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A Study of the Impact of Arduino and Visual Programming In Self-Efficacy, Motivation, Computational Thinking and 5th Grade Students' Perceptions on Electricity

Vassiliki Ntourou [1*], Michail Kalogiannakis [2], Sarantos Psycharis [3]

[1] Primary School teacher, Msc, GREECE
[2] University of Crete, Faculty of Education, Department of Preschool Education, GREECE
[3] School of Pedagogical and Technological Education, GREECE

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Abstract

This article presents a quasi-experiment which, with the use of Arduino and Scratch for Arduino (S4A), attempts to study their effect on self-efficacy and motivation towards Science Education, Computational Thinking (CT) and the views of 5th Grade students about concepts of electricity. It was conducted on the 5th Grade of a Primary School in Greece. The research team chose the quantitative method, which was conducted through the delivery of four questionnaires that were mainly consisted of close-ended questions. In order to achieve triangulation and a deeper understanding of the topic, it was considered important to include individual open interviews. The data processing failed to prove the effect on motivation, while in self-efficacy it was proved only partially. However, the effect was explicit in view of the conceptual understanding of electricity and CT. The specific project could spur the prosecution of an extended research, aiming at the probe on the one hand of how the existing outcome is confirmed and on the other hand how they are preserved through time, for the purpose of insinuating computational methods and tools into primary education.

Keywords: visual programming, self-efficacy, motivation, computational thinking, physical computing

INTRODUCTION

According to Resnick (2008) living in a Creative Society makes it imperative for a person to think and act creatively, rendering the kind and amount of possessed knowledge as unimportant. It is therefore imperative to acquire graduates that can induce the power of computational problem solving to a wide range of scientific domains, such as Physical Science, whose teaching has proved to be quite problematic worldwide because it is by nature "non-intuitive" (Barr & Stephenson, 2011; Korkmaz & Altun, 2014).

The abstract nature of concepts, such as electricity, often creates misconceptions in pupils' minds, as they are related to the microcosm, which is a mystery for them as it is "invisible" and little can be done in practice so that they can learn the way it works (Baser, 2006; Xie, et al., 2011). Therefore, if we want to teach Physics effectively it is imperative to carry out experiments (Psycharis, Botsari, Mantas, & Loukeris, 2014). However, there is a chance that the experiment doesn't result in the expected outcome, something may prove to be very confusing for the students (Baser, 2006). In this context, physical computing and computational experiment offer an appealing alternative because they can lead pupils to correlate individual concepts, achieve the connection of microcosm and macrocosm, which is something that can induce the necessary conceptual change and lead to the development of a more profound understanding, cultivating at the same time a positive attitude towards Physical Sciences, which is very important, as no matter how many qualifications a person possesses in order to complete a task, the lack in self-efficacy and motivation may result in failure (Baser, 2006; Kalogiannakis & Papadakis, 2017; Korkmaz & Altun, 2014; Psycharis, 2013; Xie et al., 2011).

✉ vassiliki_dourou@hotmail.com **(*Correspondence)** ✉ mkalogian@uoc.gr ✉ spsycharis@gmail.com

Contribution to the literature

- It proposes an interesting and effective alternative way of teaching Physics using physical computing, a subject that is considered to be very difficult worldwide due to its "non-intuitive" nature.
- It provides quantitative data for the effectiveness of visual programming and physical computing on Computational Thinking and the views of 5th Grade students about electricity.
- Its findings stimulate further research, in particular when it comes to self-efficacy and motivation.

THEORETICAL FRAMEWORK

Computational Thinking

According to Wing (2006), Computational Thinking (CT) is such an important skill that needs to be taught as writing, reading and arithmetic. Since it is a skill that can be acquired and not an inherent talent, each student possesses latent CT abilities that can be manifested through designing and applying programs (Seiter & Foreman, 2013; Wing, 2006). It could be argued that CT is a hybrid way of thinking, which combines four different kinds of thinking: logical, abstract, modelling and constrictive thinking (Liu & Wang, 2010; Voskoglou & Buckley, 2012).

Moreover, it includes a wide variety of aspects such as: abstract thinking, problem decomposition, Debug, algorithmic thinking, generalization, automation, simulation, modelling and data collection, representation and analysis (Barr & Stephenson, 2011; Kanaki & Kalogiannakis, 2018; Lee et al., 2011; Psycharis & Kotzampasaki, 2019; Weese, 2017; Weese & Feldhausen, 2017; Wing, 2006).

However, even today there is not a widely accepted definition of CT but rather an abundance of definitions, each of which uses a different aspect of CT, which leads to a different approach in the classroom (Barr, Harrison, & Conery, 2011; Barr & Stephenson, 2011; Koh, Basawapatna, Bennett, & Repenning, 2010; Hemmendinger, 2010; Mannila et al., 2014; Weese & Feldhausen, 2017). Besides, it has been argued that, no matter how the instructor interpretates CT, what is important is to correlate it with paradigms that designate the way CT can be integrated in the classroom, namely, move beyond its definitions, towards a more realistic concept (Barr & Stephenson,2011; Basawapatna, Koh, Repenning, Webb, & Marshall, 2011; Papadakis & Kalogiannakis, 2020).

It is argued that the use of computers facilitate the development of CT, since the best way to cultivate it is via programming because this way it is possible to implement the different dimensions of CT (Wing, 2006). The combination of man and computer offers the possibility of harnessing the power they have in processing information (Wing, 2008).

In the school context it is necessary to develop a rich computing environment, where the learning process will be developed through a three-stage course "use-modify-create" (p. 35) (Lee et al., 2011): in the first stage students are mere users of someone else's creation; in the second, they begin to make modifications that become increasingly complex, as they acquire new skills and gradually the creation of another becomes their property; in the last stage, aspects of CT such as subtraction, automation, and analysis are activated and thus they are encouraged to develop ideas for new computer projects of their own inspiration, which refer to topics of their choice. During this process both the teacher and the students should use computer vocabulary, where appropriate, to describe problems and solutions, to accept any possible failure on the grounds that it may lead to the right path to a successful outcome and to work in groups utilizing concepts such as problem segmentation, subtraction and negotiation (Barr & Stephenson, 2011).

Self-efficacy in Science Education

If we want to develop an understanding of the reasons why Physics is considered to be a difficult subject, we must first understand the different aspects it has among students, one of which is self-efficacy, their belief that they can complete a task which requires a specific ability, which is something that improves as they further familiarize with the subject (Lindstrøm & Sharma, 2011). Besides, self-efficacy is related to pupils' persistence in complex and challenging tasks or when they encounter difficulties and it is regarded as a predictor for learning outcomes, academic achievement and career choice in a number of cognitive domains such as Physical Sciences (Korkmaz & Altun, 2014; Schraw, Crippen, & Hartley, 2006; Weese & Feldhausen, 2017). According to Sezgintürk and Sungur (2020), it is very important to examine students' self-efficacy in Science Education as it is very important in boosting their meaningful learning and augmenting their achievement.

If we wish to enhance self-efficacy in Science Education we can use problem solving in order to make students capable of completing educational activities without direct instructions, promote teamwork, inquiry learning and make use of cognitive scaffold and visual programming languages (Papadakis, Kalogiannakis, & Zaranis, 2016; Weese, 2017).

Motivation towards Science Education

As motive we consider anything that encourages a person to act and it is believed that it affects the reasons and the way of human behavior, learning and achievement (Kalogiannakis, Papadakis & Zourmpakis, 2021). Motivation is distinguished in intrinsic and extrinsic; intrinsic motivation urges a person to engage in a task, the completion of which is an end in itself and it aims at the personal satisfaction and development and is related to academic achievement and self-efficacy, while extrinsic motivation is the positive or negative reinforcement which is created by the students' background and puts them into action (Bye, Pushkar & Conway, 2007; Kalogiannakis, Papadakis & Zourmpakis, 2021). It is imperative for the teacher to know which kind of motivation to use so that the students perform better (Kalogiannakis, Papadakis, & Zourmpakis, 2021).

Visual Programming

Through the international bibliography it has been made clear that students, although very familiar with technology, avoid learning programming because it is considered incredibly challenging (Korkmaz & Altun, 2014; Papadakis, Kalogiannakis, Zaranis, & Orfanakis, 2016; Resnick et al., 2009). Lately however, visual programming languages, such as Scratch, have fuelled the interest in teaching programming at Primary School, as they engage students in creating digital products, in a way that expresses their ideas and makes them creators instead of consumers of technology (Lye & Koh, 2014; Weese, 2017). Moreover, these languages promote the grasp of computational concepts and problem-solving strategies, as they reduce the redundant syntax of traditional programming language and, as a consequence, the cognitive load. As a result, even beginners have the ability not only to learn programming but also to acquire CT skills (Lye & Koh, 2014; Rees et al., 2016; Sengupta et al., 2013; Weese, 2017). In fact, Sengupta et al. (2015) argued that the students who were taught Sciences using visual programming exhibited a much better learning performance compared to the rest of the students and deduced that embedding computers in Sciences at Primary School is very important, as in the long run it can lead to deeper understanding of scientific concepts.

According to Sengupta et al. (2013) in order for a computer tool to be integrated in the teaching of Science Education in Primary Schools, is must have the following characteristics: it must be easy for beginners; learning activities must be integrated in the existing curriculum of Science Education; it must be easy to be used by teachers who don't have much experience in programming; and "it should not impose arbitrary ceilings on the scope and levels of complexity for modelling and analysis by students over time"(p. 362).

In accordance with the above mentioned is Scratch, a very popular visual programming language that was created in MIT. It is believed that it should be included in teaching practice, as visual programming environments are particularly easy to use, even for very young children, because they focus on learning in a playful way, similar to lego bricks, which reduces the cognitive load and the stress of failure and helps students to develop a range of very important skills for the 21st century: deeper understanding of mathematical and computational concepts, creative thinking, argumentation, collaboration, critical thinking, problem solving, algorithmic thinking, composition, self-directed learning, prediction and evaluation (Liu, Lin, Hasson, & Barnett, 2011; Lopez & Hernandez, 2015; Maloney et al., 2010; Meerbaum-Salant et al., 2013; Resnick, 2008; Resnick et al., 2009).

Students' Perception of Electricity

When students enter the educational process, they usually have formed perceptions, which are very widespread in the student body and are shaped by their daily life, language, religion and cultural background and with which they give explanations to various phenomena, which often prove to be incompatible with the scientific views (Jaakkola & Nurmi, 2008; Küçüközer & Kocakülah, 2007). Due to the abstract nature of electricity concepts and their connection to microcosm, their teaching, especially in Primary School, has proved to be very challenging (Azaiza, Bar, & Galili, 2006; Baser, 2006; Kalogiannakis, Ampartzaki, Papadakis, & Skaraki, 2018) and in preschool classroom (Glauert, 2009; Kada & Ravanis, 2016; Kaliampos, Kada, Saregar, & Ravanis, 2020; Solomonidou & Kakana, 2000). Due to their daily contact with electricity, students, prior to formal instruction, have already acquired intuitive conceptions which are inconsistent with the scientific view and have proved to resist traditional instruction; as a result it is impossible for students to associate the scientific conceptions with everyday life and keep them separated from hands-on experience (Baser, 2006; Jaakkola & Nurmi, 2008; Jaakkola, Nurmi, & Veermans, 2011).

Specifically, the students are familiar with words that have to do with electricity, such as current or energy, however, they find it difficult to understand their true meaning or distinguish between them (Glauert, 2009; Kada & Ravanis, 2016; Kaliampos, Kada, Saregar, & Ravanis, 2020; Küçüközer & Kocakülah, 2007). Although they are able to assemble the parts to make a simple circuit, they are unable to identify them as abstract drawings (Glauert, 2009; Kada & Ravanis, 2016). According to the students, each circuit includes an electricity donor, the battery, and a consumer, the light bulb, which leads them to realize that the current does not pass through the light bulb but ends up in it and is consumed (Küçüközer & Kocakülah, 2007). Moreover, they consider the battery as the provider or storage of electricity and the lamp as the consumer (Küçüközer & Kocakülah, 2007). In order to predict the brightness of a lamp, they take into account the number of lamps and batteries and their arrangement in the circuit (Küçüközer & Kocakülah, 2007). Finally, any change in some part of the circuit is considered to affect the circuit locally (Küçüközer & Kocakülah, 2007). If we take into consideration the above mentioned, we can understand that it is imperative that the instructor is well aware of students' perception in order to use them as a base for teaching electricity (Glauert, 2009; Métioui & Trudel, 2020).

Physical Computing and Computational Experiment

Physical computing is considered to be very beneficial for all age groups as it provides a high learning level, it promotes participation, interest and sharing of ideas, enforces constructive and creative learning and it cultivates creativity and imagination (Fokides & Papoutsi, 2020; Przybylla & Romeike, 2014). However, the choice of the goals to be achieved as well as the learning environment of Physical Computing must be carefully selected as it can be not only fun but also very demanding: it includes very demanding activities that increase the cognitive load and may bring about a very disagreeable learning experience (Jin, Haynie, & Kearns, 2016).

In this context the notion of computational experiment is included, where modelling and computers replace the usual experimental set-up and simulation takes the place of the classical experiment (Psycharis, 2011; Zacharia, 2007; Zacharia & Michael, 2016). It combines Physics, Math and the theory of information, it is very intriguing as it refers to real problem solving and it motivates students to make predictions and hypotheses that promote the development of scientific process (Psycharis, 2011). We can safely assume that it contributes to the cultivation of critical thinking and positive attitude towards science (Psycharis, 2013; Psycharis et al., 2013).

In general, the use of computer experimentation is recommended by many scientists, when there is no laboratory and the experiment is dangerous or requires complex and time-consuming procedures (Zacharia, 2007). These kinds of experiments are much easier to use in the classroom, as they require less space and time, do not disrupt the proper functioning of the classroom and can be repeated much more easily than the classics, thus providing more experience to students (Klahr et al., 2007; Zacharia, 2007).

However, Klahr et al. (2007) clarified that it is preferable to use natural materials in areas where the use of the senses is needed or where contact with the real situation is necessary. For example, it is argued that it is important for students to have physical contact with circuits as, although simulation can help students understand the theoretical background of electricity, in order to cause a conceptual change, it is necessary to further test their intuitive perceptions by seeing that what they observed in the simulation, is also true in reality (Jaakkola & Nurmi, 2008).

In conclusion, we could claim that the ultimate goal of the teaching of Science Education should be to exploit the potential of both experimental methods in order to maximize the effectiveness of learning process; it is therefore advisable to combine computational experiment with classical experiment when teaching Physics, as the one is complementary to the other (Jaakkola & Nurmi, 2008; Zacharia, 2007; Zacharia & Michael, 2016).

METHODOLOGY

The current research focused on electricity, as it is not only an inextricable part of our everyday life but also considered one of the most typical cases of non-intuitive knowledge, as it is inseparably connected to the obscure micro world. In this context it was attempted to answer the following questions:

1. What is the effect of visual programming and physical computing in:
   (a) students' perception of electricity concepts?
   (b) computational thinking aspects of students?
   (c) students' self-efficacy in Science Education?
   (d) students' intrinsic motivation towards Science Education?
2. Are there any distinctions between the results of the visual programming-based intervention and the intervention that is based on the textbook?

Control and Experimental Group

The study group of this research was composed of 5th Grade students of the 5th Primary School of Agia Varvara in Attica in Greece. In particular, E_1 was the experimental group and E_2 was the control group. Overall, the questionnaires of the research were answered by 33 students, 15 of whom were boys and 18 were girls, 5 of whom were Roma. When the research began any knowledge the students possessed regarding electricity was intuitive and had derived from the use of electricity in everyday life.

According to the Curriculum of the Primary School in Greece, Physics is introduced as a subject in the 5th Primary School. The pre-test questionnaires were given to both of the groups just before they were taught the electricity unit. Until that time the only reference in relation to electricity was made in the section "Energy", where the definition of electricity was given and reference was made to the conversions of forms of energy. Therefore, we can safely claim that all the knowledge they possessed at that particular time about electricity was practical-experiential knowledge, which had emerged through the daily use of electricity.

Instruments

For the purpose of this research four questionnaires were used: one for self-efficacy and motivation, one for CT, one for electricity and one for programming.

The questionnaire on self-efficacy and motivation is an adaptation of MSLQ a very popular and widely used instrument, the original version of which consists of 81 questions (Rotgans, 2009). The adaptation that was used included only 13 questions, 4 about intrinsic motivation, 4 about extrinsic motivation and 5 about self-efficacy, as it was considered very difficult for young students to answer the amount of questions of the original instrument. The questions that were used, were translated into Greek and were adapted at the linguistic ability of the students and had to be rated on a 5-point Likert scale: 1-strongly agree, 2-agree, 3- don't know, 4-disagree, 5-strongly disagree.

When it comes to the questionnaire of CT, we used the questionnaire of Psycharis and Kotzampasaki (2019) as an example, which consists of questions from the website Bebras.org. The questionnaire that was constructed included 10 questions of minimum difficulty, as the subjects of the research had no prior experience.

The questionnaire about electricity included 7 questions, 1 open-ended and 6 closed-ended. The first question, in which the students had to write what they think the electric current is, was open-ended, as we thought it was important for them to use their own words so as to have a better understanding of the conceptual models they have formed (Creswell, 2009). The rest of the questions were about the simple electric circuit, the flow of the current in it and the materials that are conduits and insulators.

The questionnaire about programming is also a modification of MSLQ. It consists of 19 questions that aim to examine students' view of programming using Arduino and the way they solve problems. This questionnaire was administered exclusively to the experimental group that received the experimental treatment.

Finally, as this experiment examined views and in order to achieve triangulation, it was deemed necessary to conduct individual semi-structured interviews to the students of the experimental group, in order to delve deeper into the subject (Creswell, 2009). Each interview lasted about 2 minutes and it aimed to examine how the students felt about making a circuit using Arduino. In total, 14 out of 15 students took part. Initially, a pilot interview was conducted with one student and, as it was ascertained that the questions were understandable and the student could answer, the interviews with the other 13 students followed. To protect their anonymity, each student chose a nickname. Through the interview, the students were asked to elaborate on their impressions about the construction of the circuit with the Arduino board and, if they found any difficulty, what it was. Finally, it should be noted that the use of soundings was necessary both to help students develop their thoughts more and to clarify what they were saying.

Instruments' Reliability

As it has already been mentioned, the questionnaires about self-efficacy, motivation and programming are adaptations of MSLQ and therefore they can be considered as reliable. However, the questionnaires about CT and electricity were created for the purposes of this survey and as a result it was considered necessary to examine their reliability. As such two months after the post-tests the students were asked to answer them again, so that we could conduct the statistical analysis of Cronbach's alpha. The test's results were .79 and .90 for CT questionnaire and .79 and .81 for electricity questionnaire, which leads to the conclusion that both questionnaires are reliable enough.

Moreover, when it comes to the interview, a pilot interview was carried out and as it was made clear that the questions were understood, then we proceeded with the rest of the interviews.

Method

The research design is considered to be an experiment and since it was conducted within the school context it is categorized as a quasi-experiment (Creswell, 2009). The pre-tests were given to the students right before they started studying the chapter of electricity.

The pre-test questionnaires were delivered to the students on the same day by their teachers (in the case of the experimental group the teacher was the researcher) just before they started teaching the electricity unit. The questionnaires for electricity, the CT and self-efficacy / motivation were completed by both groups, while the programming questionnaire was completed only by the experimental group that was to receive the experimental treatment.

The control group was taught electricity by involving students in physical experiments. The experimental group was taught the same unit both with the involvement of students in physical experiments and with the use of the computer experiments.

In total, four activities took place. One day before the start of the first activity, the researcher showed the students of the experimental group, through a projector, the working environment of S4A and talked to them about the Arduino boards. To carry out the activities, the students were divided into five teams of three members. Each team consisted of two programmers and one evaluator: the two programmers performed the wiring and put the command bricks in the correct order and the evaluator checked the wiring, the order of the commands, executed the program and, in case of error, suggested corrections. Because the researcher wanted to

Table 1. Overall results in posttests for CT in Mann-Whitney

	E1		E2			
	n	Mean Rank	n	Mean Rank	U	p
Task.1	15	20.00	18	14.50	90.000	.015
Task.2	15	17.50	18	16.58	127.500	.361
Task.3	15	20.00	18	14.50	90.000	.015
Task.4	15	22.00	16	10.38	30.000	.000
Task.5	15	18.40	18	15.83	114.000	.222
Task.6	15	22.37	17	11.32	39.500	.000
Task.7	15	18.50	14	11.25	52.500	.002
Task.8	15	19.93	17	13.47	76.000	.013
Task.9	15	20.90	18	13.75	76.500	.008
Task.10	15	21.00	17	12.53	60.000	.001

Table 2. Overall results in posttests for electricity in Mann-Whitney

	E1		E2			
	n	Mean Rank	n	Mean Rank	U	p
When the LED is on	15	23.07	18	11.94	44.000	.000
Parts of el. circuit	15	19.50	18	14.92	97.500	.030
Switch	15	19.50	18	14.92	97.500	.029
Electric current	15	18.50	18	15.75	112.500	.103
Open/closed circuit	15	22.40	18	12.50	54.000	.001
Conduits-insulators	15	22.50	18	12.50	52.500	.000

have an equal distribution of good / weak students and boys / girls in the groups, the children were not given the opportunity to choose who to work with. The experimental process was completed in four weeks.

RESULTS

At this point it was deemed necessary to mention the method used for data processing and analysis. Regarding the quantitative data, it was taken into account that in the first research question there was a correlation of variables and in the second a comparison between the two groups and as a result, it was considered of vital importance to conduct inductive statistics (Creswell, 2009). Regarding the qualitative data, the method of thematic analysis was followed.

Quantitative Data

The data that emerged were codified and input to the equivalent variables that were created in the statistical program SPSSv.24. As both groups that participated in the research were small, it was decided to apply non-parametric statistical tests. In order to determine whether there is a statistically significant change when comparing data that emerged from pretests and posttests in each group the test Wilcoxon was conducted. In order to compare the two groups that participated in the experiment the test Mann-Whitney was used. For this survey the significance level (p-value) was set to 0.05 (Creswell, 2009).

When it comes to the questionnaire about self-efficacy and motivation there was no statistically significant change in any of the tests.

When it comes to the questionnaire about CT the Wilcoxon test showed a statistically significant change in 7 out of 10 tasks in the experimental group (E_1) and in only 1 out of 10 tasks in the control group (E_2). The Mann-Whitney test showed a statistically significant change in 2 out of 10 tasks in the pretests. However, as we can see in Table 1, in the posttests only two tasks don't present a statistically significant change and if we take a closer look at the mean ranks, we will notice that E_1's performance is much better.

When it comes to the questionnaire about electricity, the Wilcoxon test showed a statistically significant change in 5 out of 6 questions in E_1 but only 2 out of 6 questions in E_2. The Mann-Whitney test showed a statistically significant change in 2 out of 6 questions in the pretests. Once again, as we can see in Table 2, in the posttests only one question doesn't present a statistically significant change and if we take a closer look at the mean ranks, we will notice that E_1's performance is much better. As we have already mentioned in the posttests there is a differential, as only one of the questions doesn't present a statistically significant change and as it is apparent in Table 2, E_1's performance is much better.

As it has already been mentioned, the questionnaire for programming was given only to the experimental group and as a result only the test Wilcoxon was conducted. In the majority of the question there was no statistically significant change. In Table 3 we present briefly the questions that showed a statistically significant change. For the record, all of them were about self-efficacy.

Table 3. Overall results for programming in Wilcoxon

	n	Z	p
I can program Arduino to switch on the LED	15	-3.337	.001
I can make an electric circuit	15	-3.213	.001
I can correct a program for Arduino	15	-2.630	.009
I can use Arduino in order to make a flashlight	15	-3.355	.001

Qualitative Data

After applying thematic analysis to the interviews, it became obvious that all of the students responded very positively in making a circuit using Arduino. The basic topics that came about were three: the opinion that students formed about the assembly, the difficulties they encountered and the way they faced these difficulties.

The majority of students described it as *"nice experience", "interesting", "easy" and "fun"* and only four of them said they found it *"difficult"*. However, it must be noted that even the students who described the process as difficult said that they liked it. In fact, eleven out of fourteen students stated that they would like to repeat such an activity *("it was a nice experience, and it was something interesting. If I could, I would like to do it again")*.

Regarding the difficulties they encountered, seven students stated that they had difficulty finding the location of the cables on the breadboard (two of them also mentioned a slight difficulty in finding the position of the resistor) and four on the Arduino. One student stated that he had difficulty dealing with the position of the resistor and the LED, while two students reported that they encountered no difficulty.

Regarding the way they solved the difficulties they faced, all of them said that what helped them was working with their team and in fact five of them said that it would be much more difficult for them if they were alone (*"Were I alone, I couldn't… it was difficult… but with the help of my team we did it*"). Finally, it is necessary to mention that even the two students who stated that they did not have any difficulty, mentioned the cooperation with their team as something very important and attributed the fact that they did not have any difficulty in working with their classmates.

DISCUSSION AND CONCLUSION

When it comes to motivation towards Science Education, the data about the effect of physical computing and visual programming were inconclusive. When it comes to self-efficacy in Science Education, the effect of the above-mentioned was verified only in the questionnaire about programming, which leads us to agree only partially with previous research (Psycharis & Kotzampasaki 2019; Weese, 2016). Moreover, it was established that the learning experience that came about with the use of visual programming contributed significantly in obtaining CT skills, which is in accordance with the international bibliography (Lye & Koh, 2014; Portelance & Bers, 2015; Psycharis & Kotzampasaki, 2019). When it comes to electricity it is clear that students, due to their everyday experience with electricity and prior to formal instruction, have formed conceptions that are inconsistent to the scientific view (Baser, 2006; Jaakkola & Nurmi, 2008). As a result, the intuitive approach of the concept of the electric current became apparent, as well as the inability to distinguish it from concepts such as electric energy, electricity and electric circuit, which is in accordance with previous research (Baser, 2006; Kada & Ravanis, 2016; Küçüközer & Kocakülah, 2007; Métioui & Trudel, 2020; Shipstone, 1984).

After the instruction the control group kept on approaching the concept of the current intuitively as well as using various models about its flow that differ from the scientific view, which verifies their resilience to traditional methods of teaching (Baser, 2006; Jaakkola & Nurmi, 2008; Jaakkola, Nurmi, & Veermans, 2011; Jaakkola, Nurmi, & Veermans, 2011; Küçüközer & Kocakülah, 2007). On the contrary, the students of the experimental group performed much better in posttests, gave the correct definition of the electric current and almost all of them used the correct model about its flow. Therefore we can safely deduce that computer experiments contribute significantly to the learning process and consequently, in understanding the principles of Physics, especially when they are combined with visual programming languages and physical experiments, which is in accordance with the related bibliography (Baser, 2006; Kalogiannakis & Papadakis, 2017; Kalogiannakis, Tzagkaraki, & Papadakis, 2021; Jaakkola & Nurmi,2008; Papadakis, Kalogiannakis & Zaranis, 2016; Chatzopoulos, Papoutsidakis, Kalogiannakis, & Psycharis, 2020; Dorouka, Papadakis, & Kalogiannakis, 2019; Papadakis & Kalogiannakis, 2021; Tzagkaraki, Papadakis, & Kalogiannakis, 2021; Sengupta et al., 2013, 2015).

After studying the qualitative data obtained from the present study, it was found that the involvement of children with physical computing and visual programming resulted in the cultivation of a positive attitude towards science, which is consistent with previous research (Kalogiannakis, Tzagkaraki, & Papadakis, 2021; Psycharis, 2013; Tzagkaraki, Papadakis, & Kalogiannakis, 2021; Vlasopoulou, Kalogiannakis, & Sifaki, 2021). In addition, the development of cooperation between students was observed and its importance was highlighted, a fact that was also confirmed by previous research (Kalogiannakis &

Papadakis, 2017; Przybylla & Romeike, 2014; Psycharis, 2013).

LIMITATIONS AND SUGGESTIONS

The contribution of this research is very important, as it is a fact that it is not enough to wait for the students to reach University to introduce them to the above concepts: since the lives of today's students are influenced by computers and many of them will pursue careers that will be directly or indirectly related to computers, it is necessary to work with algorithmic problem solving and computational methods and tools during Primary Education (Barr & Stephenson, 2011).

At this point it must be mentioned that there were some limitations to this study that should be acknowledged. Since the sample size was small we were prevented from generalizing the results. Additionally, in spite of the fact that the experimental group had no previous experience with visual programming, they didn't receive enough instructions, as the time limit was quite short. It is very likely that a more thorough instruction of visual programming would have had an effect on the final results. Lastly, it must be mentioned that the accumulated data about self-efficacy were contradictory and this is something that must be further investigated, possibly with some adaptation to the questionnaires.

If we wish to be more confident about the effect of physical computing in teaching Physics, building CT skills, in self-efficacy and internal motivation of students, then it is necessary to expand this research in more sections of Physics. It would be quite interesting to implement this study to more schools, so as to have a broader sample with a variety in geographical characteristics and see if the results are similar. Additionally, we could make use of the sample in use, so as to investigate if and to what extend the effect of physical computing and visual programming is long lasting.

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