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Procedia - Social and Behavioral Sciences 191 (2015) 1161 – 1166

Procedia
Social and Behavioral Sciences

WCES 2014

Gender Differences and Achievement in Computer Science: A Case Study

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Abstract

This study investigates the relationship between gender and achievement in the various subjects of CS. For this reason, the degrees of all graduate students who enrolled from 2002 to 2008 at the Department of CS and Technology, University of Peloponnese, Greece were studied, with a focus on the courses classified into 2 divisions: "Computer Technology and Computer Systems" and "Software Systems". The analysis of the data shows that: (a) male students have slightly better grades in most of the compulsory courses, (b) in elective courses, overall, there is no clear pattern, (c) some core hardware/ lab-based software courses are not selected by females, and (d) females perform slightly better in those courses which are chosen by the majority of them.

Selection and peer-review under responsibility of the Organizing Committee of WCES 2014

Keywords: Computer Science, Achievements, Courses, Gender;

1. Introduction

Studies over the past two decades have shown that females are underrepresented in all fields of Computing (Camp, 2002; Friend, 2013; Margolis, 2013). The female-male ratio for those involved in Computing shrinks dramatically from early student years to working years – "the pipeline shrinkage problem" (Gürer & Camp, 2002). Statistics tell us that women are largely underrepresented in all Computing careers, be they academic or within the industry. Despite the fact that many remarkable women have made their mark in the history of Computing through

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Selection and peer-review under responsibility of the Organizing Committee of WCES 2014
doi:10.1016/j.sbspro.2015.04.233

their great achievements (Gürer, 2002), female computer scientists are treated as inferior and many believe that is more natural for men than women to study computing and work in the Computing Industry. Research has shown that there are numerous factors contributing to the fact that females have a lower participation rate in Computer Science (CS) than males and that some aspects about Computing may discourage females (Cohoon et al, 2006). Some of these studies attempted to increase the number of females studying Computing, and eventually increase the number of females involved in the Computing Industry. First of all, females seem to lose interest in CS early on in life, as girls do not gain as much experience with computers as boys do during their childhood (Margolis & Fisher, 2002). The male orientation of computer games seems to be an extra factor contributing to this discouragement (Denner et al, 2012). At school, boys often tend to monopolize instructors' time, leaving the girls to try and figure things out on their own. The majority of studies have shown that positive attitudes towards CS can greatly influence the success of a student and whether he or she continues in CS (Tsagala & Kordaki, 2009; Sax et al, 2010). Females have less confidence in their abilities and individual accomplishments than males do, despite the fact that they often perform at the same levels (Ilias & Kordaki, 2006). They feel “out of place” in a male-dominated, Computing culture. Moreover, discrimination both within the classroom and within the family, limited access to computers both at school and at home and the hostile and uncomfortable environment created by boys when participating in computing activities or male partners appear to be harmful factors, causing low self-confidence (Gürer & Camp, 2002). In addition, women and men have different levels of motivation in pursuing a CS career, and their communication styles often differ, as women are often less aggressive than men in promoting themselves, attempting new or challenging activities, and pursuing awards or fellowships. It is also stated that family support plays a critical role in choice of CS as a subject of their studies and consequentially as a career pathway. Parents socialize their children based on gender stereotypes, unintentionally providing obstacles for their own daughters. This can cause lack of self-esteem and without self-confidence it is almost impossible to experience new and supposedly ‘difficult’ things such as the CS discipline (Orenstein, 2013). Moreover, one of the biggest turn-offs is the "geek factor": High School girls often envisage a career in Computing as a lifetime spent in an isolated cubicle writing code. Computer programmers depicted in popular media are overwhelmingly male, contributing to an absence of role models for would-be female computer programmers. Additionally, the lack of women in the field of research has a negative psychological effect on some female students during their studies (Cheryan et al, 2011). A successful woman in computing research, the computing industry and society in general, can act as a role model and could contribute in many extremely valuable ways to the mentoring of young, female computer scientists (DuBow et al, 2013). Despite the barriers, females are willing to participate in CS as long as they feel that their involvement is meaningful and relates to social contribution (Cohoon, 2001). They view the computer as a tool for use within a larger societal and/or interdisciplinary context (Counryman et al, 2002). Recent research has shown that, as far as undergraduate studies in CS are concerned, females appear to choose courses that belong to the theoretical division of computing, while a higher percentage of males choose courses that belong to the Software Systems division of computing (Kordaki & Berdousis, 2013). Both genders appear to choose courses from the Computer Technology division of computing (Kordaki & Berdousis, 2013) in equal numbers. However, females tend to believe that they lack the skill set needed to be successful in the field of computing (Chan et al, 2000), skills which are obtained primarily in undergraduate studies, where male and female students follow the curriculum attending compulsory courses and selected electives. With the above in mind, it is clearly important to determine if achievements in CS courses are affected by gender differentiation and connected to the selection made by male and female students. Thus, the aim of this study is to investigate the relationship between gender and achievement in the various subjects of CS. Such a study has not yet been reported. This article is organized as follows: “The context of the study” presents details about the manner in which the research was conducted, referring to the study sample and the methodology followed; “Results” gives a full description of the research findings; overall conclusions are summarized in “Conclusion”.

2. The context of the study

This study focuses on the investigation of the relationship between gender and achievement in various CS subjects. For this reason, 89 degrees covering a 6-year period of graduation at the Department of Computer Science and Technology, University of Peloponnese, Greece, were studied. In fact, the study contains the degrees of all

graduate students who enrolled from 2002 to 2008. To this end, the grades of these students in both compulsory courses and electives were studied and quantitatively-analysed. These courses are classified into 4 divisions, namely: "Computer Technology and Computer Systems" (CTCS), "Software Systems" (SS), "Theoretical Computer Science" and "General Education". Due to space limitations, this study examines the relationship between gender and achievement in the first two divisions: CTCS and SS. CTCS has 3 compulsory courses and 15 electives, while SS has 8 compulsory courses and 29 electives. In terms of methodology, this study can be characterized as a case study (Cohen & Manion, 2011).

3. Results

This section gives a full description of the research findings. The number of male graduates is 69, the number of females 20. As far as the compulsory courses are concerned, the Tables that are presented below are divided into 2 sections: males and females per course. Each section is organized as follows: the mean grade of the course (first column), the standard deviation (second column) and the percentage of the grades that are characterized as 'Excellent' – grade>=8,5 (third column). As far as the electives are concerned, the Tables are organized as described above, with one exception: there is one more column per section presenting the percentage of males/females that chose the elective. The Tables are sorted in ascending order of the mean grades of the female students.

3.1 Students' Choices and Achievements in "Computer Technology and Computer Systems" (CTCS) courses

Table 1 presents the achievements of male and female students in terms of the compulsory CTCS courses.

Table 1. Achievements in "Computer Technology and Computer Systems" (CTCS) compulsory courses

Courses	Male			Female		
	Mean grade	Std. Deviation	Excellent (grade >=8.5)	Mean grade	Std. Deviation	Excellent (grade >=8.5)
Logic Design	7.28	1.48	24.64	6.82	1.39	15.00
Computer Communication and Networks I	7.16	1.31	17.39	7.08	1.35	25.00
Computer Architecture	7.93	1.58	42.03	7.85	1.59	25.00
Mean of Means	*7.46*	*0.41*	-	*7.25*	*0.54*	

As is shown in Table 1, male students have slightly better mean grades in all compulsory CTCS division courses. The standard deviation in each course is low, pointing to grades of all students not being widely dispersed around the mean. Even if male students have slightly better mean grades in all compulsory courses, female students perform more or less as well. In Table 1, one can also see that the percentage of male students who achieve 'Excellent' (grade >=8,5) is greater than that of female students in 2 out of the 3 courses - "Logic Design" and "Computer Architecture" - and lower in "Computer Communication and Networks I". Table 2 presents the achievements of male and female students in terms of CTCS electives. As shown in Table 2, male students have a mean grade greater than 8 in 7 compulsory-elective CTCS courses: "Advanced Computer Network Issues", "Robotics", "Synthesis of Digital Architectures", "Hardware Description Languages II", "Introduction to Embedded Systems", "Digital Circuit Design" and "Computer Organization". Female students have a mean grade greater than 8 in 4 compulsory CTCS courses: "Hardware Description Languages II", "Introduction to Embedded Systems", "Digital Circuit Design" and "Computer Organization". It would seem that these 4 courses are a subset of the courses where males have a mean grade greater than 8. In these 4 courses, female students have a higher percentage of "Excellent" grades than male students, or an equal number. Moreover, 2 of these courses are chosen by more female than male students. In "Information Theory and Coding" and "Advanced Computer Architectures" - chosen by more female than male students - female students have a higher mean grade than males do. In "Information Theory and Coding," there is one female student who achieves "Excellent". However, in the aforementioned division, there are 4 courses that are not selected by female students, namely: 'Advanced Computer Network Issues, 'Robotics', 'Synthesis of Digital Architectures' and 'Computer Arithmetic'. In these courses, male students perform exceptionally well. Overall, female students perform better in 8 out of the 15 electives, while males perform better in 6 out of the 15 CTCS electives.

Table 2. Achievements in "Computer Technology and Computer Systems" (CTCS) electives

Courses	Male				Female			
	Percentage of students who select the course (%)	Mean grade	Std. Deviation	Excellent (grade >=8.5)	Percentage of students who select the course (%)	Mean grade	Std. Deviation	Excellent (grade >=8.5)
Advanced Computer Network Issues	11.59	8.25	1.10	62.50	0	0	-	0
Robotics	5.80	8.5	2.38	75.00	0	0	-	0
Synthesis of Digital Architectures	2.90	8.5	2.12	50.00	0	0	-	0
Computer Arithmetic	1.45	7	-	0	0	0	-	0
Digital Signal Processing	1.45	5	-	0	5	5	-	0
Introduction to Hardware Description Languages	55.07	7.09	1.63	26.32	55	6.59	1.39	27.27
Information theory and coding	24.64	5.65	0.95	0	40	6.69	1.46	12.50
Computer Communication and Networks II	10.14	6.93	2.07	28.57	5	7	-	0
Computer Architecture II	1.45	6	-	0	5	7	-	0
Advanced Computer Architectures	23.19	7.02	1.02	6.25	35	7.10	0.82	0
Wireless and Mobile Communications	1.45	5	-	0	10	8	0	0
Computer Organization	91.30	8.1	1.43	41.27	70	8.25	1.42	42.86
Introduction to Embedded Systems	20.29	8.29	1.38	35.71	10	8.25	0.35	50
Digital Circuit Design	30.43	8.45	1.39	57.14	35	8.57	1.09	57.14
Hardware Description Languages II	14.49	8.85	1.18	80.00	30	9.17	0.75	83.33

3.2 Students' Choices and Achievements in "Software Systems" (SS) courses

Table 3 presents the achievements of male and female students in terms of compulsory SS courses.

Table 3. Achievements in "Software Systems" (SS) compulsory courses

Courses	Male			Female		
	Mean	Std. Deviation	Excellent (grade >=8.5)	Mean	Std. Deviation	Excellent (grade >=8.5)
Operating Systems	5.89	1.18	5.80	5.60	0.94	0
System Programming	6.15	1.37	10.14	5.73	1.01	0
Databases I	6.03	1.01	2.90	6.35	1.38	10.00
Programming (C)	7.20	1.25	17.39	6.45	1.77	10.00
Data Structures	7.07	1.67	26.09	6.83	1.27	10.00
Object Oriented Programming (C++, Java)	7.19	1.61	17.93	7.02	1.85	25.00
Human Computer Interaction	6.75	1.24	7.25	7.35	1.30	20.00
Software Engineering	8.04	1.20	47.83	8	1.49	50.00
Mean of means	*6.79*	*0.73*		*6.67*	*0.81*	

As shown in Table 3, male students have slightly better mean grades in all compulsory SS division courses apart from "Database I" and "Human Computer Interaction," where female students perform slightly better. The standard deviation in each course is low. It is worth noting that 50% of female students are awarded "Excellent" in "Software Engineering" and 20% in "Human Computer Interaction". There are no female students awarded "Excellent" in "Operating Systems" and "System Programming". Only 10% of female students achieve "Excellent in "Databases I", "Programming C" and "Data Structures", whereas the percentages of "Excellent" male students are 2.90, 17.39 and 26.09, respectively. It seems that female students perform better in non-core programming courses. Table 4 presents the achievements of male and female students in terms of SS division electives. As shown in Table 4, male students have a mean grade greater than 8 in 11 elective SS courses while female students have a mean grade greater than 8 in 9 elective courses in the same division. 4 of these courses are common for both; male and female students. It is worth noting that very few females (in some cases, none at all) choose: "Java Lab", "Special Topics in Software Systems" and "C Lab"; in these courses, however, male students perform exceptionally well. In all of the 9 electives where the mean grade of female students is greater than 8, a higher percentage of female students compared to males

achieve "Excellent". "Databases I", "System Security", "Data & Information Visualization", "Information Retrieval" and "System Analysis" are courses that are not only selected by more female than male students but female students have a greater mean grade in these courses, which are not characterised as core programming courses. Overall, male students have a higher mean grade in 15 out of the 29 SS electives, while female students have a higher mean grade in 11 out of the 29 electives in the same division.

Table 4. Achievements in "Software Systems" (SS) electives

Courses	Male				Female			
	Percentage of students who select the course (%)	Mean grade	Std. Deviation	Percentage of Excellent (grade >=8.5)	Percentage of students who select the course (%)	Mean grade	Std. Deviation	Percentage of Excellent (grade >=8.5)
Java Lab	18.84	8.85	1.21	61.54	0.00	0	-	0
Special topics in software systems	7.25	9.5	0.45	100.00	0.00	0	-	0
C Lab	33.33	8.82	1.92	73.91	5.00	5	-	0
Multimedia Technology	47.83	6.85	1.66	21.21	40.00	6	1.06	0
Advanced Topics in Database	7.25	7.07	1.22	20.00	5.00	6	-	0
Data & Information Visualization	2.90	8.5	-	100.00	5.00	6	-	0
Databases II	8.70	6.17	0.75	0.00	20.00	6.25	0.95	0
Current Software Systems	20.29	7.18	1.18	21.43	15.00	6.33	1.15	0
Compilers II	49.28	6.57	1.30	11.76	40	6.56	1.89	37.50
Data Management Systems	50.72	7.31	1.41	34.29	50.00	6.65	1.33	10.00%
Parallel Programming	85.51	7.10	1.47	28.81	80.00	6.66	0.99	0.00%
Systems security	17.39	6.41	1.08	8.33	30.00	7	0.89	0.00%
Inf. Management on the Internet	31.88	8.60	1.37	68.18	25	7	1.57	40.00
Data & Inform. Visualization	11.59	7.31	0.79	12.50	15.00	7.33	1.52	33.33%
Information Retrieval	2.90	6.5	2.12	0.00	10.00	7.5	1.41	50.00%
Advanced Topics in Programming	10.14	7.5	1.70	28.57	5.00	7.5	-	0.00%
C++ Lab	13.04	7.78	1.39	22.22	5.00	7.5	-	0.00%
Intelligent Systems & Apps	4.35	8.33	0.57	33.33	15.00	7.67	1.52	33.33%
Database Management Systems	26.09	6.67	1.67	22.22	20.00	7.75	2.62	50.00%
Techniques in Machine Learning	21.74	8.33	1.63	53.33	45.00	7.89	1.61	33.33%
Information Systems	49.28	7.78	1.43	31.03	35.00	8	0.57	42.86%
Compilers	17.39	7.09	1.50	16.67	15.00	8	1.00	33.33%
System Analysis	52.17	7.5	1.46	30.56	55.00	8.09	1.04	36.36%
Artificial Intelligence	82.61	7.96	1.47	42.11	75.00	8.23	1.07	60.00%
Advanced topics in Soft. Systems	42.03	9.17	0.80	82.76	35.00	8.29	1.11	57.14%
Intelligent Systems & Apps	42.03	7.06	1.64	31.03	30.00	8.41	1.70	66.67%
Distributed Systems	23.19	9	0.70	81.25	5.00	9	-	100.00%
Virtual Reality	62.32	8.74	0.97	55.81	35.00	9	0.81	71.43%
Software Engineering II	23.19	8.25	1.62	62.50	5.00	9	-	100.00%

4. Conclusions

This study investigated the relationship between gender and achievement in some of the various CS subjects, namely "Computer Technology and Computer Systems", and "Software Systems", studying the degrees (89 degrees) earned by the students during a 6-year period of graduation at the Department of CS and Technology, University of Peloponnese, Greece. The analysis of the data showed that: (a) male students have slightly better grades in most of the compulsory courses in both CTCS and SS, (b) this changes in the electives: in some of these courses, female students have better average grades than their counterparts while in other courses males perform better, (c) some core hardware / lab-based software courses are not selected by female students, whereas in these courses male students seemed to perform exceptionally well, and (d) in those courses which are chosen by the majority of females there is a tendency for them to perform slightly better than the males and to perform "Excellent" in higher percentage.

Acknowledgements

We thank the *Eugenides Foundation* for the generous grant in support of our research.

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