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Gender and student course preferences and course performance in Computer Science departments: A case study

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Abstract

The study of gender differences in Computer Science (CS) has captured the attention of many researchers around the world. Over time, research has revealed that negative stereotypes and 'myths' about the cognitive skills, academic abilities and interests of females in CS do exist, deterring females from entering the field. Thus, this study aims to shed light on the aforementioned stereotypes and 'myths' by investigating gender differences in terms of student preferences and performance in the undergraduate courses included in the entire curriculum of a CS department. For this purpose, a case study was designed, exploiting data from a CS department in Greece; more specifically, 89 graduate degrees were quantitatively analysed. Regarding performance, the analysis of the data revealed that –apart from in a few courses– there are no statistically significant differences between the mean grades of male and female students in most of the curriculum courses of the CS department in question. Concerning student preferences in CS courses, few gender differences appear to exist. At a statistically significant level, males preferred courses related to hardware and software engineering, whereas females selected courses related to theoretical CS, humanities and social sciences.

Keywords Gender · Computer Science · Performance · Preferences · Higher Education · Western Europe

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1 Introduction

Females are underrepresented in most of the Science, Technology, Engineering and Math (STEM) fields, and also in Computer Science (CS) (Cohoon and Aspray 2006; Hill et al. 2010; Camp 2012; Ashcraft et al. 2012; Wang and Degol 2017). Actually, CS remains an especially heavily male-dominated field, even after several years of extensive efforts to promote female participation (Camp 2012; Cheryan et al. 2017). The ratio of females to males involved in CS shrinks dramatically from early student years to working years. In several countries, females are underrepresented in all fields of CS education; teaching staff in secondary education (Kordaki and Berdousis 2017), undergraduate and graduate studies (Kordaki and Berdousis 2017), as well as in the academic sector (Camp 2012; Hill et al. 2010; Berdousis and Kordaki 2016). This phenomenon, acknowledged as 'the pipeline shrinkage problem', is complex and multi-faceted, but well known and documented (Gürer and Camp 2002; Ashcraft et al. 2012).

Over time, research has identified several key social and structural factors affecting female participation in CS, often deterring them from choosing future education or careers in CS, revealing that the reasons for such low participation are multi-layered. In fact, female under-representation in CS has been attributed (Gürer and Camp 2002; Margolis and Fisher 2003; Cohoon and Aspray 2006; Barker and Aspray 2006; Ashcraft et al. 2012) to various factors such as: (a) environmental factors; including modest computer experience, lack of appropriate family support and uncomfortable (for girls) educational settings, (b) cultural factors; including negative stereotypes and myths about female cognitive abilities in CS, and (c) intrinsic motivational factors; including girls' beliefs about their low self-efficacy and competence in the CS field.

Focusing on the cultural impact, and especially on the negative stereotypes and myths about female abilities, research in STEM fields revealed that no significant differences in intelligence, ability and performance between males and females exist (O'Reilly and McNamara 2007; Matthews et al. 2009; Cunningham et al. 2015). As regards CS education, male and female students also seemed to do equally well in their CS courses (Ilias and Kordaki 2006). Nevertheless, the issue of gender differences in terms of performance in CS is still under-researched. Here, it is worth mentioning that the aforementioned negative stereotypes are based on a number of socially constructed 'myths' about gender differences in cognitive skills and academic ability. These 'myths' may not be real in the scientific and empirical sense, regarding actual measures of ability and intelligence, but in another sense they are real, because they have real social implications; they constitute obstacles that hinder female success. Nevertheless, individuals still believe in, and behave in response to, the belief of such gender differences (Alkhadrawi 2015).

The aforementioned social influence on an individual's learning and behavioral action could be explained by Social Cognitive Theory (SCT; Bandura 2001). According to SCT, the individual's beliefs, behaviours and portions of his/her knowledge acquisition can be directly related to observing others within the context of social interactions, experiences and media influences (Bandura 2001). The theory takes into account a person's past experiences, which shape whether a person will engage in a specific behavior and explain the reasons why a person engages in that behavior. Focusing on gender development and differentiation, SCT (Bussey and Bandura 1999) suggests that the development and differentiation of gender occurs through the reciprocal and bidirectional influences occurring among three factors: personal, behavioural and environmental. Apart from recognizing the importance of behavioral and cognitive factors in producing and perpetuating gender differentiation, SCT emphasizes the environment and social practices, particularly through modeling (Bussey and Bandura 1999).

Based on the above, the presence of socially constructed negative stereotypes about the abilities and skills of females in CS could deter women from entering the field. The abovementioned negative stereotypes also impact on women's preferences not only in terms of specific subject domains but also on their course-preferences within each subject-domain (Wang and Degol 2017). Thus, despite the fact that no significant differences in the performance of males and females in STEM and CS courses have been reported, and in the numbers of the courses taken, a closer examination of the course selections reveals certain persistent differences in preferences regarding STEM (Alkhadrawi 2015). The differences in course preferences are reflected in career choices as well (Amelink 2009). Even when the overall number of males and females majoring in science is nearly equal, the specific field within science still differs significantly: males take high-level mathematics, engineering, CS, and physical sciences in higher numbers, while more females take biology and chemistry (Bussey and Bandura 1999; Coley 2001; Amelink 2009). It would appear that males both attach a higher value and utility to math and have higher self-concept in math, which might explain why they choose to participate more in math than females (Van de Gaer et al. 2008). Evidence from high school and college reveals differences in student preferences as well (Amelink 2009). Nevertheless, the issue of gender differentiation in course selection in CS is also still under-researched.

Despite the relevant research in STEM and CS fields, a study investigating gender differences within CS in terms of performance and course preferences in the entire curriculum of a CS department has not been reported. Thus, based on the above, it makes sense to question whether the gender gap in CS could be also attributed to differences in performance and if there is any gender differentiation in CS course preferences. This is the contribution of this study.

The following sections present a literature review, the context of the study and the results of the data analysis. A substantiated discussion and interpretation of the research findings, in order to draw conclusions, follows. Finally, the limitations of the study and some future research dimensions are also identified.

2 Literature review

This section, presents the background of the study in terms of main barriers that contribute to the under-representation of females in STEM and CS as well as gender differences in performance and preferences in STEM fields.

2.1 Barriers contributing to the under-representation of women in CS and STEM education

In this section, the main barriers that impact on female representation in CS are presented, namely: (a) environmental, (b) cultural, and (c) intrinsic motivational.

2.1.1 Environmental factors

A review by Ashcraft et al. (2012) revealed that female perceptions, interest, confidence and attitudes towards CS are shaped by the larger environment, in which they learn about CS, including: computing experience, family support and education. Girls lose interest in CS early on, as they do not gain as much experience with computers as boys do (Margolis and Fisher 2003), while the kind of computing experience seems to be a crucial factor (Barker and Aspray 2006; Gannon 2007, 2008; Wang et al. 2015). What is more, parents and family members have significant influence as role models with the types of messages or beliefs they communicate to girls both implicitly and explicitly (Ashcraft et al. 2012). In some cases, these messages, maybe unintentionally, can be obstacles to females participating in CS (Gürer and Camp 2002). Key factors that contribute to female loss of interest in the field are also connected to their education, and especially the CS curriculum, the teaching practices and the uncomfortable (for females) learning environments (Abbiss 2008; Clegg 2001; Ashcraft et al. 2012). There is evidence that appropriate interventions in the curriculum in order to adapt it to the interests of females, promoting their abilities (Haussler and Hoffmann 2002) and providing extracurricular and informal learning experiences, such as participation in science competitions or science-related field trips (Cunningham 2007), can enhance female science performance and interest. Poor pedagogy in CS education is problematic because students' experiences in CS courses affect their decisions to major in CS, and their retention rates (Cohoon and Cohoon 2006). It is suggested that a good introduction to CS courses is a great recruiting tool (Cohoon et al. 2013).

2.1.2 Culture in the field of Computer Science

Most recent studies also argue that one novel and powerful social factor that may perpetuate the underrepresentation of women in CS is the prevalence of stereotypes within the culture of the field, which in some cases act as 'educational gatekeepers', discouraging females from entering CS (Cheryan et al. 2009, 2015). In fact, girls come up against negative stereotypes about their abilities, causing them to feel as if they are not suited to the CS field. As a result, a large gender disparity persists in higher education and careers in the STEM and CS fields, in which male participation and success exceeds that of females (Alkhadrawi 2015; Kordaki and Berdousis 2017).

In fact, evidence in the STEM field – at both high school and higher education levels - indicates that no significant differences in intelligence, ability and performance between males and females exist (Jacobs 2005; Britner 2008; O'Reilly and McNamara 2007; Matthews et al. 2009; Cunningham et al. 2015). Males seem to perform slightly better in the construct of science and have more self-efficacy, while in math performance gender differences were small and in some cases females outperformed males (Ding et al. 2006; Kiran and Sungur 2012). A study also suggests that there are no differences in performance among male and female students in CS Tertiary education (Ilias and Kordaki 2006). Nevertheless, when different subject-domains are taken into consideration, females perform better than males in terms of the social aspects of science factors and males tend to perform better than females in the constructs of science factors (Kiran and Sungur 2012). Gender gaps in the percentage of graduates earning credits in specific high school STEM courses also vary by course

(Laird et al. 2009). Upon closer inspection within the science and math fields, differences emerge in terms of which discipline - within STEM fields - males and females pursue in their education and careers (Amelink 2009). Beyer (2014) also argues that "individuals, regardless of gender, who are highly conscientious and low in relational-interdependent self-construal can earn the highest CS grades" (p.1).

2.1.3 Intrinsic motivational factors

Here it is worth mentioning that performance is closely related to domain-specific self-competence, self-efficacy beliefs and motivation, which are affected by the aforementioned negative stereotypes (Jacobs et al. 2002; Lin 2016). Those students who believe that they have the ability to accomplish a particular task actually perform better and are more motivated to select increasingly challenging tasks (Ibid). In fact, expectancies of success (such as self-efficacy) are critical issues in educational and career choices (Eccles et al. 1999; Bandura 2012). To this end, computer self-efficacy predicts involvement with computers (Compeau et al. 1999) and intention to take CS courses (Sáinz and Eccles 2012). Moreover, self-efficacy in STEM and CS may be important factors in opting to take courses and eventually selecting a major in these fields (Beyer 2014). Additional social psychological and personality factors, e.g. interest in CS, computer confidence, conscientiousness, and openness to experiences, have been acknowledged as significant predictors of the taking of CS courses (Beyer 2014; Chipman et al. 2018). Thus, increasing female computing and mathematical self-efficacy would positively affect their representation in CS. However, females tend to have low self-efficacy and believe they have little natural ability in traditionally male-dominated domains, such as mathematics, engineering, and CS (Beyer 2014). The more a subject is considered appropriate for males, the lower the female self-efficacy (Correll 2004). This self-efficacy is low when compared to actual female abilities, skills, or performance (Correll 2004; Jagacinski 2013). Regarding CS, research suggests that computer self-efficacy is also affected by computer experience (He and Freeman 2010) and previous performance (Correll 2004), while Beyer (2014) found evidence for actual gender differences in computer self-efficacy, stereotypes, interests and values.

2.2 Gender differences in performance and preferences in STEM fields

The fact that the gender gap in measures of STEM ability and achievements has narrowed and nearly disappeared has been known since the early 1990s (Meece and Courtney 1992). A review of the empirical data of a whole decade revealed that the gender gap related to STEM had narrowed significantly (Meece and Courtney 1992), while a similar analysis of longitudinal data in the US found that female STEM academic achievement was equal to that of males (Adelman 1991). There was little or no difference seen in the ability and intelligence of males and females in science subjects (Mickelson 1989). In math performance, gender differences were especially small, and in some cases females outperformed males, but only by a negligible amount (Hyde et al. 1990). Later studies emphasized the performance of males and females in high school STEM education; interestingly, the results revealed that, while males and females are similar in terms of achievement, females have higher final grades in STEM, while males have higher test scores (Saunders et al. 2004; Britner 2008). Britner (2008) also found that females in life science classes earned higher grades than boys, while Saunders et al. (2004) showed that female final grades in math were significantly higher than those of males. In contrast, in most cases males perform better in science tests (Ormrod 2007). Nevertheless, there is evidence to support females performing as well as males in academic achievement, including science (Mickelson 1989; O'Reilly and McNamara 2007), and in truth female and male students do not differ significantly in the objective examination of achievement in science knowledge (Freedman 2002). In a review of 25 years of evidence, Jacobs (2005) argued that differences in grades are generally slight and concluded that females have achieved increasing success in STEM courses, closing the gender gap, while a later study found no significant gender differences in five science academic outcomes (Matthews et al. 2009).

Research also suggests that, when different domains are taken into consideration, females perform better than males in the social aspects of science factors, and males tend to perform better than females on the constructs of science factors (Kiran and Sungur 2012). Laird et al. 2009 revealed that a more female than male graduates had higher grades in biology, chemistry, and health science/technology, while, more males than females had higher grades in physics, engineering, engineering/science technologies, and CS. Nevertheless, Van de Gaer et al. (2008) contended that gender differences in math participation and in math achievement can shift over time. In their study, they noticed that, while at first males scored significantly higher than females, the gap eventually closed and females surpassed males at higher grade levels. On the whole, evidence from the STEM field indicates that there seem to be no significant differences in performance between males and females (Hyde et al. 1990; Jacobs et al. 2002; Ding et al. 2006; Kiran and Sungur 2012).

However, despite the lack of significant gender differences in performance in STEM education, gender differences appear in the kinds of courses taken within STEM fields. Studies in recent years have revealed that gender gaps do persist in terms of enrolment in specific courses and majors (Coley 2001; Van de Gaer et al. 2008; Amelink 2009; Cunningham et al. 2015). Males seem to prefer high-level mathematics, engineering, CS, and physical sciences, while females opt more for biology and chemistry (Amelink 2009; Cunningham et al. 2015). In addition to choices made in courses and majors, choices made for extracurricular activities also appear to differ. Some evidence suggests that females were less likely than males to participate in science activities outside school (Amelink 2009). This lower level of participation may affect science interests and future participation in science fields, as well as education and career choices.

Despite the above, more research has to be done in the field of gender differences in performance and preferences in STEM education and especially in CS education.

3 Context of the study

3.1 Objective and research questions

The objective of this study is to increase our understanding of gender differences in CS by exploring the possibility of gender differences related to the courses included in the entire curriculum of a CS department in terms of: (a) course preferences, and (b) performance. Thus, the research questions of the current research are the following:

1. How well do males and females perform in courses included in a CS department's curriculum? and
2. What are the differences between males' and females' course preferences in CS departments?

This study could contribute to the field of CS curriculum and instruction by determining the extent to which more effort is needed within the education system to form appropriate CS curricula that meet women's interests, and to dispel gender myths as well as remove perceived boundaries within certain CS career paths. Subsequently, this study could lead to the incorporation of teaching strategies to challenge persistent myths about gender differences in CS performance and perceived obstacles about gender and CS.

3.2 Methodological choices

3.2.1 Research strategy

To fulfil the aforementioned objective a quantitative study was designed. The research strategy was a case study. According to Yin (2009), case studies can also be based on quantitative evidence. The Department of Computer Science and Technology (DCS&T), University of the Peloponnese –as a Computer Science Tertiary Educational institution – was selected for the case study, comprising the total sum of graduate degrees earned from the first graduation in 2008 until and including those of 2012.

The case study was subject to a research strategy due to the various advantages this presents (Farquhar 2012). In particular, this research strategy allowed the examination of gender differences in terms of performance and course preferences as contemporary real-life phenomena (Cassell and Symon 2004) within a Computer Science, Tertiary Education context.

3.2.2 Techniques and procedures

Data collection Quantitative data collection methods were applied during this research. Secondary data referring to the grades of the graduates in the compulsory and the elective CS courses they had selected from the curriculum in order to earn their graduate degree were collected from the official records of the DCS&T. The data collected concerned 89 graduates of the department. On the date of the collection of the data, these 89 graduates comprised the entirety of the graduates of the department enrolled from 2002 to 2008. Of these 89 graduates, there were 69 males ($N1 = 69$; percentage 77,53%) and 20 females ($N2 = 20$; percentage 22,47%). This gender representation reflected in the data collected is in line with relevant research into the representative typical percentage of CS graduates from CS Departments in Greece (Kordaki and Berdousis 2017). In this survey, anonymity and confidentiality were strictly maintained. Anonymity was ensured by not disclosing any reference to the personal data of the graduates apart from their gender, the courses in which they had enrolled and been successful, and their grades. Confidentiality demands that the information will not be publicly reported in a way which identifies the graduates. Finally, ethical standards, reliability and validity of the data collection and statistical analysis were followed for the best result.

Research design The research design – the conceptual structure within which the research is conducted; namely, the overall configuration of a research study so as to gather good results from the collected data – was defined following collection of the secondary data. The approach followed is described below. The secondary data referred to the grades of the 89 graduates in the compulsory and elective courses. According to the curriculum of the DCS&T, in the academic period in question, students had to enrol and pass examinations in 21 compulsory courses as well as in 25 electives in order to earn a degree. For the purposes of the current study, in compliance with the curriculum of DCS&T, the courses were classified into 3 divisions, namely: 'Theoretical Computer Science' (TCS), 'Software Systems' (SS), 'Computer Technology and Computer Systems' (CTCS). The TCS division contained theoretical CS courses: 3 compulsory and 10 electives; The SS division featured software engineering courses: 8 compulsory and 29 electives; the CTCS division included mainly hardware-oriented courses: 3 compulsory and 15 electives. There were also two groups of courses: 'Math and Physics' (M&P) consisting of 7 compulsory courses related to Math and Physics, and 'General Education' (GE) which includes 21 electives covering social, ethical, law and humanities issues. For each of the abovementioned divisions, tables for compulsory and elective courses were created, and grades of the male and female graduates were quantitatively-analyzed (Cohen et al. 2002) according to the aforementioned classification of courses.

Data analysis In order to analyze the data, statistical analysis (descriptive and inferential) was performed. To calculate the results, the Statistical Package for Social Sciences (SPSS) v.24.0 was used. Regarding the performance of male and female graduates, mean grades and standard deviation values were calculated for each of the compulsory/elective courses. Independent sample t-tests were conducted to investigate whether these mean grades differed significantly according to gender (Goodwin 2007). As far as the preferences of males and females are concerned – in each of the elective courses – the percentage of graduates (males/females) who selected a course was estimated and the chi square test for independence (with Yates Continuity Correction) was performed to examine the extent to which gender is related to course selections (McHugh 2013). For this study, elective courses selected by fewer than 5 graduates (males or females), were not taken into consideration in the performance analysis. Nevertheless, these courses are highlighted in the results section as they are indicative of the preferences of male and female graduates. Moreover, due to the large number of courses (100 courses) included in the curriculum of DCS&T, only results that are significant at $p < 0.05$ or better are discussed in the results section. Based on the research literature, most gender differences are expected to fall within a small range. Of course, there is always variability. Even though a significant gender difference is found, this does not mean all males or females differ from each other. As is usual, all statements refer to average differences between groups, not differences among individuals.

Validity and reliability Validity and reliability are of the utmost importance in a study as they form the basis on which another researcher should view a part of the research as knowledge which can be assimilated into the knowledge base of a study field (Rowley 2002). Beginning with validity, as this research is a quantitative case study -that is, a vigorous study- an attempt has been made to properly apply the appropriate statistical measures for the concepts that are under investigation (Yin 2009). As secondary data that were extracted from the original official sources, their accuracy is verified, improving the accuracy and trustworthiness of this study. Therefore, it is hoped that in this study the results will be seen to have high validity. However, as this study is a single case study, it is typically associated with analytical generalizations where already existing theories are matched against the empirical findings of the study (Rowley 2002). As this study is a quantitative study, reliability is its strength. The statistical calculations realized during data analysis have also been performed several times to ensure that measures are free of errors and therefore, consistently yield the same results over repeated testing periods. This means that the conducting of the study, such as, the data collection procedures, can be repeated with the same results every time, thus increasing the reliability of the results. Since the scope and the analysis of data, with reference to quantitative aspects, is as comprehensive and inclusive as possible, the conducting of the study can be repeated by any researcher (Yin 2009).

4 Results

In this section, the results that emerged from the data analysis are presented in subsections for each of the above-mentioned 3 divisions of courses, and for M&P compulsory courses and GE electives. For each of the aforementioned groups of courses, performance (in compulsory courses) and preferences in electives, as well as performance in said electives are presented in the Tables. Specifically, the Tables referring to the performance in compulsory courses presents descriptive statistics - mean grades and standard deviation (SD) values - along with the independent samples t-test results for the equality of means. As far as the electives are concerned, similar Tables are generated regarding graduate performance, while for graduate preferences two more columns are added to present the percentage of graduates (males and females) who selected the corresponding elective.

4.1 Graduate choices and performance in "Theoretical Computer Science" courses

4.1.1 TCS compulsory courses: Graduate performance

As it is shown in Table 1, the differences in the mean grades of males and females are not statistically significant.

4.1.2 TCS electives: Graduates preferences

An inspection of the number of graduates who selected each of the 10 electives in TCS division reveals that there were 3 elective courses that were selected by a very small

Table 1 Performance in "Theoretical Computer Science" compulsory courses

Graduates' performance in "Theoretical Computer Science" compulsory courses							
Courses	Group statistics				Independent samples test - T test for equality of means		
	Male		Female				
	Mean grade (I)	SD	Mean Grade (J)	SD	t	Sig. (2-tailed)	Mean Difference (I-J)
Introduction to the Science & Technology of Informatics	7.80	1.26	7.25	1.77	1.289	0.209	0.547
Computational Science I	8.33	1.69	8.10	1.77	0.537	0.593	0.233
Theory of Computation	6.75	1.27	6.83	1.13	−0.249	0.804	−0.078

number of female graduates (fewer than five). These courses are related to applied mathematics and theoretical CS ('Operational Research'), the study of mathematical structures ('Graph Theory') and other advanced topics in TCS ('Advanced Topics in TCS'). These courses were also selected by fewer than 16 (25%) males.

For the remaining 7 elective courses of the TCS division, Table 2 illustrates the percentage of male and female graduates who selected the corresponding elective course, and the mean and standard deviation values of the grades of male and female graduates for each course.

At first glance, it seems that female graduates selected more electives (6 electives) at a higher percentage compared to males. Nevertheless, the chi-square test for independence indicates that there are only 3 significant associations in favor of females in the following courses: (a) *'Computational Geometry'* [X^2 (1) = 3.606, $p = 0.048$], (b) *'Fractals'* [X^2 (1) = 3.562, $p = 0.049$], and (c) *'Cryptography'* [X^2 (1) = 6.253, $p = 0.012$].

4.1.3 TCS electives: Graduate performance

Concerning the performance of male and female graduates in these 7 TCS division electives, Tables 2 and 3 reveals that according to the independent sample t-test that was conducted to compare the mean grades of male and female graduates, there was no actual statistically significant difference in the mean grade of the electives in the TCS division.

4.2 Student choices and performance in "System Software" (SS) courses

4.2.1 SS compulsory courses: Graduate Performance

Regarding the compulsory courses of the SS division, the statistical analysis reveals that the only difference statistically significant in favor of males is in the mean grade of *'Computer Programming I'* [Mean difference = 1.17; t (51.509) =3.964, $p < 0.001$].

Table 2 Preferences and performance in "Theoretical Computer Science" electives

Graduates' preferences and performance in "Theoretical Computer Science" electives									
Courses	Group Statistics						Independent Samples Test - T test for equality of means		
	Preferences		Performance						
	Male	Female	Male		Female				
	Graduates who selected the course (%)		Mean grade (J)	SD	Mean grade (J)	SD	t	Sig (2-tailed)	Mean difference (I-J)
Combinatorial Optimization	91.30	90	8.31	1.34	8.44	1.28	−0.381	0.704	−0.13
Computational Geometry	36.23	60	8.06	1.39	7.88	1.54	0.365	0.717	0.18
Computational Science II	49.28	50	9.20	0.87	9.25	0.72	−0.146	0.885	−0.05
Parallel Algorithms	76.81	90	7.64	1.93	7.69	1.82	−0.102	0.919	−0.05
Computational Complexity	24.64	25	6.91	0.77	7.10	1.02	−0.445	0.661	−0.19
Fractals	27.54	35	7.68	1.31	8.14	1.49	−0.762	0.453	−0.46
Cryptography	14.49	40	6.60	1.50	7.50	1.07	−1.424	0.174	−0.90

Table 3 Performance in "Software Systems" compulsory courses

Graduates' performance in "Software Systems" compulsory courses							
Courses	Group Statistics				Independent Samples Test - T test for equality of means		
	Male		Female				
	Mean grade (I)	SD	Mean grade (J)	SD	t	Sig. (2-tailed)	Mean Difference (I-J)
Computer Programming, I	7.31	1.62	6.15	0.99	3.964	0.000	1.17**
System Programming	6.14	1.37	5.70	1.02	1.321	0.190	0.44
Data Structures	7.10	1.67	6.70	1.27	0.992	0.324	0.40
Operating Systems	5.89	1.18	5.60	0.94	1.010	0.315	0.29
Object Oriented Programming	7.19	1.61	7.03	1.85	0.386	0.700	0.16
Software Technology	8.04	1.21	8.00	1.50	0.134	0.894	0.04
Database I	6.03	1.01	6.35	1.39	−1.143	0.256	−0.32
Human Computer Interaction	6.75	1.24	7.35	1.85	−1.869	0.045	−0.60*

*The difference is significant at the 0.05 level

**The difference is significant at the 0.01 level

On the other hand, females performed statistically significant better in '*Human Computer Interaction*' (Mean difference 0.60 in favor of females) [t(87) = −1.869; p = 0.045]. It is worth noting that neither males nor females achieved excellent performance in these 8 compulsory courses, as there was no single grade equal to 8.5 or higher.

4.2.2 SS electives: Graduate preferences

Regarding graduate selections, it is worth noting that there are 14 electives for the SS division that were selected by a very small number of females (fewer than 5; 25% of female graduates). These courses were: *core programming courses ('C Lab', 'Java Lab', 'C++ Lab', 'Theories of Programming Languages'), databases ('Database Management Systems', 'Information retrieval', 'Databases II'), software applications ('Current Software Systems', 'Distributed Systems', 'Software Engineering', 'Data and information visualization')* and other *advanced and special topics in SS ('Advanced topics in Programming', 'Advanced Topics in Databases', 'Special topics in software systems').* The above-mentioned courses were also selected by less than 25% of male graduates. Even though the above mentioned 14 electives reveal the subjects that females do not prefer, they are not taken into account in the performance analysis as they are selected by fewer than five graduates.

For the remaining 13 elective courses, Table 4 illustrates the percentage of male and female graduates who selected the corresponding elective courses, and the mean and standard deviation values of the grades of male and female graduates for each course. The chi-square tests for independence indicate that there are significant associations in favor of males in the course '*Advanced User Interfaces*, *VR*' [X^2 (1) = 4.701, p = 0.030], and in favor of females in the course '*Machine learning & data mining*' [X^2 (1) = 4.260, p = 0.039].

4.2.3 SS electives: Graduate performance

Table 4 shows that the differences in the mean grades, in favor of males, that are statistically significant concern: (a) '*Information management on the Internet*' [Mean difference = 1.60; t(87) = 2.102; p = 0.030), (b) '*Advanced topics in Software Systems*' [Mean difference = 0.88; t(34) = 2.428; p = 0.021], and (c) '*Systems Security*' [Mean difference = 1.41; t(87) = 2.345; p = 0.023].

Interestingly, despite the fact that female graduates achieved higher mean grades in half of the electives of this division, the statistical analysis did not however reveal any statistical significant differences in favor of females.

4.3 Student choices and performance in "Computer Technology and Computer Systems" (CTCS) courses

4.3.1 CTCS compulsory courses: Graduate performance

The performance of male and female graduates in CTCS compulsory courses is illustrated in Table 5, revealing that the differences in the mean grades of males and females are not statistically significant.

Table 4 Preferences and performance in "Software Systems" electives

Graduates' preferences and performance in "Software Systems" electives

Courses	Group Statistics						Independent Samples Test – T test for equality of means		
	Preferences		Performance						
	Male	Female	Male		Female				
	Graduates who selected the course (%)		Mean Grade (I)	SD	Mean Grade (I)	SD	t	Sig. (2-tailed)	Mean Difference (I-J)
Info management on the Internet	31.88	25	8.6	1.11	7	1.87	2.102	0.030	1.60*
Advanced topics in Soft. Systems	42.03	35	9.17	0.80	8.29	1.11	2.428	0.021	0.88*
Multimedia Technology	47.83	40	6.85	1.32	6.00	1.45	1.783	0.093	0.85
Data management systems	50.72	50	7.31	1.42	6.65	1.33	1.321	0.193	0.66
Compilers II	49.28	40	6.57	1.30	6.56	1.89	0.020	0.984	0.01
Parallel programming	85.51	80	7.64	1.94	7.69	1.62	−0.102	0.919	−0.05
Advanced User Interfaces, VR	62.32	35	8.74	0.98	9	0.82	−0.654	0.516	−0.26
Artificial Intelligence	82.61	75	7.96	1.47	8.23	1.70	−0.628	0.532	−0.27
Information Systems	49.28	35	7.50	1.46	8.09	1.04	−1.241	0.221	−0.59
Intelligent Systems & Applications	42.03	30	7.50	1.65	8.42	0.92	−1.072	0.291	−0.81
Systems security	17.39	30	8.41	1.32	7	1.56	2.345	0.023	1.41*
Machine learning & data mining	21.74	45	8.33	1.63	7.89	1.62	0.648	0.524	0.44
System analysis	52.17	55	7.51	1.48	8.09	1.04	−1.196	0.238	−0.58

*The difference is significant at the 0.05 level

4.3.2 CTCS electives: Graduate preferences

Regarding graduate choices, a review of the number of male and female graduates who selected each course reveals that a small number of females (fewer than five female graduates) selected courses related to *advanced computer networks issues* (*'Advanced Computer Network Issues', 'Computer Communications and Networks II', 'Digital Signal Processing'*) and *computer engineering ('Synthesis of Digital Architectures', 'Introduction to embedded systems', 'Computer arithmetic'*) and *'Robotics', 'Computer Architecture II'*; and *'Wireless & Mobile Communications'*. All the aforementioned courses were also selected by fewer than 14 males (20% of male graduates). The above mentioned 9 courses were not taken into consideration in the performance analysis.

Table 5 Performance in "Computer Technology and Computer Systems" compulsory courses

Graduates' performance in "Computer Technology and Computer Systems" compulsory courses							
Courses	Groups Statistics				Independent Samples Test - T test for equality of means		
	Male		Female				
	Mean grade (I)	SD	Mean grade (J)	SD	t	Sig. (2-tailed)	Mean Difference (I-J)
Computer Networks I	7.93	1.59	7.85	1.69	0.207	0.836	0.845
Logic Design	7.28	1.48	6.83	1.40	1.212	0.229	0.450
Computer Architecture I	7.16	1.31	7.18	1.35	−0.047	0.963	−0.156

Table 6 demonstrates the percentage of male and female graduates who selected the rest of electives (6 out of 15 electives) from the CTCS division, and the mean and standard deviation values of the grades of male and female graduates for each course.

The chi-square tests for independence indicate that males, at a significantly higher percentage compared to that of females, prefer courses related to computer architecture, such as: (a) *'Hardware Description Languages II'* [X^2 (1) = 11.221, p = 0.001], and (b) *'Computer organization'* [X^2 (1) = 6.033, p = 0.014].

Regarding female graduate choices, Table 6 shows that a higher percentage of them compared to that for males selected certain courses, but chi-square tests indicate that there are no significant associations between gender and those course selections.

4.3.3 CTCS electives: Graduate performance

As shown in Table 6, the mean differences in favor of males are not statistically significant. Conversely, the statistical analysis indicated that the difference in the mean values is statistically significant in the case of '*Information theory and coding*' in favor of females [Mean difference = 1.04; t(34) = −2.148; p = 0.042]. All in all, with the exception of the previously mentioned course, it seems that male and female graduates performed equally well in the CTCS division electives.

4.4 Graduate performance in "Mathematics & Physics" (M&P) courses

The analysis of the grades of the graduates in M&P courses is illustrated in Table 7. The independent sample t-test that was conducted to compare the mean grades of male and female graduates in M&P courses indicated that there were statistically significant differences in favor of males in the mean grades of 2 courses: (a) '*Linear Algebra*' [Mean difference = 0.89; t(87) = 2.782; p = 0.007], and (b) '*Mathematics I*' [Mean difference = 0.61; t(87) = 1.728; p = 0.048]. Yet, both male and female graduates achieved mean grades in all M&P courses far below 8.5 ("Excellent").

Table 6 Preferences and Performance in "Computer Technology and Computer Systems" electives

Graduates' preferences and performance in "Computer Technology and Computer Systems" electives									
Courses	Group Statistics						Independent Samples Test - T test for equality of means		
	Preferences		Performance						
	Male	Female	Male		Female				
	Graduates who selected the course (%)		Mean Grade (I)	SD	Mean Grade (I)	SD	t	Sig. (2-tailed)	Mean Difference (I-J)
Hardware Description Languages I	55.07	55	7.09	1.63	6.59	1.39	0.926	0.359	0.50
Computer organization	91.30	70	8.10	1.43	8.25	1.42	−0.348	0.729	−0.15
Advanced Computer Architectures	23.19	35	7.13	1.02	7	0.82	0.284	0.779	0.13
Digital circuit design	30.43	35	8.45	1.40	8.57	1.10	−0.205	0.839	−0.12
Hardware description languages II	14.49	30	8.85	1.18	9.17	0.75	−0.585	0.568	−0.32
Information theory and coding	24.64	40	5.65	0.95	6.69	1.46	−2.148	0.042	−1.04*

*The difference is significant at the 0.05 level

Table 7 Performance in "Mathematics & Physics" compulsory courses

Graduates' Performance in "Mathematics & Physics" compulsory courses							
Courses	Groups Statistics				Independent Samples Test - T test for equality of means		
	Male		Female				
	Mean grade (I)	Std. Deviation	Mean grade (J)	Std. Deviation	t	Sig. (2-tailed)	Mean Difference (I-J)
Linear Algebra	6.44	1.31	5.55	1.06	2.782	0.007	0.89*
Prob. Theory & Statistics	7.14	1.84	6.45	1.68	1.500	0.137	0.69
Mathematics I	6.59	1.43	5.98	1.27	1.728	0.048	0.61*
Arithmetic Analysis	7.10	1.58	6.60	1.47	1.265	0.209	0.50
Mathematics II	6.33	1.58	6.13	1.61	0.518	0.606	0.21
Physics I	7.28	1.83	7.38	1.89	−0.213	0.832	−0.10
Discrete Mathematics	6.20	1.05	6.63	1.06	−1.581	0.117	−0.42

*The difference is significant at the 0.05 level

4.5 Graduate preferences and performance in "General Education" (GE) electives

4.5.1 GE electives: Graduate preferences

Electives in GE cover a wide range of subjects that can be applied to many different careers and students can choose them according to their interests. An inspection of the number of graduates who selected each of the electives in GE uncovers the fact that females did not prefer courses (courses selected by 1–2 females) related to *marketing and management perspective of CS* (*'Introduction to Economic Science I'*, *'Introduction to Economic Science II'*, *'New product and service development'*), the *study of mathematical models* ('Game Theory'), and specific issues related to social implications of CS *'Legal issues in informatics'*. The aforementioned 5 courses were also selected by fewer than 10 male-graduates (7%). Due to the fact that few female students selected these courses, they are not taken into consideration in the performance analysis.

Table 8 reveals that the majority of the remainder of GE electives were selected by a higher percentage of females than males. Nonetheless, the chi-square tests for independence indicate that females, at significantly higher percentages compared to those of males, preferred courses regarding *Humanities and Social Sciences,* such as: (a) *'Pedagogy'* [X^2 (1) = 3.771, p = 0.048], (b) *'Sociology'* [X^2 (1) = 3.662, p = 0.049], and (c) '*Cognitive Science'* [X^2 (1) = 14.175, p = 0.001].

4.5.2 GE electives: Graduate performance

Male graduates performed better, compared to females, in half of the electives. However, the statistical analysis reveals that there was a statistically significant difference in the mean grades in favor of males in *'Social and Professional Issues'* [Mean difference = 2.66; t(87) = 4.310; p = 0.001]. Likewise, the statistical analysis reveals that there was a statistically significant difference in the mean grades in favor of females in *'Differential Equation'* [Mean difference = 1.36; t(87) = −1.987; p = 0.047].

All in all, an inspection of the mean grades reveals that male and female performance in GE electives was remarkable. In fact, female graduates performed excellently (mean grade equal to or higher than 8.5) in more electives compared to males (11 and 7 GE electives correspondingly).

5 Discussion

The analysis of the data reveals some interesting findings in terms of CS graduate: (a) preferences and (b) performance.

CS Graduate preferences The analysis of the data shows that the statistically significant different selections in favor of males related to only 3 courses; namely, 2 electives related to computer architecture from the CTCS division ('Hardware Description Languages II' and 'Computer organization') and one course from the SS division ('Advanced User Interfaces, VR'). Male graduates also selected more courses than did females from the SS and CTCS divisions, although not to a significant level. GE electives were also not as popular among male students as among females. In that sense, the course selections of male graduates from

Table 8 Preferences and Performance in "General Education" electives

Graduates' preferences and performance in "General Education" electives									
Courses	Group Statistics						Independent Samples Test - T test for equality of means		
	Preferences		Performance						
	Male	Female	Male		Female				
	Graduates who selected the course (%)		Mean Grade (I)	SD	Mean Grade (I)	SD	t	Sig. (2-tailed)	Mean Difference (I-J)
English	92.75	80	6.60	1.07	6.38	1.48	0.671	0.504	0.22
Social and Professional Issues	18.84	25	8.46	1.20	5.8	1.10	4.310	0.001	2.66*
English Terminology	94.20	100	7.30	1.24	6.87	1.23	1.339	0.184	0.43
Computers and Education	27.54	30	8.05	1.18	8.50	1.22	−0.804	0.429	0.55
History of Computers	73.91	80	8.06	1.07	7.81	1.22	0.778	0.439	0.25
Pedagogics	68.12	90	7.13	1.74	7.14	1.53	0.022	0.983	0.01
Sociology	27.54	50	8.63	1.38	8.60	1.89	0.051	0.959	0.03
Didactics of Informatics	20.29	25	8.86	0.66	9	1.41	−0.218	0.837	−0.14
Cognitive Science	11.59	25	9	1.30	9.80	0.45	−1.301	0.220	−0.80
Psychology	34.76	55	7.79	1.44	8.63	1.14	−1.706	0.097	−0.84
Management Information Systems	13.04	35	8.40	1.14	9.25	0.96	−1.189	0.273	−0.85
Banking IT	11.59	25	7.63	1.89	8.60	0.82	−1.281	0.228	−0.97
Differential Equation	42.03	45	7.31	1.91	8.67	1.78	−1.987	0.047	−1.36*

*The difference is significant at the 0.05 level

the department under study seem to follow some of the findings of earlier studies in other STEM fields which support that males take mathematics, engineering, CS, and physical sciences in higher numbers when compared to females (Coley 2001; Amelink 2009).

On the other hand, more females than males – at a statistically significant level – expressed a preference for the following 7 courses: (a) 3 courses from the TCS division (namely; '*Computational Geometry*', '*Cryptography*', and '*Computer fractals*'), (b) one course from the SS division ('*Machine learning & data mining*'), and (c) 3 courses from the GE division related to *humanities and social sciences* (namely; '*pedagogy*', '*sociology*' and '*cognitive science*'). The previously mentioned female graduates' selections are in accordance with the findings of relevant studies in CS, which support the view that females prefer the social aspects of CS and the solutions of community problems over computing for the sake of computing (Margolis et al. 2000). They seek to interact with people rather than things, desire to be helpful to others or society, and pursue a combination of career and family (Beyer 2014) in a "balanced" life with multiple roles and goals (Eccles 2007). Such a tendency and female student preferences in social sciences and humanities have also been mentioned in earlier studies in other STEM fields (Coley 2001; Amelink 2009).

Nevertheless, some courses in the CS curriculum were not a popular choice with either female or male graduates (selected by less than 25% of both of them). These concerned: (a) *applied mathematics and theoretical CS, the study of mathematical structure and other advanced topics* (from the TCS division), (b) *core programming courses, databases, software applications, and other advanced and special topics in SS (*from the SS division), (c) almost one third of the electives from the CTCS division, which were about *computer engineering, robotics* and *advanced computer network issues, and* (d) the *marketing and management perspective of CS,* and *the study of mathematical models* (from the GE division).

Based on all the above, it would appear that males seem to prefer *hardware and software engineering courses*, while females prefer to study courses related to *theoretical issues* in CS as well as to *humanities and social sciences*. The aforementioned differences in gender preference regarding the courses of a CS department probably reflect: (a) some stereotypical views of engineering as a masculine field, (b) previous experience in the field; for example, females entered university having less previous experience in programming than males (Beyer and Haller 2006), and thus they avoid taking lab-based programming courses, (c) diverse personality characteristics (Beyer 2014), (d) low female self efficacy beliefs in CS (Beyer 2014), despite their having successfully managed to pass the demanding national exams to enter a Greek-CS department, and (e) diverse values and interests, as males prefer mathematical and engineering subjects while females prefer subjects oriented towards helping others and interacting with people (Beyer and Haller 2006).

CS Graduate performance The analysis of the data shows that, regarding graduate performance in the compulsory courses, the only differences in the mean grades that reach statistical significance, in favor of males, concerned one core programming course ('Computer programming'), and two Mathematical courses ('Linear Algebra' and 'Mathematics').

Considering the electives, the mean grades of male-graduates which were statistically significant – in favor of males – referred to just 4 courses; namely, 3 courses from the SS division (*'Information management on the Internet', 'Advanced topics in Software Systems'* and *'Systems Security'*) and one course from the GE division (*'Social and Professional Issues'*). Despite the fact that males performed better than females in more electives of the SS division and in GE courses that covered a variety of issues, their mean grades did not reach a significant level of difference. Finally, no statistically significant differences in favor of males emerged regarding the electives that they selected from the TCS and CTCS divisions.

In contrast, females performed better than males in some compulsory courses, but the only statistically significant difference in favor of females concerned '*Human Computer Interaction*'. Despite the lower mean grades in most of the compulsory courses, female graduates performed equally well, or even better, in electives. Specifically, females performed better than males in more TCS electives, and in some of the electives included in the SS division, yet these differences are not statistically significant. Moreover, even though females performed better than males in the majority of the CTCS electives, the only statistically significant difference in the mean grades in favor of females concerned just one course: '*Information theory and coding*'. Finally, regarding GE electives, females actually performed well, achieving excellent mean grades in 4 electives in the field of *Humanities* and *Social Sciences*. Nevertheless, the only statistically significant difference, in favor of females, in GE electives concerned '*Differential Equations*'.

Overall, the analysis of the data revealed that there were few significant differences in the performance of males and females (in 7 and 3 specific CS courses correspondingly), indicating that the myth about actual gender differences in cognitive skill and academic ability is not based on real data. This finding is in line with relevant studies in STEM and CS fields (Ding et al. 2006; Ilias and Kordaki 2006; Kiran and Sungur 2012; Alkhadrawi 2015).The aforementioned studies support the view that actual differences in performance among males and females are not statistically significant; when different domains are taken into consideration, females perform better than males in the social aspects of science factors while males tend to perform better than females in the constructs of science factors (Kiran and Sungur 2012).

6 Conclusions

This study focused on the investigation of gender differences in terms of undergraduate preferences and performance in CS undergraduate courses comprising the entire curriculum of a CS department. A single case study was performed exploiting the records from a CS department in Greece – the Department of CS and Technology, University of the Peloponnese – and data from 89 graduate degrees earned by CS students were quantitatively analyzed.

The data analysis revealed some statistically significant differentiation of preferences between male and female CS graduates. In fact, a higher percentage of males than females preferred courses related to *software and hardware engineering*, whereas a higher percentage of females than males preferred courses related to the study of *theoretical computer science* issues, as well as courses related to the *social and human aspects of CS*. Despite the fact that female preferences in social sciences and humanities have been mentioned by other researchers in relation to STEM education, female preferences in theoretical computer science courses as well as in social sciences and humanities – at the Tertiary level of CS education – have not yet been reported in the literature. Nevertheless, it is worth mentioning that gender differences in terms of preferences in CS courses included in the CS department in question concern only a small number of courses (10 out of 75 elective courses). Yet, there is a large number of electives (31 out of 75 electives) which were chosen by less than 25% of both female and male graduates.

In terms of performance, it seems that there are no significant differences between the mean grades of males and females in most of the CS courses. Any statistically significant differences in performance were present in only a few CS courses (10 out of 100 courses) in favor of males (7 courses) and females (3 courses). In this sense, striking differences in performance in CS, as in other STEM fields (Ding et al. 2006; Kiran and Sungur 2012; Alkhadrawi 2015), are not observed, and any differences in CS are not differences in skills or ability but actually socially constructed 'myths' that constitute obstacles that hinder female success.

Limitations of the study Although some of the results are in line with the findings of other studies, this study is confined to a certain period of time as well as a particular CS Department in Greece with a specific curriculum and degree requirements. Any generalization of these results should be undertaken with caution and be limited to countries and CS Departments that have similar characteristics to those of the participants in this study.

Implications of the study and future research directions The absence of significant differences in the performance of male and female graduates -documented by the findings of this study- seem to challenge the 'myth' that there are actual gender differences in cognitive skills and academic ability in CS. Thus, this study can contribute to the field of CS teaching and learning, and to CS teacher education, so that CS teachers and students may be able to dispel such gender 'myths' and remove perceived boundaries within certain CS career paths. This study also provides some useful insights into the preferences of males and females in CS, triggering an effort for the modification of the CS curriculum and CS instruction in order to adjust the content of CS to the preferences and the interests of males and females as well.

This study also yields interesting research prospects. An investigation of CS teacher beliefs about the gender gap in CS and the differences between males and females may uncover the presence, or the absence, of the 'myth' of gender differences in CS education. Moreover, a further investigation of student preferences in CS, this time through qualitative studies, would reveal any elements impacting on their course choices. Eventually, appropriate educational programs could be designed, implemented and evaluated in order to render every aspect of CS interesting, appealing and fascinating for both males and females in Secondary and Tertiary education.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

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