Gender and Performance in Computer Science Curriculum Courses

Marina Lepp and Anne-Mari Kasemetsa
Institute of Computer Science, University of Tartu, Estonia

marina.lepp@ut.ee
anne-mari.kasemetsa@ut.ee

Abstract: Despite numerous initiatives and research efforts dedicated to increasing female representation in computer science, the overall percentage of women in this field continues to remain low. Over time, research has shown the existence of negative stereotypes and "myths" regarding the cognitive abilities and academic skills of women in computer science, which discourage them from pursuing careers in the field. The aim of the research is to examine these stereotypes by exploring gender differences in student performance across undergraduate courses within a Computer Science (CS) curriculum at the University of Tartu. The final grades of six compulsory courses of the CS curriculum were analysed, two courses of which are mathematical, "Calculus" and "Discrete Mathematics"; two involve programming, "Object-Oriented Programming" and "Algorithms and Data Structures"; and two courses teach basic knowledge of the CS field, "Databases" and "Operating Systems". To get a better overview, the period of five years (2018-2023) was selected, and three different types of analyses were performed: general (covering all the courses), module-based and course-based analysis. Mann-Whitney U-test was used to compare grades. The results showed that the academic performance of women and men in CS is very similar. Only very few statistically significant differences were found between the genders. Many of the statistically significant differences favoured women (in courses like Calculus, Object-Oriented Programming, and Databases), except in one course: Operating Systems. Based on the results, it can be argued that women perform equally well or, in some instances, even better than men in CS studies. The analysis confirms that supporting women's participation in computer science is warranted, as there are no significant gender differences in cognitive abilities and academic skills in CS.

Keywords: Gender, Computer Science, Performance, Higher Education, Performance Gender Gap.

1. Introduction

Despite various research works and initiatives, women are still underrepresented in every field of natural sciences, including computer science (OECD, 2022). 70%-80% of students studying at the bachelor's level in computer science (CS) are men (Womentech, 2023). This means that most of the feedback on subjects and the curricula comes from men. This is indicative of the gender data gap, that is a situation in which most globally collected information, from economic to medical data, is primarily derived from men or designed based on male characteristics (World Economic Forum, 2020). Without collecting and categorizing data by gender, it becomes impossible to determine whether the same approach can yield varying outcomes for each gender. In such a situation, the conditions favouring women's learning may not be noticed, and therefore, it is worthwhile to study the performance of female and male students separately. Due to the gender gap, there are many gender stereotypes and "myths" in computer science (Master, Meltzoff, & Cheryan, 2021). One of the stereotypes is that women are less competent in CS than men. The present study tries to explore such stereotypical understandings of the CS field with the aim of investigating gender differences in performance across compulsory courses in CS at the University of Tartu over multiple years. In total, six different compulsory courses in the curriculum are studied: Calculus, Discrete Mathematics, Object-Oriented Programming, Algorithms and Data Structures, Databases and Operating Systems. The main research question is: What are the gender differences in the final grades of the six courses selected for the CS curriculum at the University of Tartu during the years 2018-2023?

The paper is divided into four main parts: literature review, methodology, results, and discussion. The literature review gives an overview of previous studies that deal with female learning results in computer science. The methodology explains the sample, the data to be handled, and the analysis methods. The results section provides the results of the data analysis. The discussion section presents possible explanations for the results of the analysis and answers to the research question.

2. Literature Review

Today, there are still gender disparities in the participation of women at university and in the labour market in the field of computer science and information technology (IT). It even appears that the participation of women in studying CS decreased between the years 1971 and 2011 (Sax et al., 2017). Some initiatives aim to encourage women's involvement in IT, provide training and support their successful participation in tech: UnicornSquad (https://unicornsquad.ee), Women Who Code (https://womenwhocode.com), Women in Tech (https://women-

in-tech.org), TechWomen (https://techwomen.org), etc. However, women's participation in IT still faces persistent challenges. In the 2019 survey of the Programme for International Student Assessment (PISA), it was found that boys are more confident than girls in their chosen science field (Mostafa, 2019). This is also confirmed in the study by Falkner et al. (2015), where women majoring in CS concurred that they are confident in their mathematics and logic abilities but often have doubts within the discipline, which can be due to the stereotype of today's society that women are stronger in jobs related to communication and men in technical jobs. Low self-esteem in professional skills can cause the so-called impostor syndrome - the feeling that the acquired knowledge is insufficient (Mak, Kleitman, & Abbott, 2019). Such a feeling strongly erodes the sense of belonging and motivation. The impostor syndrome in the CS field has been noted by different studies (Abbate et al., 2023; Falkner et al., 2015), where female CS students stated that they constantly felt the need to prove their competence to feel at an equal level with male students.

It has been found that women's lower self-belief and confidence in computer science knowledge and skills develop already in secondary school (Mahajan & Thirumalai, 2022). According to the PISA 2019 results, a difference between the academic results of girls and boys in school education becomes noticeable by age 15 - boys get higher results in science subjects and girls in language-related subjects (Mostafa, 2019). A girl and a boy at the same education level can choose their higher education path based on this point of comparison. Consequently, more boys choose the field of natural sciences in higher education, and more girls choose the field of sociology; a similar trend can be observed later, when they enter the labour market (Mostafa, 2019). However, no gender differences in programming performance were found among secondary school students (Lau & Yuen, 2009). The proportion of females taking CS courses at the high school level has remained the same and even slightly decreased (Mahajan & Thirumalai, 2022). Less exposure to the field before university and lower confidence in their skills are the main reasons why fewer females choose CS later (Babes-Vroman et al., 2017; Master et al., 2017).

There are contradictory results about gender differences in academic performance in computer science. Some studies have found that there are no significant differences in the academic results of women and men in CS at the higher education level (Berdousis & Kordaki, 2019; Duran, Haaranen, & Hellas, 2020; YeckehZaare & Resnick, 2019). In an analysis of the learning outcomes of an introductory programming course, it was found that there are no gender differences in the final exam scores, but women studied more hours and more thoroughly than men on average (YeckehZaare & Resnick, 2019). Men's earlier exposure to professional knowledge is cited as one possible reason. In an analysis of gender differences in code, it was found that there are differences in the structure but not in the quality of the code (Brooke, 2024). There are also no significant gender differences in the learning outcomes in local programming courses; however, men perform slightly better in MOOCs (Duran, Haaranen, & Hellas, 2020). Conversely, it was observed that men initially performed better in programming at the beginning of the course, but the final pass rate for women was significantly higher than for men (Quille, Culligan, & Bergin, 2017). Similarly, female students obtained higher final exam scores in an introductory CS course (YeckehZaare et al., 2021). In addition, women significantly outperformed men in one programming comprehension question following the tutorial, indicating that women may possess a stronger aptitude for computer programming (Du & Wimmer, 2019).

In courses related to algorithms and data structures, gender does not significantly impact student performance, as differences between the two genders have rarely been statistically significant, and in cases where differences did emerge, women consistently outperformed men academically (Dagklis et al., 2024). In mathematical courses, it has been found that female students do as well as male students (Bridgeman & Wendler, 1991), that women do better than men (Strum & Moroh, 1995), or vice versa (Berdousis & Kordaki, 2019; Else-Quest, Hyde, & Linn, 2010). No significant gender differences have been found in discrete mathematics (Vilner & Zur, 2006). Not many gender-level differences have been found in other professional courses that are not strongly related to programming or mathematics (Berdousis & Kordaki, 2019). Although the academic results of women and men in different courses are at the same level, it has been found that there is a performance gap as more men than women graduate with bachelor's first-class degrees (70% or higher academic performance) in computer science (Wagner, 2016).

As there are contradictory results from previous research about gender performance in computer science, it is essential to analyse in-depth gender differences in student performance across undergraduate courses within a CS curriculum, examining different courses separately, combining them by topic and considering a longer time period to explore general trends.

3. Data and Methodology

For the analysis, six different courses were selected from the compulsory courses of the computer science curriculum at the University of Tartu (hereafter: UT). The UT CS curriculum consists of four mandatory modules: basic mathematics module, IT basic module, programming direction module, and IT speciality module. In order to cover as much of the compulsory curriculum as possible, courses were chosen from each of the four modules. However, the IT basic module and the IT speciality module were combined for further analysis. All the chosen courses are worth six credits, where each credit is equivalent to 26 hours of study. The courses to be analysed are the following:

- Mathematics module: Calculus, Discrete Mathematics
- IT module: Databases (IT basic module), Operating Systems (IT speciality module)
- Programming direction module: Object-Oriented Programming, Algorithms and Data Structures

A quantitative study was conducted to address the research question. The sample of the study consists of UT students (see Table 1) and the data are the final grades of these students in six compulsory courses during 5 academic years (2018/19-2022/23). There were 2463 students, with 860 (34.9%) females and 1603 (65.1%) males, reflecting a similar gender imbalance observed in previous studies (Berdousis & Kordaki, 2019; Womentech, 2023).

Table 1: Number of students in each analyzed course and academic year and gender distribution

	Calculus		Disc. Math.		Databases		Op. Systems		OOP		Algorithms	
	♀ %	♂ %	♀ %	♂ %	♀ %	♂ %	♀ %	♂ %	♀ %	♂ %	♀ %	♂ %
2018/ 2019		379		171		231		155		295		159
	36	64	29	71	30	70	18	82	27	73	22	78
2019/ 2020		402		194		218		184		268		181
	41	59	24	76	28	72	18	82	27	73	21	79
2020/ 2021		326		159		212		228		259		231
	36	64	36	64	30	70	21	79	31	69	25	75
2021/ 2022		367		131		233		167		226		169
	35	65	25	75	37	63	25	75	33	67	28	72
2022/ 2023		414		260		344		214		324		205
	29	71	30	70	33	67	28	72	31	69	27	73

The data contains all exam results obtained by the same individual in the chosen period (8822 grades in total). In data processing, only the most recent exam performance in each course was retained for everyone (7306 grades in total). The learning result for each course is indicated on the scale 'A'-'F', where 'A' corresponds to an excellent pass and 'F' signifies a failure to pass the course. In addition, there is a separate result 'not present', which means that the student was admitted to the exam but did not appear, or the student did not participate in the study during the entire semester. In addition to the scale of letter grades 'A'-'F', a numerical scale was used in the analysis. The conversion scheme was as follows: 'A': 5, 'B': 4, 'C': 3, 'D': 2, 'E': 1, 'F': 0, 'not present': 0.

The Python Pandas library was used for the data analysis. The analysis is divided into three parts: general analysis where the results of all courses are analyzed simultaneously, analysis based on modules where similar courses have been analyzed together, and analysis of individual courses. In all three analyses, the statistical indicators of the final grades (arithmetic mean, median, standard deviation) were found. The distribution of final grades was checked using the Shapiro-Wilk test. Since the distribution of final scores departed significantly from normality in all analyses, the non-parametric Mann-Whitney U-test was used to determine whether there are statistically significant differences between gender final grades. The significance level limit was set at 0.05.

4. Results

Generally, there are no major differences in the final grades of female and male students when all the explored courses are viewed together in the considered period (see Table 2). Average results are similar for women and

men, and no statistically significant difference between the combined academic results for women and men could be found in any of the studied years. The arithmetic means of final grades in the mathematics module (Calculus and Discrete Mathematics) show similar results for women and men, with a slight downward trend over the observed period (see Table 2). A statistically significant difference appears only in 2020/21, with women scoring higher than men. In the IT module (courses Databases and Operating Systems), women and men also perform similarly, with a statistical difference only in 2018/19, when women score higher. In the programming module (Object-Oriented Programming and Algorithms and Data Structures), performance is comparable between genders, except in 2019/20, where women achieved a higher average score (see Table 2).

Table 2: Results of all courses together and by modules by gender and year

		All Courses		**Math. Module**		**IT Module**		**Prog. Module**	
		♀	♂	♀	♂	♀	♂	♀	♂
2018/ 2019	Mean (SD)	2.86 (1.72)	2.66 (1.70)	2.52 (1.76)	2.27 (1.68)	**3.45** (1.61)	**3.00** (1.72)	2.89 (1.62)	2.79 (1.64)
	U (p)	183922.5 (0.053)		31096.5 (0.124)		11891.0 (**0.022**)		18770.5 (0.610)	
2019/ 2020	Mean (SD)	2.89 (1.81)	2.92 (1.76)	2.24 (1.73)	2.43 (1.74)	3.54 (1.64)	3.28 (1.67)	**3.58** (1.67)	**3.16** (1.73)
	U (p)	215986.5 (0.794)		43251.0 (0.183)		12994.0 (0.150)		16080.5 (**0.020**)	
2020/ 2021	Mean (SD)	2.84 (1.73)	2.73 (1.82)	**2.25** (1.60)	**1.93** (1.70)	3.13 (1.81)	3.09 (1.76)	3.36 (1.60)	3.09 (1.75)
	U (p)	203016.5 (0.347)		23753.0 (**0.023**)		17939.5 (0.706)		22312.0 (0.199)	
2021/ 2022	Mean (SD)	2.73 (1.67)	2.57 (1.76)	1.65 (1.32)	1.71 (1.57)	3.57 (1.29)	3.22 (1.59)	3.26 (1.69)	2.98 (1.73)
	U (p)	172396.0 (0.151)		26681.0 (0.715)		15565.5 (0.080)		15052.5 (0.137)	
2022/ 2023	Mean (SD)	2.51 (1.81)	2.45 (1.88)	1.53 (1.53)	1.43 (1.60)	3.02 (1.57)	3.03 (1.69)	3.21 (1.83)	3.14 (1.82)
	U (p)	320130.5 (0.527)		44897.5 (0.259)		34020.0 (0.723)		28433.5 (0.672)	

Table 3: Results for each course by gender and year

		Calculus		**Disc. Math.**		**Databases**		**Op. Systems**		**OOP**		**Algorithms**	
		♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂
2018/ 2019	M (SD)	**2.56** (1.73)	**2.11** (1.72)	2.43 (1.86)	2.58 (1.55)	3.64 (1.57)	3.50 (1.60)	3.00 (1.63)	2.37 (1.66)	3.03 (1.74)	3.12 (1.67)	2.57 (1.29)	2.23 (1.43)
	U (p)	14086.0 (**0.015**)		3199.5 (0.465)		5289.5 (0.504)		1398.0 (0.073)		8771.5 (0.707)		1868.0 (0.200)	
2019/ 2020	M (SD)	2.06 (1.72)	2.26 (1.73)	2.87 (1.61)	2.70 (1.73)	3.75 (1.65)	3.57 (1.71)	3.15 (1.57)	2.98 (1.58)	**4.14** (1.41)	**3.71** (1.62)	2.50 (1.62)	2.41 (1.60)
	U (p)	20901.5 (0.231)		3234.5 (0.605)		4423.0 (0.422)		2340.0 (0.579)		6004.5 (**0.034**)		2643.5 (0.796)	
2020/ 2021	M (SD)	**2.47** (1.60)	**2.05** (1.69)	1.83 (1.53)	1.69 (1.71)	**3.70** (1.69)	**3.20** (1.82)	**2.41** (1.71)	**3.01** (1.71)	3.70 (1.56)	3.46 (1.65)	2.89 (1.55)	2.71 (1.79)
	U (p)	10355.0 (**0.023**)		2689.5 (0.381)		3865.0 (**0.036**)		5266.5 (**0.029**)		6514.0 (0.265)		4688.0 (0.530)	
2021/ 2022	M (SD)	1.68 (1.40)	1.66 (1.55)	1.55 (1.00)	1.82 (1.63)	3.80 (0.97)	3.51 (1.42)	3.10 (1.69)	2.88 (1.72)	3.84 (1.38)	3.68 (1.53)	2.36 (1.76)	2.11 (1.58)
	U (p)	14831.5 (0.583)		1635.0 (0.923)		5852.5 (0.325)		2445.0 (0.499)		5385.0 (0.588)		2674.0 (0.489)	
2022/ 2023	M (SD)	1.72 (1.59)	1.54 (1.72)	1.23 (1.39)	1.25 (1.39)	3.34 (1.50)	3.03 (1.64)	**2.39** (1.53)	**3.02** (1.76)	4.02 (1.36)	3.83 (1.48)	1.73 (1.65)	2.11 (1.79)
	U (p)	16184.0 (0.149)		7201.5 (0.923)		11728.5 (0.089)		5608.5 (**0.009**)		10505.0 (0.303)		4606.5 (0.192)	

In the course Calculus, women and men perform at similar levels, with a slight downward trend in final grades over five years (see Table 3). Statistically significant differences appear only in 2018/19 and 2020/21, with women scoring higher in both years. In Discrete Mathematics, a similar downward trend in average scores is seen for both genders, with no statistically significant differences between them throughout the period. In the Databases course, there is no noticeable upward or downward trend in final grades for either gender, with a statistically significant difference in only 2020/21 when females scored higher. In Operating Systems, women's grades show a slight downward trend, while men's grades trend upward. Statistically significant differences appear in 2020/21 and 2022/23, with males scoring higher in both years. In Object-Oriented Programming, a slight upward trend appears in final grades for both genders, with a statistically significant difference in 2019/20 when females scored higher. In the course Algorithms and Data Structures, no clear trend or significant difference between genders is observed over the five-year period (see Table 3).

5. Discussion

The aim of this research was to detect possible differences in the results of the six compulsory courses of the Computer Science curriculum at the University of Tartu based on gender during the years 2018-2023. The analysis did reveal statistically significant differences between the genders, but they were only a few in number, so it can be said in general terms that the performance of females and males in the studied CS courses is at the same level, and there are no major differences in study results. Based on the general analysis of all courses together, there is no statistically significant difference between the final grades of female and male students in any considered academic year. The results of this analysis coincide with the results of previous studies, where it has been found that there are no significant differences in the learning outcomes of women and men in computer science (YeckehZaare & Resnick, 2019).

In the analysis of the modules, a statistical difference between genders was found in each module in one academic year out of five - 2020/21 in the mathematics module, 2018/19 in the IT module, and 2019/20 in the programming module. Female students had better results than males in all relevant modules in the mentioned academic years. In the academic years 2019/20 and 2020/21, the difference could have been caused by the change in the study forms due to the coronavirus pandemic - perhaps independent/online study was more suitable or easier for female students. This theory, however, is not supported by a previous study, which found that online learning did not have a strong impact on exam results compared to face-to-face learning (Rataj & Wójcik, 2022). Since a difference was found in each module in only one of the five observed years, in the bigger picture, there are no major differences between the genders in the final grades in the modules, either. In addition, since the years of detected differences were different for each module, it can be assumed that the difference between the genders in these years was random or related to natural differences in the learning abilities of the particular cohorts.

The analysis of the individual courses showed that the observed six courses can be divided into three groups. First, there are two courses where no statistical difference was found between the final grades of women and men in any of the studied years. These courses are Discrete Mathematics and Algorithms and Data Structures. Research conducted at other universities has also found no significant differences between the genders' results in the algorithmics (Dagklis et al., 2024) and the discrete mathematics courses (Vilner & Zur, 2006). These two courses deal with similar topics to some extent, which may also explain why the results are similar. A possible explanation for why there are no differences between the study results of men and women in these courses may be that these two courses both rely to some extent on previously completed courses, i.e. both courses have a prerequisite course. Other courses also have prerequisites, but the prerequisites of these particular courses include content that the student will most likely encounter for the first time at university. This means that in these courses, both genders have solid knowledge of the prerequisite courses they have recently passed, with a lesser role played by the knowledge acquired before university or females' lesser exposure to computer science before university that has been observed in previous studies (Babes-Vroman et al., 2017; Master et al., 2017).

Secondly, in two courses, a statistical difference was found between the final grades of the genders in one of the five academic years - 2019/20 in Object-Oriented Programming and 2020/21 in Databases. In both courses, women's results were better than men's in the mentioned academic years. Although differences were found, one year out of five still shows that, in general, there are no major differences between the academic results of females and males in these courses. It is possible that the difference in the given years was a matter of chance. There is also a possibility that the difference is due to changes in the study organization resulting from the coronavirus pandemic in 2019/20 and 2020/21. In the two aforementioned courses, most of the points are distributed among several different study forms. Since it has previously been found that female students

distribute more study load over a longer period of time (YeckehZaare et al., 2021) and students who do this tend to get better results (Lau & Yuen, 2009), this could potentially explain why significantly better results were found for females in these two courses.

Thirdly, in two courses, a statistically significant difference was found between the final grades in two of the five academic years - 2018/19 and 2020/21 in Calculus and 2020/21 and 2022/23 in Operating Systems. In the course Calculus, females had better results in both the aforementioned academic years; in Operating Systems, on the contrary, males had better results in both academic years. In Calculus, the reasons for the gender differences are likely to be the same as in the maths module. Operating Systems is the only course where males had statistically significantly better results than females. As mentioned in an earlier study, the results of females in this course may be lower because of lesser interest or motivation of female students in the given technical field (Falkner et al., 2015). Although there were more differences in these courses, even two out of five years do not amount to a major difference between the final grades of the genders.

6. Conclusions

This article aimed to explore gender differences in performance across compulsory courses within the Computer Science curriculum at the University of Tartu. The analysis covered the final results of six courses from 2018/19 to 2022/23. Data analysis was conducted in three parts: general (all courses combined), module-based (grouping similar courses), and course-based analysis. The findings indicate that female and male performance in the evaluated CS courses is largely comparable, with only a few significant differences observed. Nearly all statistically significant differences in the final grades found in the analysis were in favour of women; only in one course - Operating Systems - did male students have better results.

The conducted study can be helpful to lecturers and program managers of the CS curricula who want to increase the participation of females in the CS field or to better support both female and male students in the courses and programs. The results of the research revealed that there are no major differences in the results of genders in CS, and based on this, it can be said that women's participation in CS should not be hindered by the stereotypical notion that men do better in computer science than women.

These findings can be applied in several ways to encourage greater female participation in computer science. Educators and program managers could use this data to design inclusive teaching strategies and foster a supportive learning environment that challenges gender stereotypes. Outreach programs could highlight these results to dispel myths about gendered performance differences, encouraging more women to enrol in CS programs. Educators, employers, and policymakers should be informed about these results to raise awareness about unconscious biases and their potential impacts on women's participation in CS. This research can also be used to argue against discriminatory hiring practices in academia and industry, advocating for policies that ensure equal opportunities for men and women. Finally, institutions can develop news or articles showcasing the achievements of women in CS and leverage social media platforms to disseminate bite-sized insights from the research to reach a broader audience and break stereotypes. By demonstrating that gender does not predict academic performance in computer science, these findings can be crucial in building more inclusive academic cultures and inspiring a diverse generation of future technologists.

The results are reliable because data from several different courses and a longer time period than one academic year were used. If only one academic year was selected, the results would show statistically significant differences somewhere, but looking at a longer period, we can see a more general trend, indicating that these differences can be random, not occurring with certainty every year. However, in the current analysis, the selected courses cover only 37.5% of the compulsory part of the curriculum (out of four mandatory modules). Because of this, the results of this analysis do not show a well-rounded picture of gender differences in learning outcomes in CS. For an even more complete picture, all compulsory courses should be included in future studies. Although a period of five years is enough to notice slight differences, a longer period could be investigated in further studies for a more comprehensive picture. To better understand gender differences in CS study results, further studies could also include the CS curricula of other universities.

References

Abbate, J., Narasimhan, S., Odeh, S., Bedwei, F.N., Musse, S. R. & Rieser, V. (2023) 'Women share highs and lows in computer science for Ada Lovelace Day', *Nature*, Vol. 622, pp. 238-241. Springer Nature. https://doi.org/10.1038/d41586-023-03146-8

Babes-Vroman, M., Juniewicz, I., Lucarelli, B., Fox, N., Nguyen, T., Tjang, A., Haldeman, G., Mehta, A., & Chokshi, R. (2017) 'Exploring gender diversity in CS at a large public R1 research university', in *Proceedings of the Technical Symposium on Computer Science Education*. ACM, NY, USA, pp. 51–56. https://doi.org/10.1145/3017680.3017773

Berdousis, I. & Kordaki, M. (2019) 'Gender and student course preferences and course performance in computer science departments: A case study', *Education and Information Technologies*, Vol. 24, pp. 1269–1291. https://doi.org/10.1007/s10639-018-9828-x

Bridgeman, B. & Wendler, C. (1991) 'Gender differences in predictors of college mathematics performance and in college mathematics course grades', *Journal of Educational Psychology*, Vol. 83, No. 2, pp. 275–284. https://doi.org/10.1037/0022-0663.83.2.275

Brooke, S. (2024) 'Programmed differently? Testing for gender differences in Python programming style and quality on GitHub', *Journal of Computer-Mediated Communication*, Vol. 29, No. 1. https://doi.org/10.1093/jcmc/zmad049

Dagklis, E., Stratzemi, M., Koloniari, G. & Karakasidis, A. (2024) 'Programming errors and academic performance in an introductory data structures course: A per gender analysis', in *Towards a hybrid, flexible and socially engaged higher education*. ICL 2023. LNNS, Vol. 911. Springer, Cham. https://doi.org/10.1007/978-3-031-53382-2_6

Du, J. & Wimmer, H. (2019) 'Hour of code: A study of gender differences in computing', *Information Systems Education Journal*, Vol. 17, No. 4, pp. 91-100.

Duran, R., Haaranen, L. & Hellas, A. (2020) 'Gender differences in introductory programming: Comparing MOOCs and local courses', in *Proceedings of the Technical Symposium on Computer Science Education*. ACM, NY, USA, pp. 692–698. https://doi.org/10.1145/3328778.3366852

Else-Quest, N.M., Hyde, J.S. & Linn, M.C. (2010) 'Cross-national patterns of gender differences in mathematics: A meta-analysis', *Psychological Bulletin*, Vol. 136. No. 1, pp. 103–127. https://doi.org/10.1037/a0018053

Falkner, K., Szabo, C., Michell, D., Szorenyi, A. & Thyer, S. (2015) 'Gender gap in academia: Perceptions of female computer science academics', in *Proceedings of the Conference on Innovation and Technology in Computer Science Education.* ACM, NY, USA, pp. 111–116. https://doi.org/10.1145/2729094.2742595

Lau, W.W.F. & Yuen, A.H.K. (2009) 'Exploring the effects of gender and learning styles on computer programming performance: Implications for programming pedagogy', *British Journal of Educational Technology*, Vol. 40, pp. 696–712. https://doi.org/10.1111/j.1467-8535.2008.00847.x

Mahajan, K. & Thirumalai, G. (2022) 'An analysis of gender gap in computer science in high school', *Journal of Student Research*, Vol. 11, No. 2. https://doi.org/10.47611/jsrhs.v11i2.2572

Mak, K.K.L., Kleitman, S. & Abbott, M.J. (2019) 'Impostor phenomenon measurement scales: A systematic review', *Frontiers in Psychology*, Vol. 10. https://doi.org/10.3389/fpsyg.2019.00671

Master, A., Cheryan, S., Moscatelli, A. & Meltzoff, A.N. (2017) 'Programming experience promotes higher STEM motivation among first-grade girls', *Journal of Experimental Child Psychology*, Vol. 160, pp. 92–106. https://doi.org/10.1016/j.jecp.2017.03.013

Master, A.H., Meltzoff, A.N. & Cheryan, S. (2021) 'Gender stereotypes about interests start early and cause gender disparities in computer science and engineering', *Proceedings of the National Academy of Sciences*, Vol. 118, No. 48. https://doi.org/10.1073/pnas.2100030118

Mostafa, T. (2019) 'Why don't more girls choose to pursue a science career?', *PISA in Focus*, No. 93. OECD Publishing, Paris. https://doi.org/10.1787/02bd2b68-en

OECD (2022) 'Education at a Glance 2022'. https://doi.org/10.1787/3197152b-en

Quille, K., Culligan, N. & Bergin, S. (2017) 'Insights on gender differences in CS1: A multi-institutional, multi-variate study', in *Proceedings of the Conference on Innovation and Technology in Computer Science Education*. ACM, NY, USA, pp. 263–268. https://doi.org/10.1145/3059009.3059048

Rataj, M. & Wójcik, J. (2022). 'The Impact of Covid-19 on Online Final Exam Scores Among Computer Science Students', in *Proceedings of the European Conference on Knowledge Management,* Vol. 23, No. 2,

Poland. https://doi.org/10.34190/eckm.23.2.644

Sax, L.J., Lehman, K.J., Jacobs, J.A., Kanny, M.A., Lim, G., Monje-Paulson, L. & Zimmerman, H.B. (2017) 'Anatomy of an enduring gender gap: The evolution of women's participation in computer science', *The Journal of Higher Education*, Vol. 88, No. 2, pp. 258–293. https://doi.org/10.1080/00221546.2016.1257306

Strum, D. & Moroh, M. (1995) 'Gender and computer science majors: Perceptions and reality', *Emerging Technologies, Lifelong Learning, NECC '95*, IR 017 705, New York.

Vilner, T. & Zur, E. (2006) 'Once she makes it, she is there: Gender differences in computer science study', in *Proceedings of the Conference on Innovation and Technology in Computer Science Education*. ACM, NY, USA, pp. 227–231. https://doi.org/10.1145/1140124.1140185

Wagner, I. (2016) 'Gender and performance in computer science', *ACM Transactions on Computing Education*, Vol. 16, No. 3, Article 11. https://doi.org/10.1145/2920173

Womentech (2023) 'Women in technology statistics: Where are we in 2023?', *Womentech Network*. Available at: https://www.womentech.net/en-us/women-technology-statistics#

World Economic Forum (2020) 'The Global Gender Gap Index', *World Economic Forum*. Available at: https://www.weforum.org/publications/gender-gap-2020-report-100-years-pay-equality/

YeckehZaare, I. & Resnick, P. (2019) 'Speed and studying: Gendered pathways to success', in *Proceedings of the Technical Symposium on Computer Science Education*. ACM, NY, USA, pp. 693–698. https://doi.org/10.1145/3287324.3287417

YeckehZaare, I., Fox, E., Grot, G., Chen, S., Walkosak, C., Kwon, K., Hoffmann, A., Steir, J., McGeough, O. & Silverstein, N. (2021) 'Incentivized spacing and gender in computer science education', in *Proceedings of the Conference on International Computing Education Research*. ACM, NY, USA, pp. 18–28. https://doi.org/10.1145/3446871.3469760