Employing Mobile Technologies to Investigate the Association Between Abstraction Skills and Performance in Environmental Studies in Early Primary School

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Abstract—Harmonised with the shift of education to satisfying the requirements of modern societies for cultivating 21st century skills, we introduce the novel idea of the synergistic development of computational thinking skills and environmental awareness in the early primary school years, by employing mobile technologies.

Keywords—mobile technologies, computational thinking, abstraction, environmental study

1 Introduction

Over the last decades, the growing development of mobile telecommunication technologies reshaped the daily life of the members of contemporary societies, structuring it around mobile gadgets and applications. Indeed, mobile devices and services are inextricably linked with modern public goods and contexts, such as mobile banking [1], mobile health care [2] and mobile learning (m-learning) [3], [4], [5]. As far as m-learning is concerned, it has become the object of interest of educators, researchers and policy-makers, opening up new venues for learning and educational assessment [5]. Considering the pervasiveness and rapidly extending functionality and benefits of mobile technologies, UNESCO applauds their potential to facilitate and improve the learning process, especially in poor and minority communities, targeting the equality of opportunity in education [6].

On the other hand, the introduction of 21st century skills, such as computational thinking and environmental awareness, is more relevant than ever. Indeed, until the end of this century, computational thinking is expected to become a fundamental skill, just as reading, writing and arithmetic are at present [7]. Since it is accepted as a set of significant competencies necessary for citizens of modern societies, several countries have already adopted policies for its development from kindergarten to secondary education [8], [9]. As far as the demand for cultivating environmental awareness is concerned, it rises because of the need for controlling or preventing major environmental problems,

that is to say, pollution [10], [11], climate change [12], [13], waste disposal [14], [15], ocean acidification [16], loss of biodiversity [17], deforestation [18], ozone layer depletion [13], etc.

Our research study supports the innovative idea of the concurrent enhancement of environmental consciousness and computational thinking during the early primary school years [19], [20], providing a sturdy base for forthcoming studies that will stimulate the design of computational thinking activities with ecological reflection. The novelty of our research contribution stems from the fact that there is no recorded study to investigate the correlation between fundamental computational thinking competencies of first graders, such as abstraction skills, with their performance in the Environmental Study course. Moreover, the majority of the pertinent surveys focus on older children [20], [21], resulting in the under-exploration of the sensitive first school years.

Our research objective was to investigate the above-mentioned correlation, employing mobile technologies. This paper introduces a part of our work that focuses on abstraction, as one of the most important computational thinking competencies. Thus, the research question is structured as follows: "Is there an association between abstraction skills and educational achievements in the Environmental Study course during the early years of primary school?" In order to answer the research question, we conducted a research study within the context of a robust ethical framework, in the school year 2018–2019, on the island of Crete, in Heraklion city. 435 primary school students of first and second grade participated in this research study. The sample was grade balanced—218 first graders (50.11%) and 217 second graders (49.89%)—and gender balanced—210 girls (48.28%) and 225 boys (51.72%).

2 Theoretical framework

In this section, we shortly present the theoretical framework of two fundamental pillars of our research study i.e., m-learning and abstraction skills.

2.1 M-learning

In the modern digital era, the impressive development of mobile technologies has entailed the reformation of orientations, dispositions and stances in education, changing the dominant approaches to learning [22]. In the present research study, we define m-learning as a process of learning performed across several contexts—as far as time, location and other environmental factors are concerned—where learners can take advantage of access to learning resources employing smart mobile devices, namely, smartphones and tablet computers [23].

The adoption of mobile technologies and devices in the educational process entails a plethora of advantages, such as:

- The provision of more suitable and natural learning approaches to the digital natives' generation [24].
- The introduction of new ways of learning that exploit applications, games, simulations, etc. [25], [26].

- The facilitation of study and access to the learning material anytime, anywhere [27].
- The empowerment of collaborative learning [26], [28].
- The advocacy of self-regulated learning [24].
- The improvement of access to education in developing countries and remote areas [29].
- The provision of learning opportunities to people with disabilities [29].

Nevertheless, m-learning introduces several disadvantages too, such as [23], [27]:

- Small screens limit the amount and type of information displayed.
- Devices become outdated very quickly, due to the rapid change of the market.
- Battery limitations are introduced.
- Bandwidth may decrease when a considerable number of users occupy wireless networks simultaneously.

In this regard, the continuity of m-learning demands the joint support of mobile manufacturers, service providers and specialists in the industry of training.

2.2 Abstraction

Wing, who coined the term of computational thinking in 2006, characterised abstraction as one of its most noteworthy aspects [30]. It is an advanced thought process, which is employed for tracking down common essential attributes of objects that are members of the same group. At the same time, objects' minor differences are ignored, in order to achieve the goal of an object to stand for many [30]. Thus, abstraction has two faces: (a) the act of not taking into account exceptional attributes of an object so to become representative for others of its kind and (b) the act of generalising by giving prominence to common attributes of instances of an object [31]. The case of the hippopotamus is indicative. The hippopotamus is a herbivorous mammal, since the anatomy of its stomach does not justify eating meat [32]. However, in literature, there are few cases recorded that hippopotami consumed meat, became predators or even cannibals [33]. This behavior is deviant and may occur in cases of eating disorders [32]. Nonetheless, no generality is lost due to these few exceptions. On the contrary, the hippopotamus is characterized as herbivorous, in the context of abstraction. In the light of the foregoing, we could argue that a criterion for the assessment of abstraction skills could be the ability to identify exceptions that do not cause loss of generality when ignored.

3 Methodology

In order to answer the research question, we have to assess both abstraction skills and content understanding of the Environmental Study course of first graders.

Regarding the assessment of abstraction skills, the collection of data is performed according to the principles of mixed methodology. For the needs of collecting quantitative data, we employ method triangulation. In both of the methods we propose, the students have to complete the task of assigning the values of a particular attribute to a group of inanimate objects or living organisms.

The backbone of the first method for collecting quantitative data is the digital platform PhysGramming we implemented from scratch in the context of our research [34]. PhysGramming runs on desktops, as well as on smart mobile devices and provides children the opportunity to create their own digital games. It introduces a hybrid schema of text-based and visual programming styles, paying emphasis on object-orientation [34].

The second method we propose for collecting quantitative data is based on the completion of worksheets. In the case of worksheets, students have to select inanimate objects or living organisms that meet particular criteria.

In both methods, the inanimate objects or living organisms are presented on the tool via pictures the teacher provides. It is important to highlight that the teacher who employs the assessment tool determines its content, in accordance with various factors, namely, the course's unit under study, the students' place of residence, etc. To put it another way, the teacher customizes the tools taking into consideration meaningful criteria, relevant to the context it is applied.

At a qualitative level, personal semi-structured interviews are conducted. The content of the interviews is related to the content of the unit under study. The combined results of both quantitative and qualitative data, place students into one of the four levels of abstraction: Excellent, Satisfactory, Medium and Basic. We came to these four levels based on the statistical analysis applied to the data of a relevant pilot study we conducted.

To understand the evaluation method we propose, we will discuss the way we utilized it in our research study, examining students' perceptions about the fauna of Crete i.e., the island on which the research study took place. We paid extra attention to the case of the crocodile, since a crocodile was spotted in a lake of Crete not long ago. Moreover, a popular family tavern hosted a crocodile up to the present time, for many years. Students who didn't classify the crocodile in the fauna of Crete successfully exercised their abstraction ability. At this point, it has to be clarified that the fauna of Crete was not discussed in the classroom before the evaluation tool was applied. Thus, students' perceptions were not related to the comprehension of the course's content.

It makes sense that the employment of the proposed assessment tool in another region of Greece, or abroad, entails the examination of students' perceptions regarding relevant environmental issues. In this case, the teacher has to modify the content of the assessment tool accordingly.

In quantitative terms, the estimation of the levels of abstraction skills is based on the statistical analysis of the data resulting from the indexing of the worksheets and the examination of students' achievements which are recorded in the log files of PhysGramming [34]. The fewer mistakes students make, the higher the level of their abstraction ability is. In qualitative terms, we perform statistical analysis on the data derived from the interviews.

As far as the assessment of the content understanding is concerned, students are assessed via relevant worksheets. In our research study, we examined students' perceptions about animals' eating habits. According to their performance, they were placed into one of the four levels of content understanding: Excellent, Very Good, Good and Almost Good. We came to these four levels based on the statistical analysis applied to the data of a relevant pilot study we conducted.

4 Results

Within the context of the statistical analysis of the research data, we constructed contingency tables, implemented chi-square tests and calculated p-values, in order to bring out possible correlations between the variables under study. Since we confirmed the correlation between abstraction skills and the content understanding of the Environmental Study course (chi-square = 20.23, df = 9, p-value = 0.01654), we calculated odds ratio, in order to determine the probability of occurrence of the values of the dependent variable, regarding the independent variable.

After that, we performed ordinal logistic regression analysis, with the aim of classifying the data by determining thresholds that delimit the probability intervals for each class. Due to the results obtained, students with higher levels of comprehension of the content of the Environmental Study course are 13% more likely to be classified to higher levels of abstraction, than students with lower levels of the course's content comprehension.

Finally, we employed the machine learning technique, in order to foretell the possibility of new data to be placed at the levels of the variables under study (Figure 1). The results verify the relation between the levels of abstraction skills in relation to content understanding.

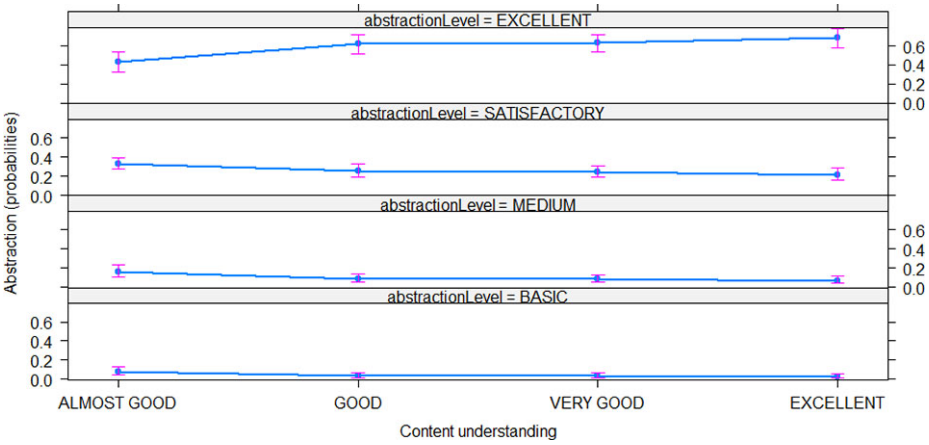

Fig. 1. Abstraction skills in relation to content understanding

5 Discussion

Our idea of investigating the potential correlation between fundamental computational thinking skills, such as abstraction, and the content understanding of the Environmental Study course was emerged from the contemporary social and educational demand of cultivating 21st century skills in compulsory education, even from the early years [19], [35]. Verifying this synergy facilitates the design of relevant educational

policies and the construction of relevant educational activities that support the concurrent cultivation of the above-mentioned skills.

Trying to empower the impact of the proposed digital assessment tool on students and teachers, we employed mobile technologies [4], which, indeed, facilitated the acceptance of the assessment tool and developed a festive atmosphere in the classroom. Important originality of the proposed assessment tool is the fact that students experience their first contact with fundamental principles and concepts of object-oriented programming [34]. Nevertheless, we avoid any direct reference to these principles and concepts, so as not to invalidate the playful and friendly nature of the tool.

6 Conclusions

Assessment is a dominant aspect of learning and pedagogy [35]. Our work pays exclusive attention to evaluating competencies related to the fundamental aspects of computational thinking in early primary school amid environmental studies, employing mobile technologies. We propose a relevant assessment tool, aiming to support the evaluation of computational thinking skills, adding to the field of computational thinking development. The proposed tool contributes to the design and the evaluation of targeted teaching interventions for introducing computational thinking in formal education.

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