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The role of gender in students' achievement and self-efficacy in STEM

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Introduction

The underrepresentation of girls and women in studies areas of Science, Technology, Engineering, and Mathematics (STEM) is a worldwide phenomenon. This underrepresentation is a continual concern for social scientists and policymakers (Stoet & Geary, 2018). While more women are studying science than ever before, recruitment to key areas, namely physics and engineering remains stagnant (Smith, 2011). In a cross-country study carried out by Stoet and Geary (2018) it was found that women obtained fewer college degrees in STEM disciplines than men in all assessed nations. Based on this, fewer college degrees in STEM disciplines possibly lead to fewer career opportunities for females in STEM areas than males. The factors that may influence males' and females' educational and career choices will be discussed in this paper.

First of all, in this section the factors that may affect educational and career choices will be presented from a broader scope but not limited to gender. To better understand educational and career choice, Ming-Te Wang and Degol (2013) direct attention to Eccles' (1983, 2009) expectancy–value theory in which there are three major components, psychological, biological and socialization components. The psychological component consists of competence beliefs, goals, interests, and values (Ming-Te Wang & Degol, 2013) while, the biological component of behavior genetic and hormone influences on the development of abilities, competence beliefs, and values (Ming-Te Wang & Degol, 2013). The socialization component consists of social, cultural, and contextual influences on the development of self-beliefs, goals, interests, and values (Ming-Te Wang & Degol, 2013). Based on Eccles' (1983, 2009) expectancy–value model, Ming-te Wang and Degol (2013) point out that achievement-related choices (e.g. high school course enrollment and college major selection) and career aspirations and choices are most directly influenced psychologically by ability, perceived competence (e.g., expectations for success), and the subjective task value attached to the various available options. For example, deciding to pursue a STEM related university degree, depends on the individual's actual achievement

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in STEM related areas and on his/her perceived achievement in STEM areas – referring to his/her self-efficacy in the subject area. In addition, the decision to a certain university degree could be due to the "subjective task value" referring to interest value, utility value, attainment value and cost (Ming-te Wang & Degol, 2013). For instance, the decision to pursue a STEM related university degree could be due to the individual's enjoyment when studying STEM subjects, personal goals, personal fulfillment and psychological, economic, and social costs a STEM related degree and career would possible involve.

Furthermore, examining educational and career choices from a gender point of view, Ming-te Wang and Degol (2013) identify six empirically supported factors as the leading causes of female underrepresentation in STEM fields: (a) cognitive ability, (b) relative cognitive strengths, (c) career preferences, (d) lifestyle values, (e) field-specific ability beliefs, and (f) gender-related stereotypes and biases. Ming Te Wang and Degol (2017) point out that stereotypes and biases are sociocultural factors that potentially affect these cognitive and motivational factors. Sociocultural factors, such as societal beliefs and expectations of male/female differences in ability and cultural pressures to pursue traditionally masculine or feminine interests, are far more likely than biology alone to impact career decisions (Ming Te Wang & Degol, 2017). This view is also in line with Ceci, Williams, and Barnett (2009) that point out that socio-cultural barriers rather than biological factors impede females from pursuing education and a career in STEM areas. Females may opt for a different to STEM career because they may not feel competent enough due to sociocultural stereotypes or because these stereotypes force them to choose a traditionally female-oriented area of studies. Dasgupta and Stout (2014) also share the view that stereotypes have a lot to do with STEM educational and career choices by pointing out that culturally ubiquitous stereotypes consistently portray ideal scientists, engineers, and technology innovators as male. The mismatch between masculine STEM stereotypes and feminine gender role expectations creates barriers for girls' and women's participation in STEM at every life stage (Dasgupta & Stout, 2014).Given the research presented above, it could be concluded that stereotypes, gender role expectations and sociocultural pressure are related with female underrepresentation in STEM areas of studies. In this research, we are going to look into females' achievement and self-efficacy in STEM areas of studies and based on that we are going to further explore their underrepresentation in STEM areas of studies. In particular, from all STEM disciplines (Science, Technology, Engineering and Mathematics), the focus of this study will be on Technology and Engineering and more specifically in programming. Main objective of the study is to explore gender differences in STEM subjects. Below, the two specific objectives of our study are outlined:

- To explore previous research on gender differences in achievement and self-efficacy in STEM subjects and more specifically in Technology and Engineering disciplines.
- To study potential gender differences in achievement and self-efficacy of primary school students in STEM subjects and particularly in Technology and Engineering disciplines in a programming lesson.

Theoretical Framework

Gender differences in students' achievement in STEM subjects

In the mid-nineties, it was found that gender achievement differences in science, engineering and mathematics either were diminishing or had disappeared (Eisenberg, Martin, & Fabes, 1996). A more recent international research on adolescent achievement, demonstrated that girls perform similarly or better than boys on generic science literacy tests in most nations (Stoet & Geary, 2018). However, different to their achievement rate, boys' personal academic strengths in science and mathematics, while girls' strengths are in reading comprehension (Stoet & Geary, 2018).Taking Finland as an example, girls' absolute science scores were higher than those of boys, however, boys were often better in science relative to their overall academic average (Stoet & Geary, 2018). Similarly, girls might have scored higher than boys in science, but they were often even better at reading (Stoet & Geary, 2018). This conclusion is also in line with Ming-te Wang & Degol (2013) that report that the group with both high math and high verbal ability included more females than males.

More precisely, regarding students' acquisition of skills in the area of Technology and Engineering, according to Atmatzidou and Demetriadis (2016), girls need longer time to reach the same skills level as boys in computational thinking. Both genders are able to reach the same skill level, however, girls need more training sessions (Atmatzidou & Demetriadis, 2016). This proves that time is an essential commodity for CT skills development; skills level evaluated in later session have been found in most cases to be significantly improved when compared to initial session. Atmatzidou and Demetriadis (2016). Apart from gender, differences in computational thinking skills development could be due to age, student cognitive developmental level and students' attitudes relevant to following instructions and afford workload induced by the task (Atmatzidou & Demetriadis, 2016). As far as a research carried out in the framework of an introductory programming class in tertiary education, it was found that women and men displayed equivalent competency in robotics activities (Milto, Rogers, & Portsmore, 2003). In an introductory programming course this time in middle school, females outperformed peer males (Qian & Lehman, 2016a). Regarding Educational Robotics, in a study investigating whether pre-school boys and girls are equally successful in a series of building and programming tasks with tangible/graphical computer language, it was observed that both girls and boys can have a successful and rewarding experience being exposed to robotics and programming as early as kindergarten (Sullivan & Bers, 2012). Pre-school girls in this study reflected very few areas in which they did not perform equally to their male counterparts as properly attaching robotic materials, and programming using Ifs (Sullivan & Bers, 2012). This preschool Robotics Program allowed girls an introduction to robotics and computer programming in which they mastered advanced concepts and created a successful final project that they could feel proud of (Sullivan & Bers, 2012).

To conclude, based on research carried out in STEM areas (Stoet & Geary, 2018; Ming-te Wang & Degol, 2013) and specific to technology and engineering research (Atmatzidou & Demetriadis, 2016; Qian & Lehman, 2016a; Sullivan, Kazakoff, & Bers, 2013), females can achieve results as high as males in STEM subject areas and more precisely in Technology and Engineering disciplines across education levels.

Gender differences in self-efficacy

Regarding STEM areas of studies, males seem to be more confident than females in their skills in STEM disciplines (Schunk & Pajares, 2002). In the same line, in an engineering course in tertiary education, Milto *et al.* (2003) report that even though males and females displayed equivalent achievement rates, males were more confident in their abilities. This view is also confirmed by a more recent research in secondary education (Stoet & Geary, 2018); in this cross-country study it was observed that boys often expressed higher self-efficacy than girls in science despite the fact that girls attained higher achievement rates than boys. Below, an attempt will be made to explain this phenomenon based on current literature.

Authors report that the gender differences in self-efficacy are related to the students' personal academic strength (Stoet & Geary, 2018). As boys' academic strengths most often lie in the area of science, their self-efficacy is higher in the area of science –meaning that they feel more confident with the subjects that they are comparatively better at. Looking into factors influencing self-efficacy in STEM, it is worth mentioning other studies examining self-efficacy from a psychological point of view. According to Eccles and Midgley (1989) gender differences in self-efficacy are related to developmental level. Eccles and Midgley (1989) underline that there is little evidence for differences in self-efficacy among elementary-aged children. Differences begin to emerge following children's transition to middle or junior high school (Eccles & Midgley, 1989) with girls typically showing a decline in self-efficacy beliefs. This could be due to the fact that girls as grow older are more exposed to stereotypes, gender role expectations and sociocultural pressure. Interestingly Schunk and Pajares (2002) express a diametrically opposed view to all the above, underlining that self-efficacy actually affects achievement in children and adolescents rather than achievement affects self-efficacy. Based on the above, self-efficacy varies in males and females is STEM areas of studies, however is that the case in students' interest and enjoyment in STEM? Back in the nineties, Jones (1991), reported that girls are interested in science, but are given fewer opportunities for exposure and success in science. In a recent research Stoet and Geary (2018) report that boys often find more joy and a broader interest in science than girls.

In order to encourage females to pursue studies and careers in STEM and more specifically in the area of technology and engineering, it is proposed to support them to participate in short-term, well-structured robotics educational program (Weinberg, Pettibone, Thomas, & Stephen, 2007). Weinberg and colleagues (2007) report that the educational robotics programs as "Botball" may help to reduce the gender gap in science and engineering through reducing beliefs in traditional gender roles and increasing positive attitudes about engineering and science and careers in these areas. In the same line, Alvarado, Dodds, and Libeskind-Hadas (2012) suggest that students should participate in conferences, competitions and celebrations of women in computing. Furthermore, Schunk and Pajares (2002) propose to provide students with clear performance information about their capabilities or progress in learning to deal with gender differences in self-efficacy among adolescents. To increase female participation, motivation to succeed, and aspirations in STEM Dasgupta and Stout (2014), proposes to create learning and professional environments that foster belonging. At each life stage, evidence-based programs, practices, and policies can keep girls and women engaged in STEM (Dasgupta & Stout, 2014). Taking all the above into consideration, females' self-efficacy and interest in STEM disciplines could be reinforced through their participation in programs, conferences, competitions and celebrations of women in STEM. Females' participation in well-structured learning programs that foster belonging would enable them to confront social and cultural stereotypes and boost their self-efficacy and interest in STEM. In the following section gender differences and Scratch programming will be discussed as Scratch is the primary resource employed in this study.

Gender differences in Scratch programming

Scratch programming language is a virtual programming environment (VEP) for children. VPE has not been formally defined in the literature, but it has often been referred to as a software environment enabling users to drag and drop blocks of code in a visual way (Cheng, 2019). VPE can allow users to select appropriate blocks of code and snap them together to create complete programs (Cheng, 2019). With Scratch programming, the students can get really creative (Resnick *et al.*, 2009; Romeike, 2008), they can understand mathematics (Resnick *et al.*, 2009) and acquire 21st century skills (Resnick *et al.,* 2009). In previous research on students' achievement in Scratch, gender does not seem to have an impact on learners' performance in programming (Qian & Lehman, 2016b; Tekerek, 2014). Instead of gender, students' performance differences in programming seem to be better explained by their academic performance in non-programming subjects (Qian & Lehman, 2016b). In our research we are going to study the gender differences in students' achievement and self-efficacy in programming with Scratch.

Methodology

The study

The introductory lesson to Scratch programming language was conducted in a non-formal educational institution in Greece. The lesson plan and methodology are described in Esteve-González (2017). The participants were in total 27 primary school pupils (15 boys and 12 girls) between from 9 to 12 years old. The lesson had 3 parts: in the first part pupils were introduced to Scratch digital environment and experimented with the basic programming blocks, in the second part of the lesson the students had to solve basic programming problems, and in the third part of the lesson the pupils created an animation in Scratch using algorithms creatively. The delivery of the sessions was based on exploratory, story-telling and project-based teaching approaches. Objective of the introductory lesson was to introduce students to Computational Thinking and reinforce students' skills in the area of STEAM education (Esteve-González, 2017).

Instruments

In this study, data were gathered on students' achievement and self-efficacy through an evaluation report and a questionnaire. Regarding students' achievement rates, the teacher filled out an evaluation report and assigned a grade per lesson part to every student. As far as students' self-efficacy is concerned, a questionnaire was filled out by the students upon completion of the lesson. The questionnaire was filled out online by each pupil right after the lesson and consisted of 11 three-point Likert scale items and collected pupils' feedback on Scratch interface, on the overall Scratch lesson, the learning outcomes and last but not least it collected feedback on perceived easiness for each of the three parts of the lesson. In this study, the following items referring to perceived easiness will only be taken into consideration: "The 1st part of the lesson was easy", "The 2nd part of the lesson was easy" and "The 3rd part of the lesson was easy". The variables of this study are gender, achievement and self-efficacy; gender is the independent variable while achievement and self-efficacy are the dependent variables. Conclusions for achievement are drawn on the teacher's evaluation report while conclusions on self-efficacy are based on the questionnaire items on perceived easiness. The data analysis was carried out in excel: both groups' (males and females) achievement rates per lesson part were calculated in excel and were juxtaposed with both groups' self-efficacy rates. Self-efficacy was calculated based on the students' answers on the questionnaire items - students replied with a yes or a no whether they considered the lesson part easy or not. The percentage of the students that considered the lesson easy was calculated per gender and was used to determine students' self-efficacy in programming.

Results and Discussion

Based on results of our previous study, the introductory lesson to Scratch received really positive feedback from the students (Schina, Esteve-Gonzalez, & Usart, 2018); all three lesson parts received really high percentages of enjoyment feedback from the pupils. Now, in this research we are going to further look into the introductory lesson to Scratch and examine students' achievement and self-efficacy rates from a gender point of view as described in the previous section.

Gender differences in students' achievement in Scratch introductory programming

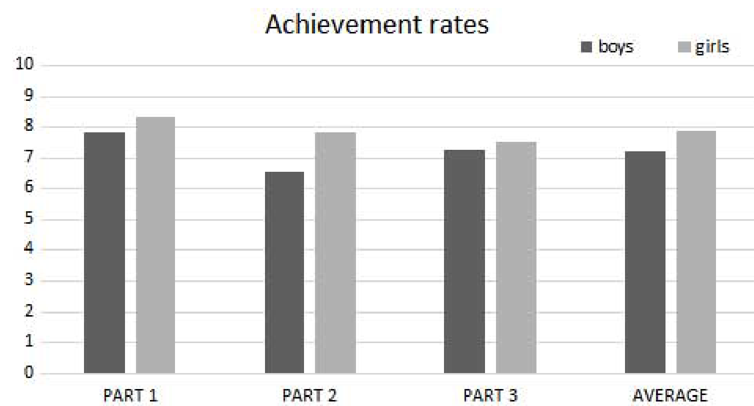

Figure 1. Achievement rates per gender

Students' achievement in the Scratch programming lesson was calculated both per section and in total (Figure 1). In Part 1 boys achieved 7.8 out of 10 while girls slightly higher, 8.33. In the second part boys got 6.53 while girls over a grade higher 7.83. In the third part a less prominent achievement difference is observed with girls achieving 7.5 while boys 7.27. Calculating the two groups' average scores boys got 7.2 while girls 7.88. It is observed that the females' performance is slightly higher than males' performance in all three parts of the lesson. The results are in line with previous research on the field reporting that in an introductory programming lesson females outperformed peer males (Qian & Lehman, 2016a). Further investigating gender differences in performance in Part 2, this part referred to the resolution of 10 worksheet-based Scratch challenges. The achievement difference of 1.3 points could be in accordance with previous research reporting that males are more reluctant compared to females when it comes to carrying out writing tasks (Merisuo-Storm, 2006). Based on this, males' reluctance to complete writing tasks could be associated with their lower achievement rate in this specific part of the lesson.

Gender differences in students' self-efficacy in Scratch introductory programming

Students' self-efficacy rates in the Scratch programming lesson were calculated both per section and in total. As displayed in Figure 2, there is a tendency of males to demonstrate higher self-efficacy in all three parts of the lesson as more males than females declare that the lesson parts were easy. Males seem to be extremely confident about the first part of the lesson, with the absolute majority pointing out that this lesson part was easy while a slightly lower percentage of females report to find this lesson part easy (91%). In the second part of the lesson both groups' self-efficacy drops, however, males still demonstrate a slightly higher self-efficacy than females. The most significant difference in self-efficacy is observed in Part 3 with 87% of males to report that the lesson was easy while only 50% report so. The average results (89% males; 72% females) are in line with previous studies reporting that males express a higher self-efficacy that females in a programming course (Milto, 2003).

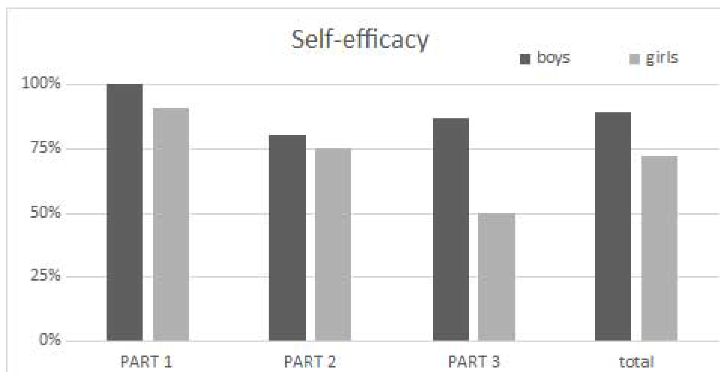

Figure 2. Self-efficacy rates per gender

Looking at the results of achievement and self-efficacy in parallel, we may see that females outperform males, however, they display a lower self-efficacy than them. This has also been observed in in secondary education in (Stoet & Geary, 2018); in this cross-country study it was observed that boys often expressed higher self-efficacy than girls in science despite the fact that girls attained higher achievement rates than boys.

Conclusions and future research

In this study we examined students' achievement and self-efficacy in an introductory programming lesson from a gender point of view. We found out that female students outperformed male however, interestingly, female students demonstrated a lower self-efficacy than males. Our study is in line with previous studies in STEM disciplines reporting that females tend to have lower self-efficacy in STEM than males even though they may achieve higher scores than males. Our study confirms this view in the Technology and Engineering disciplines of STEM education and more specifically in a visual programming lesson for primary school children. With our study, females' higher achievement rates and lower self-efficacy is for the first time observed in the context of Greek primary school education in an introductory Scratch lesson. Given the limited sample and the short duration of the study, the conclusions drawn cannot be generalized. In the future, a study gathering information from a larger group over a long period of time should be implemented to enable us to make more reliable deductions. Apart from carrying out a more extensive research regarding achievement and self-efficacy per gender, it is important to study in the future how we could boost female self-efficacy in STEM and more specifically in the field of technology and engineering. It could be more thoroughly studied how technology can be integrated into the curriculum not only to reinforce students' learning but also to promote both genders' self-efficacy in technology. Finally, to address females' lower self-efficacy, we could also carry out a research to find out at which age differences in self-efficacy start to appear.

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