Gender Gap? A Snapshot of a Bachelor Computer Science Course at Graz University of Technology

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ABSTRACT

Although career chances are good, technology, engineering and especially computer science (CS) related studies still do not attract as many female students as other fields. This paper describes a study in the context of an introductory CS course for first semester university students. In this course essential programming concepts are taught and exercised. The first contact with programming is crucial to keep students in the long run. By conducting a survey before and after the course we aim at finding short-term measures to improve the course on organizational level and answer questions about gender equality, such as "Are female students disadvantaged and thereby negatively affects their grades?" and "Is there a difference between female and male students in their perceived CS education prior to university and if, does this have an impact on their academic performance?". Female and male students' self ratings regarding their programming skills are investigated concerning gender differences and whether they have an impact on their academic performance. Our results show, that neither previous education nor the students' performance differ significantly according to gender. Self ratings differ significantly between genders, but for both genders self ratings do not correlate with academic performance.

CCS CONCEPTS

• **Social and professional topics → Computing education**.

KEYWORDS

computer science education, gender studies, university course

ACM Reference Format:
Christian Schindler and Matthias Müller. 2019. Gender Gap? A Snapshot of a Bachelor Computer Science Course at Graz University of Technology. In *European Conference on Software Architecture (ECSA), September 9–13, 2019, Paris, France.* ACM, New York, NY, USA, 5 pages. https://doi.org/10.1145/3344948.3344969

1 INTRODUCTION

The gender gap in STEM (Science, Technology, Engineering, and Mathematics) related fields, especially also affecting computer science (CS), gained worldwide attention in recent years [9]. We can see today that diversity is not only a matter of equality, but also fosters innovation and development [3]. Therefore, a significant number of researchers, practitioners, and educators today deal with this topic. Many different organizations worldwide try to change gender inequality, to introduce principles, create resources, and initiate events that respond to the still existing challenges in diversity in computer science [3, 9]. Universities all over the world face and combat the issue of a low number of female students in STEM subjects and started special initiatives in this regard [2]. Actions are also needed in elementary, middle, and high school to attract more female students to CS and eliminate existing stereotypes or barriers in the long run [2, 10]. One aspect that has been highlighted, is that female students often do not feel prepared well enough at school for a CS related study [1, 10]. Therefore, it is important to help students to experience a smooth and pleasant start for their CS study program. Furthermore, as the approaches of various organizations in the domain have also shown, the first experiences in computing are especially important to keep females further engaged [3].

Due to this fact, we evaluated the first programming course of CS students who just started their career at Graz University of Technology and compared the participation of students (female and male) in various aspects. The study aims to identify differences between male and female students regarding their prior computer science education in school; and the differences in performance. The study is internally also used to prepare for a restructuring of the course, its content, and teaching methods.

2 SITUATION AT UNIVERSITY LEVEL

For a long time tech-studies were dominated by males. We now can observe that this fact is coming (slowly) to a change. In some technical fields, such as chemical engineering or architecture (see Figure 1 for percentage of female students in our university's different departments), women today even represent the majority of students. Targeting potential female students through different actions at various stages, e.g., cooperation with schools or offering internships, comes to fruition and heavily contributes to the ongoing change. As an example, Graz University of Technology provides special information campaigns under the umbrella of *Frauen in die Technik (Women into Tech)*[1], and also practical ICT related courses for girls, called *CoMaed (Computer and Girls)*[2].

Figure 1 represents the percentage of female students in Graz University of Technology's different departments. Measurement are based on students in the first semester of the study program[3]. We see that the two computer science related study programs (CS

ECSA, September 9–13, 2019, Paris, France

ACM ISBN 978-1-4503-7142-1/19/09…$15.00
https://doi.org/10.1145/3344948.3344969

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[2] https://www.comaed.tugraz.at/
[3] data available at https://online.tugraz.at/tug_online/Studierendenstatistik.html

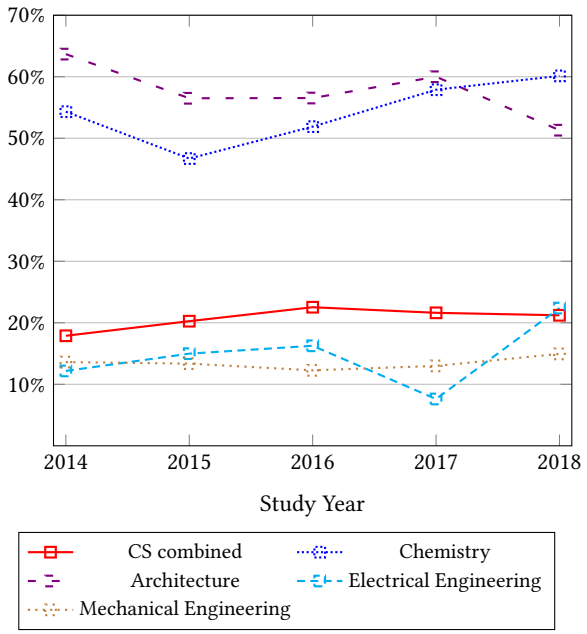

Figure 1: Percentage of female students per academic year of selected study programs at Graz University of Technology. *CS-combined* representing *Computer Science,* and *Software-Engineering and Business Management.*

combined in Figure 1) still attract a very low percentage of new female students. Overall, we see that there are big differences depending on the field, but the general trend, for most programs, is positive. By just regarding the CS related studies in the past 5 years, we can spot a linear positive upward trend of roughly one percent per year. The growth rate solely for *Computer Science*, not regarding *Software Engineering and Business Management*, is even higher. However, these numbers just represent students coming new to these studies, which is just one side of the coin. It is also important to keep, or even rise, this percentage through the duration of the programs, i.e., the drop-out rate of female students should not be higher as for male students. As already outlined before, the first year for the students is essential and therefore needs special attention, motivating the authors to conduct this study.

3 STUDY SETUP

3.1 Use Case

The course *Programming 0*[4] at Graz University of Technology is a course combining theory (lectures) with practical assignments. It is part of the bachelor program of the computer science related studies (*Computer Science*, and *Software Development and Business Management*) and is scheduled at the very beginning of the first semester. It therefore is the first encounter with programming at the university. It is held over a blocked time span of four weeks including six mandatory lectures, six optional Q&A sessions for the practical assignments, and a final assignment review where every student has to present and explain their submitted work. The course is intended to introduce first semester students to programming, show them that it can be easy and fun, and teach them basic programming principles, such as the use of variables, if-then-else conditions, loops, and messaging. Students could enroll the course in two ways, a.) as programming-beginners with mandatory attendance for the course lectures and participation in various small assignments, or b.) as advanced programmers who only need to prove their skills in solving a dispensary assignment, and participating in a final assignment review to finish the course.

[4]https://tinyurl.com/Programming-0

3.2 Research Questions

First, the study was designed to find ideas and identify short-term measures what could be changed in the *Programming 0* course on organizational level to improve the students' preparation for the upcoming programming challenges in the course of their further computer science studies. This led us to the first research question:

- RQ1: *Can we find short-term changes of the course on organizational level to improve the students' preparation for upcoming coding challenges in their future CS studies?*

Second, we wanted to find out if female students are in any way put at a disadvantage or in other ways discriminated in our course that negatively affect their grade. Hence our second research question emerged:

- RQ2: *Are female students in any way disadvantaged which is negatively affecting their grades?*

Third, we were interested in the students' prior perceived computer science education in school and their potential implications leading us to the following research question :

- RQ3: *Is there a difference between female and male students in their perceived CS education in school, and if, does it have an impact on their course performance?*

Fourth, we were interested in the self ratings of the students' programming skills and its implications, which led us to the following set of research questions:

- RQ4.1 *Do the self ratings of programming skills prior to the course differ between male and female students?*
- RQ4.2 *Do the self ratings of programming skills correlate with the course grades?*
- RQ4.3 *Do the self ratings of programming skills increase compared to the values before the course?*

3.3 Evaluation Method

We conducted a short survey before the course (pre-test), i.e., before any lectures were held about programming. In this survey we asked whether the students had CS classes, for how many years

	female		male		total	
students	72	22.5%	248	77.5%	320	100%
self rating	68	94.4%	228	91.9%	296	92.5%
graded	61	84.7%	212	85.5%	273	85.3%
not graded	11	15.3%	36	14.5%	47	14.7%
flunked	14	23.0%	77	36.3%	91	33.3%
finished positively	47	77.0%	135	63.7%	182	66.7%
# students with CS in school	46	67.7%	166	72.8%	212	71.6%
# students with progr. in school	27	39.7%	111	48.7%	138	43.1%
average years CS edu. in school	2.31	-	2.31	-	2.31	-
average grading 1...very good 5...insufficient	2.59	-	2.87	-	2.73	-
average self rating 0...no skills 5...expert skills	0.96	-	1.4	-	1.3	-
max. self rating	3	-	5	-	-	-

Table 1: Key figures *Programming 0* winter term 2018.

and if they have learned programming in these classes. Furthermore, the students had to self-rate their programming skills on a six-level rating-scale from 0 (no programming skills) to 5 (expert programming skills). These information were later put into relation with the overall grading and their gender to answer the research questions. After the main part of the lecture a second survey was conducted (post-test) to find out if in this short period of time an increase of the students' self-rating has happened. Both surveys were designed to be as short as possible to increase the chance of being fully answered during the lecture. Both surveys were handed out on paper during the lectures which turned out to be a very effective way to reach most of the 400 enrolled students and having a high response rate.

3.4 Participants

The course was separated between beginners and advanced students regarding their programming skills. Students had to judge for themselves and select the skill level at the registration for the course. The advanced group was enrolled by 101 students. The beginner's group, we put the focus of our analysis on, was enrolled by 320 students.

4 STUDY RESULTS

4.1 Participant Numbers and Response Rate

In Table 1 one can see the accumulated key figures of the study related to the gender differences. From the 320 students enrolled in the beginner's group 72 (22.5%) were female and 248 (77.5%) male. This corresponds, of course, with the overall female percentage chart of computer science studies at Graz University of Technology (see Figure 1), and the number of new students in this semester[5],

[5]https://tinyurl.com/TUG1stSemBak

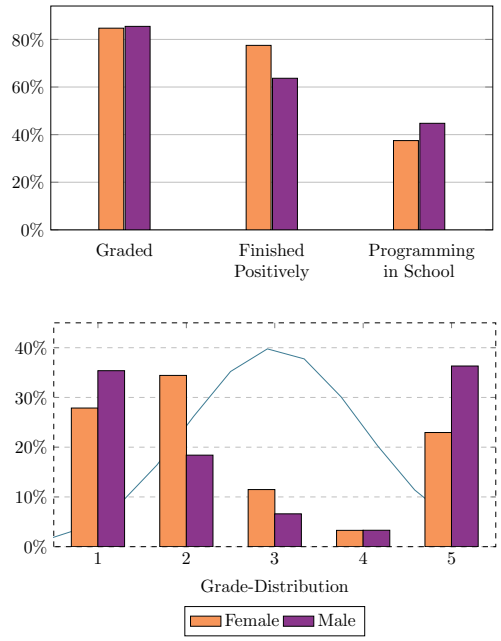

Figure 2: Analysis of *Programming 0* participants in the winter term 2018

implying that this course is fortunately not too hard and a reservoir for failed students. The test participation rate was quite high due to the fact that the questionnaire was embedded into the mandatory course lectures. We reached over 92% of the enrolled students, 94.4% of the female and 91.9% of our male students. Compared to typical response rates within the university's online study management system for evaluations (3% - 15%), this can be considered a very high response rate.

4.2 Academic Performance

The Austrian grading system at schools and universities is between *1 (very good)* and *5 (insufficient)*. 273 (85.3%) of the enrolled beginner students were graded, whereas 47 (14.7%) were not graded. The female share of the graded students is 84.7% (61) and similarly the male share is 85.5% (212), depicted in the first chart of Figure 2. The course was finished with a positive grade (1-4) by 77% of the female (47) and 63.7% (135) of the male students. A third (33.33%) of the students did not pass the course positively (grade 5), 14 female (22.95%) and 77 male (36.32%). The χ^2 test of independence (H_0-hypothesis, that the variables are independent) for the categories *pass/fail* and the groups *female/male* is 3.81. The p-value is 0.51 which is not less or equal to the significance-level $p < 0.05$, therefore the variables are independent (i.e., H_0 holds).

The average grading values of female and male students are $M_f = 2.59$ and $M_m = 2.87$ respectively (see also Table 1). The grading distribution can be seen in the second chart of Figure 2; it is such that there are significantly less medium grades (3 and 4) given than very good (1 or 2) or fail (5) grades. This distribution is remarkable because it is almost inverse to the gaussian distribution. This also means that there is room for improvement to motivate

students to move from the right-end of the scale (fail=5) to the medium grades.

In respect to RQ2, we can see that gender is not significant whether one passes or fails the course hence females are not disadvantaged so that their performance is negatively impacted. Therefore RQ2 can be answered with *no*.

4.3 Impact of Pre-University CS Education

In Austria there is no unified computer science (CS) curriculum across the different kinds of schools (elementary/middle/high school). Even in similar school types CS classes can be completely different which is reflected by the answers to the perceived CS education prior to university. To answer RQ3, we distinguish between *having CS classes at schools* and *learning how to program* because the former does not necessarily imply the latter. The percentage of students who had computer science classes in school was 72.6% in total, 67.7% female (46) and 72.8% male (166) students. This information was gathered with the pre-test, therefore only students who took this pre-test are considered. The χ^2 test of independence for the categories *CS in school/no CS in school* and the groups *female/male* is 3.18. The p-value is 0.075 which is not less or equal to the significance-level $p < 0.05$, therefore the variables are independent (i.e., H_0 holds). Although there is a slight difference between female and male students who learned programming at school, 39.7% (27) female compared to 48.7% (111) male students, the χ^2 test of independence for the categories *programming in school/no programming in school* and the groups *female/male* is 1.6966. The p-value is 0.19 which is not less or equal to the significance-level $p < 0.05$, therefore the variables are independent (i.e., H_0 holds). RQ3 therefore, can be answered with *no*.

4.4 Correlation between Self Rating and Academic Performance

It is known from literature that there is a significant difference between female and male students in how they rate their own competence in a subject [4–6, 9]. In this study, students were asked to self-rate their programming skills on a six-level scale: *0 (no skills)*, *1 (some skills)*, *2 (fair skills)*, *3 (good skills)*, *4 (very good skills)* and finally *5 (expert skills)*. Six levels were chosen to avoid confusion with the school grading scale and the bias for the neutral position.

Female students rate themselves with an average $M_f = 0.96$ (close to *some skills*); male students rate themselves with an average $M_m = 1.4$ (between *some skills* and *fair skills*). It is remarkable that so many (mostly male) students in the beginner's course rated themselves as having *some skills* or more. This means that they already have programming skills and should have enrolled in the advanced group. This shows that there is a need for an intermediate group since these students despite their assertion of having programming skills, feared to enroll in the advanced group and ended up in the beginner's group. In regard to RQ1 introduction of an intermediate group is an easy short-term change which could improve the course. Second, female students rated themselves with a maximum value of three (*good skills*), their male fellow students rated themselves with a maximum of five (*expert skills*).

In regard of RQ4.1 (whether the self ratings differ between female and male students) we ran an unpaired t-test on the groups of self ratings. The p-value equals 0.0031 - this is considered to be very statistically significant. The difference of the mean value of male and female students equals 0.43 with a 95% confidence interval of this difference from 0.15 to 0.72 (intermediate values during calculation: $t = 2.98$, $df = 294$, standard error of difference = 0.146). Therefore, RQ4.1 can be definitely answered with *yes*.
In regard of RQ4.2 (whether the ratings in the post-test increased compared to the pre-test) we investigated that the self rating has positively changed even with the very short duration of the course which can be seen in Figure 3. We ran a paired t-test on both the female and male self ratings from the pre- and post-test. For the female self ratings the p-value equals 0.0001 - which is considered to be very statistically significant. The difference of the mean values *before* and *after* equals -0.46 with a 95% confidence interval of this difference from -0.69 to -0.24 ($t = 4.0777$, $df = 55$, standard error of difference = 0.114). The paired t-test on the male ratings were similar: p-value was less than 0.0001 which is considered to be very statistically significant. The mean value difference *before* and *after* equals -0.36 with a 95% confidence interval of this difference from -0.47 to -0.26. With these results RQ4.2 can be definitely answered with *yes* meaning that the course has a perceived programming skill increase for all students.

To answer RQ4.3 (whether the self ratings correlate with the course grading) we used the Spearman rank correlation test. Neither the female nor the male self-ratings correlated with the course grading. Although there was a slight increase of the self ratings' rank-correlation, from the pre-test to the post-test, this increase was also not statistically significant. RQ4.3 therefore, can be definitely answered with *no*. This means that the male overestimation of programming skills is not justified. At first we believed in Kruger and Dunning's "Unskilled and unaware" [7] effect but this is not the case since it also means that the female students do not have a more accurate self rating, they just rate humbler.

5 DISCUSSION AND CONSEQUENCES FOR COURSE DESIGN

From winter term 2019 on the *Programming 0* course will be enhanced from 1.5 ECTS (European Credit Transfer and Accumulation System) to 3.0 ECTS. This will on one side allow to get into more depth with the dealt content and on the other side help to better respond to the individual needs of the students. Splitting up the first-semester students in groups of beginners, intermediates, and advanced will additionally support students to start with the CS related study independently of their pre-university CS education and is also expected to foster their interest in CS. By better adapting the course to the students' different skill levels, the number of negative grades shall be reduced and more students be enabled to get the best grade *1 (very good)* while still keeping the same grading requirements. This has also the potential to increase equality. Although, the captured fail-rate of female students is lower than the one of male students, in comparison less get graded with a *1 (very good)*. Besides this course specific changes, also more detailed evaluations are proposed. Whereas this evaluation is the first snapshot on the introductory course, further long-term work covering several semesters and different courses at this University is planned. This may help to better understand gender-specific aspects in higher CS

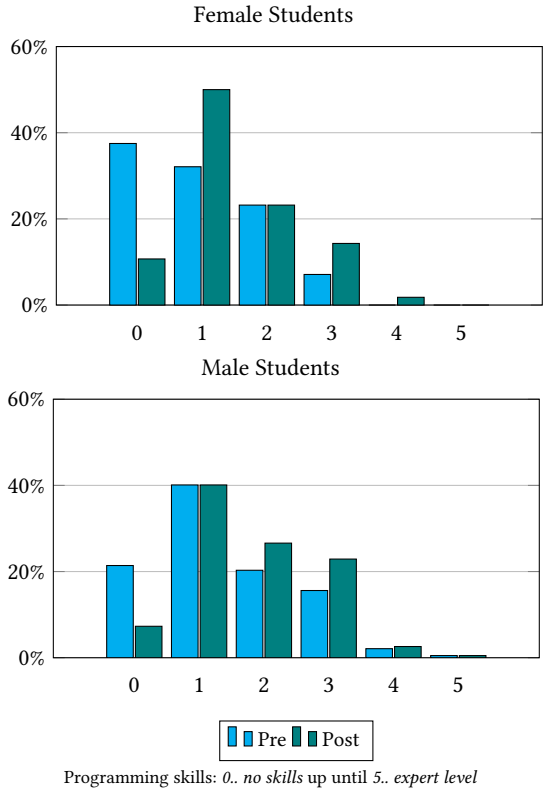

Figure 3: Female and male students' self-rating *before* and *after* the course

education. In a next step in particular the first year, that as research has shown is essential for their excitement for CS on a long term basis, should be in the focus of evaluation and is expected to provide further results in the upcoming study year. In this context also the success of the proposed changes of the aforementioned course can provide statements on how students with different background, e.g., education, knowledge, or also gender, can be supported best in their start of a CS study program.

6 CONCLUSION

In this work we analyzed an introductory computer science course at Graz University of Technology by gender. Primarily it turned out, that performance differences between female and male students are not significant. Beyond this, the following conclusions can be drawn: a.) Failing or passing the course as well as the course grades are independent from the students' gender; b.) Whether students have had computer science or programming lessons in school is independent from the students' gender. This indicates they had savored similar education related to CS and also programming; c.) The student's self-rating for both genders increased from pre- to post-test which indicates that despite the short course duration the course content had a positive effect. This effect might be amplified when the course is expanded (efforts and credits doubled) from winter term 2019 on, and d.) Female students did rate themselves humbler than the males did, which can be alleviated by enhancing the way of determining their self-rating by additional guidance questions [8]. The data shows that female students are not discriminated or underperforming in this course, which is comforting, but nevertheless they are still underrepresented in CS studies in general. There are no significant differences between female and male students in this higher educational context, also indicating the importance of actions before students come to university. This study outlines that although there is no gap between female and male students in the matter of skills or previous education, there is still one in the number of CS-students which is closing only very slowly in the investigated environment. So efforts to promote CS studies should further be increased since it is not obvious why they are only increasing with a humble rate of around 1% per year in comparison to other studies such as chemistry. Furthermore, the computer science curriculum in Austrian schools should be unified and programming lessons fostered as for instance in the UK. This might ultimately also positively affect the subjective self-rating of female students and confidence to study CS, since their skills get comparable to others already during schools and before starting a study program at Graz University of Technology. Further work is intended to investigate the long-term effects and progress of the students. In addition, comparisons to similar courses at other universities may help to improve and gain general applicable results.

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