ENHANCING COMPUTATIONAL THINKING SKILLS IN EARLY CHILDHOOD EDUCATION

ABSTRACT
Nowadays, cultivating computational thinking in PK-12 emerges as a compelling vision. In this sense, we introduce an educational framework that aims to familiarise children at the first two grades of primary school with fundamental competencies of computational thinking, such as: collection, organization and analysis of data, algorithmic thinking, abstraction, generalization and evaluation. The basis of the proposed framework is a novel computational educational environment, which establishes an innovative hybrid schema of visual and text-based programming techniques, focusing on object-orientation. We also suggest a relevant assessment process, in order to examine if the objectives of our educational approach are met. This paper reports two pilot studies, conducted within the context of physical and natural science courses in a first and a second grade class, in a primary school in Greece, in May 2018. Findings provide very promising indications for meeting our goals to introduce and practice computational thinking concepts at first stages of schooling, actualising at the same time a mild first contact of young students with object-oriented programming syntax.

Keywords: computational thinking, science education, early childhood education.

INTRODUCTION
Computational thinking (CT) is expected to be a fundamental skill for everyone by the middle of the 21st century, just like reading, writing and arithmetic are at the moment (Wing, 2006). Over the last two decades, the idea of introducing CT in compulsory education has gained the attention of educators, researchers and policymakers. Thus, a substantial body of literature has been developed designating CT as an essential ingredient of studying a plethora of disciplines in PK-12 (Grover & Pea, 2013). Elements that are widely accepted as comprising CT, are; collection, organisation and analysis of data, algorithmic thinking, abstraction, generalisation and evaluation. These elements also constitute the basis of policies that aim to cultivate CT and provide means of assessing its development (Barr & Stephenson, 2011; Grover & Pea, 2013).
The essence of our research is enhancing CT elements in the elementary grades, since these elements correspond to skills applicable and beneficial in everyday life. Our main research question can be formulated as follows; “Can CT elements be introduced in the first and second grade of primary school within the context of physical and natural science courses, through the creation of digital games using a developmentally appropriate computational environment?” To answer this question we developed a novel educational framework established on the theory of constructivism and game-based learning. Its backbone is an educational computational environment PhysGramming (Kanaki & Kalogiannakis, 2018). Through PhysGramming children turn into creators of digital games, according to the theory of constructivism. Its innovative feature is that while children create their own games within the context of physical science courses, they become familiar with basic CT elements, even though no specific reference is made to them.
Through PhysGramming we also attempt to mildly expose students of elementary grades to basic programming techniques, following the recent years’ trend of encouraging cultivating the basic programming skills as soon as possible in schooling, starting from kindergarten (Flannery et al., 2013; Voogt et al., 2015). Indeed, it is evidenced that programming fosters individuals’ exposure to CT (Lye & Koh, 2014; Wing, 2006), enhances their creativity, reinforces their problem-solving skills and exercises planning competencies (Kazakoff et al., 2013). Within this context, we focus on familiarising young children through PhysGramming with object-oriented programming syntax, establishing an innovative hybrid schema of visual and text-based programming techniques. We opt in favor of object-oriented programming since it is inseparable from object-oriented thinking, a skill people cultivate from the beginning of their lives (Hillar, 2015).
The educational framework we propose is accompanied with a relevant assessment tool that enables educators to assess the potential development of skills related to CT. We paid extra attention in constructing a valid and reliable assessment tool, since we are aware that without attention to assessment, no research effort could ever gain a serious role and place in the academic and the educational scene (Grover & Pea, 2013). Enriching the assessment tool to evaluate learning of object-oriented syntax is one of our near future research interests.
This paper reports two pilot studies, conducted in a first and a second grade class, in a primary school in Greece, in May 2018, aiming to answer the research question and, supplementally, to assess the feasibility of PhysGramming and to detect its impact on students regarding their satisfaction.

Keywords: computational thinking, science education, early childhood education.
METHOD

The pilots were conducted by the first author attuned to the ethical guidelines of educational research and were both followed by an assistant researcher - observer. The target group was 27 children; 15 first grade students (four girls and eleven boys) and 12 second grade students (seven girls and five boys). The pilots (one for each class) were implemented in the computer laboratory of the school as part of the study of the environment. In Greece, this course encompasses the study of physical and natural sciences. Each pilot lasted three instructional hours (each one lasts 45 minutes). Children sat in pairs at the workstations. The researcher gave brief instructions about the functionality of PhysGramming. Each child had one hour to create their games and play with them. Since both children of a pair had completed their tasks, they could play their games together. The subject of both pilots was the study of the animals, focusing on their eating habits. Firstly, the students had to select some available images of the animals they wanted to deal with or paint their own ones. For each image, a command line appeared on the screen. The structure of the command line was; IMAGE.name=value (“IMAGE” represents the image of the animal). After determining the names of the animals, the students should specify their eating habits. The structure of relevant command lines was; IMAGE.eating habits=value. The dot symbol placed in both the command lines points to the syntax of text-based OOP.

Given the name and the eating habits of each animal, PhysGramming had the essential information demanded to create digital games. PhysGramming is programmed to provide three kind of games; puzzles, matching games and group games. The inclusion of puzzles aims at cultivating algorithmic thinking (Hsu & Wang, 2018). Through group games, we attempt to foster the children’s ability to organize data. Matching games set the target of empowering the skill to identify and to designate the characteristics of an object and thus, the ability to make generalisations.

Regarding the rest of the CT elements, since the topic of the pilots was the study of the animals, we attempted to enhance the ability of collecting data by providing children with irrelevant pictures. While selecting pictures to create their games, children should ignore them. On the subject of data analysis, we focused on practicing students’ ability to point out mistakes. Thus, we provided children screenshots in which command lines were constructed with mistakes deliberately made. As far as the validation skill is concerned, since it is constantly required while playing a game, we assume that it was practiced successfully when children solved the games. The relevant assessment tool we propose focuses on each one of the CT concepts we aim to cultivate (Kanaki & Kalogiannakis, 2018). For each concept, we examine qualitative and quantitative factors that could lead us to conclusions about cultivating the concept in question. For example, regarding algorithmic thinking, the relevant qualitative data are provided by PhysGramming itself, which is programmed to keep track of students’ actions and depict them on log files.

These files, that do not include sensitive personal data, reveal if students are able to solve puzzles and the kind of puzzle they solve. At this point, we should clarify that PhysGramming constructs 4 kind of puzzles; with 4, 6, 9 or 12 pieces. The more the pieces of a puzzle are, the more the difficulty in solving it increases. The quantitative data are derived from personal interviews, in order to determine if students hatch out a plan to solve the puzzles or if they act randomly. In the second case, the whole process involves just luck and no algorithmic thinking. Quantitative and qualitative data were analysed together for each student, in order to determine whether algorithmic thinking was successfully practiced. Due to space limitations, we skip presenting the methods adopted to assess the other CT concepts (Kanaki & Kalogiannakis, 2018), intending to discuss them at the conference.

RESULTS

The thorough examination and study of the obtained data by the authors of the article revealed that the overwhelming majority of children successfully practiced the CT competencies. Difficulties that children faced were focused on assigning values to the eating habits of the animals. They also faced difficulties within the context of data analysis, when designating wrong perceptions regarding the eating habits of the animals. Indeed, we found out that 4 children assigned wrong values to the attribute in question and 5 children did not manage to point out wrong perceptions. Nevertheless, we suspect that these difficulties might result from the poor understanding of the content of the relevant topic. This hypothesis is about to be examined shortly in a research we plan to conduct. As regards the rest of the CT competencies, they were successfully practiced by all the members of the target group.
It is notable that, during the pilot studies, no question was posed about the syntax of the command lines. On the contrary, on their first contact with PhysGramming, most of the adults are puzzled over the use of the dot symbol in command lines. This fact makes stronger our hypothesis that OOP should be introduced at the first stages of schooling when children accept and absorb new information easily.

The proposed educational approach proved to be warmly received by students. While interviewing students, we investigated aspects of the approach they liked or disliked. We received a vast majority of enthusiastic responses and no negative response. A very interesting response was; “I liked it because I have to think, to create and to improvise”.

DISCUSSION

The most important characteristic of the proposed educational framework is that children turn into creators, according to the theory of constructivism, while participating in physical science courses, in a way that provides familiarity with the basic principles of CT, without a direct reference to them. It also gives vent to children’s imagination, creativity and self-expression. Moreover, it satisfies the self-reliant philosophy of digital natives, the contemporary educational trend to disseminate CT and the need for encouraging technological culture.

Our research is of general interest to the ESERA community, especially to scholars that applaud developing CT in the first grades of primary school. It also concerns educators, researchers and policymakers that opt in favor of the theory of constructivist learning, endorse student-centered education, advocate game-based learning and are ready to adopt educational approaches that transform students from passive consumers to active creators of new technologies.

CONCLUSION

CT is an ability that should be cultivated by all the productive members of a modern society. The rationale for our research arose from the limited literature on cultivating CT in early elementary grades. In this paper, we present the idea of enhancing fundamental CT concepts at early childhood ages, through a fruitful, creative and engaging educational framework. The results stemming from the pilot studies are very promising and reveal the feasibility of the proposed approach and the satisfaction of children while using PhysGramming. The positive learning impact we detected indicates that the current research could form the basis of a relevant and more extensive future work.

REFERENCES


Kanaki, K., & Kalogiannakis, M. (2018). Introducing fundamental object-oriented programming concepts in preschool education within the context of physical science courses, Education and Information Technologies, 23(6), 2673-2698.


