandings, express their personal ideas, practice their work-group skills and learn programming basics. Building a game requires a higher level of thinking and the ability to solve problems proactively. Firstly, students were encouraged to decide on the type of game they would like to build taking as inspiration the NASA game they played. Students were urged to ask questions and provide help to others, if needed. Developing a collaborative game is a complex task which requires strong ICT skills. Primary school students generally have no previous programming experience and a low ICT skill level. For this reason "Scratch" (http://scratch.mit.edu) developed by the research group at the MIT Media Lab was introduced to students as visual programming language designed for young learners. Scratch is a free and open source, which gives students the opportunity to understand how to code using block coding instead of typing commands. The students were familiar with "Scratch" because they have been using it since the third grade and they had already developed a basic competency programming. They were also encouraged to use the digital environment in order to imagine, discuss, create, play and share the game with their friends and classmates on the web. In order to facilitate cooperation, negotiation and collaboration the teacher gave different areas of responsibility to each learner of the team (problem finding, problem solving, generate ideas, concept design, implementation, animation, sound, visuals etc.).

Students made mistakes while programming and learnt from their mistakes by debugging their coding project. There were seven games created, each by one of the pairs formed during the class. The games varied in complexity (timer, scoring system) and all used keyboard and mouse control to play the game. All games consisted of a Mars rover (sprite) that landed on Mars and had the same backdrop theme (Mars surface area). The teams coded the rover to start moving each time a key is pressed and to turn in the direction they wanted by pressing other keys. By reordering the programming blocks, they created command blocks that made their rover turn in the direction of their wish and by adjusting the numerical content of these blocks, they made their rover move slowly or fast. They also used conditions. When the Mars rover was moving around, if it touched an object (water, gold, Martians etc.) then it caused an event to happen (change score, bounce, disappear). Throughout game development, students took turns testing out other students' game functionality and design. All games ended with a sound playing and a message stating "WE ARE THE WINNERS!" A characteristic screenshot from the development environment is presented in **Fig. 1**. Engagement during classroom activities was high on inspiring, designing and making a game and provided the stimulus to learn more.

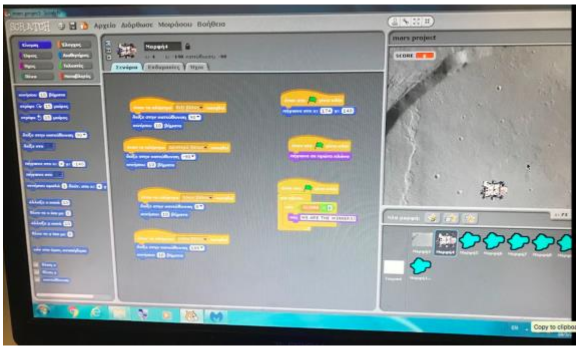

Fig. 1. Characteristic screenshot of a team's Mars game development project

3.2 Case II

The next co-creative activity was implementing augmented reality in designing and producing AR-animation system to represent what students have learnt about the moon, its surface and the first man who stepped on the moon. In order to achieve this, Blippbuilder by Blippar [4] was used in building the augmented contents. Blippar allows applications to be developed for both Android and iOS operating systems. Blippar for Education platform includes a suite of three products tailored for teachers: an Educator Dashboard, an Educator Community, and a special Educator version of BlippBuilder. Initially, students learned and discussed about moon surface, the craters, the marks on its surface and the dusty footsteps of astronauts as depicted by historical photographs [27]. Students were randomly divided in 4 groups of 3 students and 1 pair. Each group collected information about a certain learning topic (erosion and atmosphere, tectonics and craters, volcanism and craters, the unseen side of the moon and the first step on moon), to share, discuss and verify to accurate. Students were encouraged to build an augmented tour on moon using a drag and drop of "Blippbuilder" portraying the gathered information regarding their learning topic.

Before starting all students of the club educated on the Blippbuilder AR Creator for education. They watched video tutorials and discussed and analyzed the workflow with their teacher. Interaction and dialogue in the classroom among students and with teacher was the key to overcome difficulties and develop representational competence. Students then created an account with Blippar, downloaded the Blippar app to their mobile devices (smart phones, tablets and iPads) in order to be able to iterate on content creation with Blippbuilder. They decided the on the location of the markers (the real-word 2D image) that they were going to use for their topic, created their graphics built in Photoshop and uploaded them into Blippbuilder. YouTube videos and mp3 sounds were also added through drag and drop interface. Once they finished building their blipps they tested in on their mobile devices and they set it live (**Fig. 2**).

Fig. 2. A group of students viewing the created content on Blippbuilder

3.3 Case III

At the end of the school year the 14 students of the "Space Explorers Club" were motivated by their teacher to create a formative evaluation Astronomy-quiz for the other students of the school, who did not participate in the Astronomy Club, in order to test their peers' knowledge. Involving games in the teaching process is a method to open up knowledge transfer and to increase students' interest. Space Explorers were engaged in content in a fun way. For this purpose, the teacher introduced a game-based learning platform, Kahoot! [19]. "Kahoot!" is a student response framework that engages students through game-like pre-made or improvised quizzes, discussions and reviews. It is a free and simple tool to learn and utilize. Initially, the 14th Club students divided in two groups of seven created two accounts on Kahoot! and then they logged into their account created two quizzes for evaluation of astronomy knowledge named "Astronomy Quiz 1" and "Astronomy Quiz 2". The students also uploaded pictures and music to each question of the quiz by using the "drag and drop option" in order to look aesthetically better. For each question, the students as creators included up to four answers for the other students to choose from. Time and score value for each question were set at 10 seconds and 1,000 points respectively. During the creation of the quizzes the students acted as a team supporting one another and they were moving all around the class. The students of the club created 14 questions for each quiz working collaboratively.

After creating the quiz the teacher received the PIN code for both quizzes and launched the quiz for the 25 evaluated students (Year 5 and Year 6). These did not participate in the "Space Explorers Club", were randomly divided into groups of three or two and used their own mobile devices (cell phones, tablets and iPads) in order to compete on which group knows best on Astronomy. They signed in using the web address (https://Kahoot.it) to access this eLearning platform and the selected team mode to use on device per team. They entered the game pin displayed on the SMART Board and the game started with active participation in the classroom.

The students of the school were excited about playing both games that were created by the Space Explorers. Fun and joy surrounded the games strengthening group dynamics. It must be noted that for reasons of confidence building the "Space Explorers" group facilitated along with the teacher the quiz session answering clarifying questions and helping with the technical nuances of the system. After quizzing, the percentage of right answers and time scores were seen in the SMART Board display. The real-time feedback further engaged students and gained their attention. Indeed, students remarked that they enjoyed this assignment because they were creatively using technology within a learning environment.

4 Discussion

This work presented 3 cases of co-creations in primary education. The cases by themselves are not impressive for study on the methods and scope of co-creation and the content created was adequate for use by other participants in the educational scope of this endeavor. The key outcome from this work is, however, the use of co-creative methodologies for purely educational aims. The 3 cases had a common structure that is at the core of co-creation. Informing the user/student about what is the “product” that is to be built. 2) Providing her/him with a toolset that facilitates this creative process and removes highly technical burdens. 3) Offering the creative freedom to the participant to express himself and produce ownership of the created “product” so that 4) the participant/user engages with the “product”. In all of the presented cases this workflow was followed as an educational method. First the students were informed about the educational topic. Then the facilitating teacher provided an easy to use technical solution for exploring the topic creatively, without resorting to heavy programming solutions. After that, the little learners were left to their own devices to develop content as they saw fit, while, at the same time, implicitly being educated on the topic. Finally, the content that was developed was “published” either as material for others, or for the learners themselves to engage and anchor, through it, the implicitly transferred knowledge. That way the learners absorbed the content and concluded the educational process.

This direct overlapping of the co-creative workflow with the educational process is also formalized in the tenets of constructivist learning. The idea of constructivist learning includes four components. These are: 1) Students construct meaning on their own, 2) new learning is built on previous information and knowledge, 3) learning is united with social association and interaction and 4) meaningful learning develops through authentic tasks [10]. Additionally, by using technology from the constructivist perspective learners can 1) access, select and interpret information, 2) review and adjust their work to enhance the quality, 3) share or exchange information with others and present data, 4) assess their work and enhance efficiency, 5) be innovative and take risks and 6) gain certainty, boost confidence and independence [15].

Given this theoretical context, this work is the first step towards exploring the interplay between co-creative methods and constructivist educational paradigms.

Moreover, further analysis and research must be conducted to validate or not the interaction and learning experiences of students in STEM. For this purpose, in order to examine the degree to which these variables (ex. excitement, engagement, learning) are affected in co-creation situations, a multidimensional co-creation STEM experience scale should be created and be combined with in depth interviews that may provide future insight into the students experiences and learning.

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