Academic Achievement and Choices of Computing and Control Engineering Students in relation to Gender

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INTRODUCTION

The gender ratio of students of computing and control engineering is typically considerably skewed in favour of male students. Although females tend to outnumber males in the majority of university programmes, this discipline, similarly to other engineering areas, has continued to attract much greater attention of male students. Such persisting asymmetry has motivated us to further investigate how the two genders differ with respect to their academic achievement and choices in this discipline, especially because there are also many stereotypes and much anecdotal evidence surrounding students in computing programmes.

In order to formally evaluate some of the supposed differences between the genders in the context of engineering education, we conduct a descriptive study on the sample featuring data about student course performance in an undergraduate computing and control engineering study programme. For each course, gender

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representation is calculated and student performance with respect to gender is evaluated. Moreover, these values are investigated over a set of consecutive study years so that any gender-related change in academic performance could be detected. We are particularly interested if there is such change between the first years of study, which include more generic engineering education, and the final years, which are more focused on elective and highly specialized courses. Student choice between different specialisations is also investigated in relation to gender.

1 RELATED WORK

There are numerous studies on bias in students' enrollment and achievement in relation to gender. One group of these studies try to explain and deal with skewness of the gender ratio for students who are being educated in the field of science, technology, engineering, and mathematics (STEM) [1], [2], [3]. For example, in [1], the authors conclude that female students are more pessimistic about the easiness of getting a job in the field of STEM, even though males and females do not significantly differ in their perception. On the other hand, perceptions about the difficulty of performing engineering duties differ remarkably as male students are expecting more effort to be needed. Although there is an increase in the ratio of women studying science, recruitments in key areas, namely physics and engineering, remain stagnant, as presented in [2]. An explanation for this matter, according to much of the literature in this area, could lie in socio-cultural barriers to STEM education that women experience. Some of the prominent explanations, such as causation of top mathematic scores with gender gap in quantitative-based fields like computer science and engineering, were evaluated within [3] and found not to be empirically satisfactory. Instead, the persisting gender gap in STEM fields was plausibly attributable to differences in the way that women and men link college major and occupation.

The second group of studies focus on gender differences in academic achievement. These differences are likely to be a result of achievement-related beliefs among female engineering students as they identify engineering aptitude as a fixed ability, correlated with extrinsic factors [4]. With respect to the stereotype that within science courses male population outperforms the female one, in [5] and [6], it is shown that it is possible to reduce its effect and hence reduce achievement gap between the genders. A brief psychological intervention is introduced as a promising way to mediate the impact of stereotype threat [7] and thereby reduce the gap. A special case of stereotype threat might be observed within Computing and Control Engineering courses, as a vast majority of assessments are computer based and computers are more likely to be seen as *boy-toys*. Therefore, a female population that has incorporated such beliefs and taken these classes tends to underachieve. The cause of the underachievement is associated with the pressure to overcome the stereotype, i.e., the fear that they will be viewed as part of a negative stereotype [8]. Furthermore, computer anxiety [9], which appears to be a function of gender, may be seen as yet another reason for the achievement gap between the two genders and the fact that female students do not pursue computer programming courses as much as male students. These feelings of discomfort, stress, or anxiety that female students experience when responding to computers and programming courses often come from the fact that the style of programming that is taught and strongly encouraged in today's programming classes may be more in concordance with the way that male students are used to think about and solve problems [8]. Moreover, examples and exercises that support lectures and that can be found within textbooks are under-representing females. This is considered to be a low-profile educational issue with vast consequences on gender bias as discussed in [10].

Our findings only partially agree with the conclusions of the abovementioned studies. The female students of Computing and Control Engineering featured in our study make up only between 8% and 15% of the enrolled students at various years of study, which is not untypical of STEM fields. Moreover, male students perform slightly better in programming courses. However, female students perform better in mathematics and advanced courses on applied computer science and informatics.

2 DESCRIPTION OF THE STUDY

2.1 Research questions

In this descriptive study, we analyse differences in academic achievement and choices between male and female engineering students. We formulate the following research questions:

- RQ1: Does the number of completed assignments per course differ between male and female students?
- RQ2: Does the achievement in course assignments differ between male and female students?
- RQ3: Is there a gender related difference in course achievement between the common and specialised courses?
- RQ4: Is the choice of a study specialisation related to student gender?

2.2 Background and data

The evaluation is performed using the achievement data about students who have undertaken a bachelor study programme in Computing and Control Engineering at the Faculty of Technical Sciences (University of Novi Sad, Serbia). This study programme lasts four academic years (8 semesters) and was redesigned in the Bologna Process. In the past decade, in Serbia, which is now a member of the European Higher Education Area (EHEA), a new law on higher education was adopted and large education reforms made. As a result, the study programme was significantly updated according to the aforementioned regulations and is still being improved. Additional information about the latest version of the programme may be found in [11]. Enrolled students may choose one of the three specialisations: *Automatic Control and Systems Engineering* (*ACSE*), *Applied Computer Science and Informatics* (*ACSI*), and *Computer Engineering and Computer Communications* (*CECC*). After the first two years of study, which encompass common introductory courses, students select one of the three paths in their third year of study.

The featured data sample has been collected over the past few years and primarily includes assessment results for students who enrolled in the academic year 2009-2010. The academic achievement of these students is recorded for eight courses over a period of four academic years (the whole study programme): from 2009-2010 to 2012-2013. Special attention is given to the selection of courses for this study so that the comparison between the genders could be done for courses which are held at different years (there are two courses from each study year) and represent different important areas of competence. The sample set is constructed so that it closely resembles the general principle used to design the curriculum: “about 15% of the courses belong to the academic and general education subjects, about 20% are theoretical and methodological courses, about 35% are scientific and professional courses and 30% are professional and applied courses” [11]. The details about the selected courses may be found in *Table 1*. The courses from the first two years of study (*Mathematical Analysis 1*, *Programming Languages and Data Structures*, *Object Programming*, and *Operating Systems*) are mandatory for all enrolled students. On the other hand, the featured courses from the last two years of study (*Databases 1*, *Human-Computer Interaction*, *Databases 2*, and *Computer Graphics*) are mandatory only for students who specialise in *ACSI*.

Table 1. Courses selected for the analysis

Course Name	Study Year	Study Semester	Course Category
Mathematical Analysis 1	1st	1st	Academic and general-educational courses
Programming Languages and Data Structures	1st	1st	Theoretical methodological courses
Object Programming	2nd	3rd	Professional applicative courses
Operating Systems	2nd	4th	Professional applicative courses
Databases 1	3rd	5th	Professional applicative courses
Human-Computer Interaction	3rd	6th	Scientific or academic professional courses
Databases 2	4th	7th	Scientific or academic professional courses
Computer Graphics	4th	7th	Scientific or academic professional courses

Collected assessment results include student performance in: tests, practical assignments, project assignments, and attendance. Assessment records have been extracted from official course records and loaded into a specially designed database, whose schema is a variation of the schema presented in [12] with additional auxiliary attributes. For each assessment result (12341 records), there is information about the involved student (274 records), course (8 records), study year and semester, time, assessment type (84 records), and measurement unit (4 records).

2.3 Methodology

In order to answer the four principal research questions of this study, we employ statistical measures to describe student performance with respect to student gender. Due to the characteristics of the data sample (differing distributions and few female students in many subsets), we do not rely on statistical significance testing except when analysing the relation between student gender and choice of specialisation.

For the purpose of answering the question RQ1, we count the number of completed assignments for all students in the selected courses. We consider an assignment completed by a student, if the student submitted the assignment (or did the test) and obtained a score greater than zero. Student achievement in the selected courses, which is evaluated when answering the questions RQ2 and RQ3, is calculated for each student as a ratio of the sum of achieved scores and the maximum total score in a particular course. The gender related difference between the common and specialised courses is investigated by comparing the mean achievement score between the genders for each course and evaluating the findings for the common and specialised courses separately. The dependence between the student gender and choice of specialisation (the question RQ4) is checked by counting the number of male and female students in each specialisation path and applying the Fisher's exact test to the contingency matrix obtained in this manner.

With the goal of making the results more comprehensible and representative of the underlying trends, we shape the study according to the following three decisions.

First, we restrict all of the analyses to students who enrolled in the academic year 2009-2010. Their achievement throughout the rest of the study programme is tracked in the selected eight courses over a period of four academic years (from 2009-2010 to 2012-2013). It is not unusual that in the same year of study there are students who have already attended some of the courses, or enrolled in different years or even different versions of the study programme as opposed to the majority. In order to minimise the effect of such outliers, we have decided to exclude students who repeated some of the study years from the analyses. In this manner, the analyses start on a sample of 183 students (168 males and 15 females) in the first year and end on a sample of 75 students (64 males and 11 females) in the fourth study year.

Second, for the courses in the last two years of study, we evaluate the performance of students who chose to specialise in *ACSI*. The main reason for this decision is an uneven distribution of students between the three specialisations. A majority of students chose *ACSI* and only few female students chose some of the other two specialisations. Therefore, the best sample in terms of having both genders adequately represented appears to be the one featuring *ACSI* students.

Third, owing to the fact that the revised study programme puts focus on constant student engagement and assessment throughout a semester, we analyse student performance only in pre-exam assessments conducted throughout a semester. Student achievement in these assessments typically determines around 70% of the final grade in a course while the results in written and/or oral exams account for around 30% of the final grade. Moreover, in most courses, once a test is conducted or deadline for submitting an assignment passes, students rarely have an opportunity to improve their score in that particular assessment. The only alternative is to repeat the course in the following academic year. For these reasons, we consider pre-exam results a good indicator of overall student performance and use them in the analyses.

3 RESULTS AND DISCUSSION

3.1 Completed course assignments

In *Table 2*, for each course (*Course Name*), we present the total number of assignments (N_A), as well as mean (*M*), standard deviation (*SD*), skewness (*SK*), and count (*N*) values concerning completed assignments for both male (marked by *M* in subscript) and female (marked by *F* in subscript) students.

Table 2. Completed assignments in each course with respect to gender

Course Name	N_A	N_M	M_M	SD_M	SK_M	N_F	M_F	SD_F	SK_F
Mathematical Analysis 1	25	168	14.56	7.06	-0.76	15	17.13	7.19	-0.89
Programming Languages and Data Structures	5	162	4.56	0.97	-2.62	15	4.53	1.13	-2.18
Object Programming	4	131	3.30	1.23	-1.67	13	3.69	0.63	-1.60
Operating Systems	5	116	4.53	1.14	-2.45	13	4.69	0.48	-0.74
Databases 1	6	100	5.38	1.49	-2.91	11	5.82	0.40	-1.43
Human-Computer Interaction	11	68	8.44	2.86	-1.65	11	9.27	0.79	-0.43
Databases 2	6	64	5.83	0.83	-5.81	11	6.0	0.0	/
Computer Graphics	5	64	4.41	1.16	-2.18	11	4.91	0.30	-2.47

According to the findings, in 7 out of 8 courses, female students complete on average more assignments as opposed to male students. In the 8th course (*Programming Languages and Data Structures*), which is a course where males outperform females, there is practically no difference regarding this variable. In general, the females did more assignments in almost all of the analysed courses, but this persisting difference between the genders is small. However, in a course on mathematics (*Mathematical Analysis 1*), the difference is approximately 10% in favour of females. A considerably better performance of females in that course (see the following subsection) might be linked to the difference in assignment completion.

3.2 Course achievement

In *Table 3*, we present average course (*Course Name*) achievement in percentages for male (marked by *M* in subscript) and female (marked by *F* in subscript) students. For each course we determine student count (N), as well as mean (*M*) value and standard deviation (*SD*) for student performance in theory tests (marked by T in superscript), practical assignments and projects (marked by P in superscript), and all pre-exam assessments (marked by S in superscript).

Table 3. Course achievement with respect to gender

Course Name	N_M	M^S_M	SD^S_M	M^T_M	SD^T_M	M^P_M	SD^P_M	N_F	M^S_F	SD^S_F	M^T_F	SD^T_F	M^P_F	SD^P_F
Mathematical Analysis 1	168	37.88	24.73	36.31	24.38	39.16	26.64	15	50.86	26.86	46.35	29.34	54.55	25.64
Programming Languages and Data Structures	162	62.50	26.51	59.57	25.21	66.42	34.47	15	58.10	25.90	55.50	23.74	61.56	34.43
Object Programming	131	57.36	28.98	14.81	19.51	63.44	32.59	13	67.98	20.90	13.85	21.42	75.71	24.13
Operating Systems	116	62.61	24.92	68.12	27.86	49.76	24.24	13	58.90	20.19	61.43	23.77	53.01	17.03
Databases 1	100	58.47	20.58	29.47	23.09	84.05	23.18	11	68.29	14.24	45.76	22.22	92.24	6.81
Human-Computer Interaction	68	56.43	23.00	54.11	24.47	57.54	24.88	11	64.40	13.33	63.65	21.16	64.76	13.90
Databases 2	64	81.95	17.63	62.19	29.36	83.09	17.75	11	91.71	6.02	78.79	13.60	91.88	7.10
Computer Graphics	64	73.04	17.62	45.31	25.42	89.68	18.15	11	80.37	10.60	58.51	21.09	93.49	7.17

These findings indicate that female students perform better in mathematics (*Mathematical Analysis 1*), one programming course (*Object Programming*), one professional applicative course (*Databases 1*), and all of the scientific/academic professional courses (*Human-Computer Interaction*, *Databases 2*, *Computer Graphics*). On average, their scores are approximately 10% higher than those of male students. On the other hand, male students have an advantage of approximately 4% in two programming courses (*Programming Languages and Data Structures* and *Operating Systems*). In 6 out of 8 courses, when one gender has better overall performance, it also has better performance in both theoretical and practical assignments. The two mismatches occur in two programming subjects (*Object Programming* and *Operating Systems*). The results suggest that female students have a clear advantage in mathematics and scientific/academic courses, while male students have certain advantage in programming courses.

3.3 Common vs. specialised courses

If we arrange the mean overall scores from *Table 3* by course and gender, we obtain a chart presented in *Fig. 1*. All four common courses are organised during the first two study years, while the four specialised courses for *ACSI* students are organised during the last two study years. The chart in Fig. 1 illustrates that, in common courses, no gender performs absolutely better than the other. However, female students outperform male students in all specialised courses.

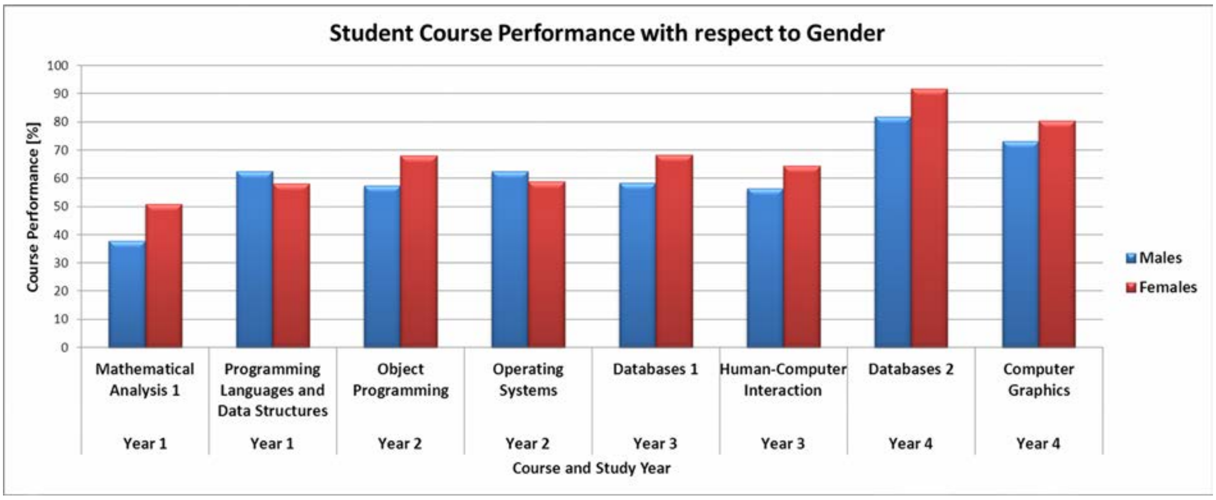

Fig. 1. Mean Course Performance with respect to Gender

3.4 Choice of specialisation

If we break down the distribution of third year students by their gender and chosen specialisation, we obtain a contingency matrix shown in *Table 4*.

Table 4. Gender-Specialisation contingency matrix

	ACSE	ACSI	CECC	Total
Males students	8	68	32	108
Female students	2	11	0	13
Total	10	79	32	121

Female students make up approximately 10% of students at the third year of study. This ratio is preserved for the *ACSE* specialisation, while there are disproportionately more females in the *ACSI* group. On the other hand, the greatest deviation from the ratio is observed in the *CECC* group, which is focused on programming for embedded systems. Within 32 students in that group, there is not a single female student, which indicates a clear disinterest of females in pursuing this specialisation. If we apply a version of the Fisher's Exact Test featured in the R statistical environment, we obtain a p-value of 0.03015, which is significant at the 0.05 level.

4 SUMMARY

In this study, we analyse course performance and choices of students enrolled in Computing and Control Engineering. Female students complete slightly more assignments and outperform male students in mathematics and advanced scientific/academic courses, while male students have a slight advantage in programming courses. The male preference for programming has been previously observed. However, the advantage of female students in the majority of courses has not been regularly detected in similar studies. Those courses include programming but do not primarily focus on that area, which could be a crucial characteristic in the investigation of this unexpected finding. We also hypothesise that the small group of enrolled female students may include enthusiasts who are well-prepared, and motivated to pursue a career in a computer-related field, which leads to good results. Nonetheless, a further inquiry into these issues would require a separate study.

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